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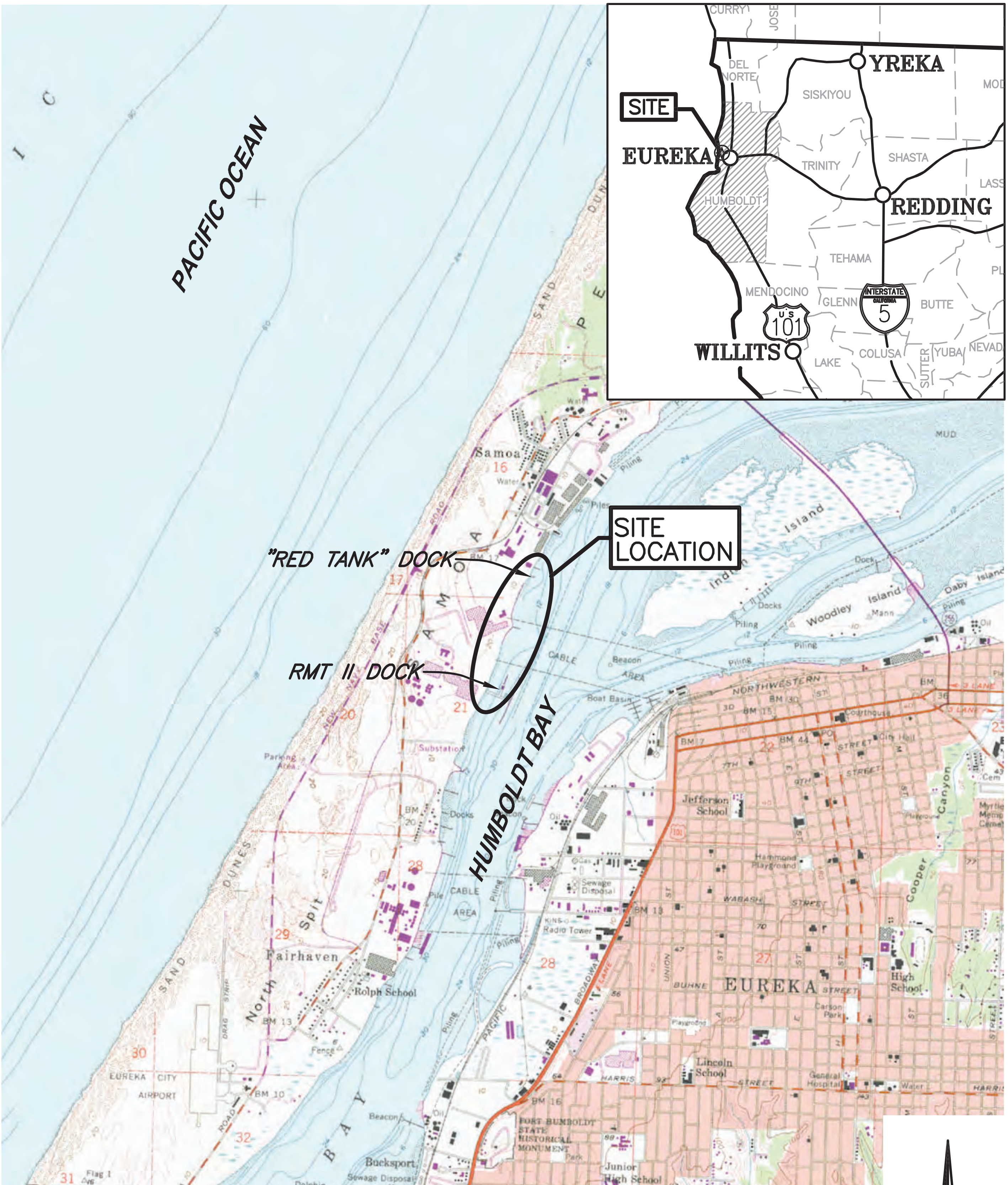
W11a

1-21-0653

(Humboldt Bay Harbor, Recreation, and Conservation District)

May 8, 2024

EXHIBITS



SOURCE: EUREKA USGS
7.5 MINUTE QUADRANGLE

EXHIBIT NO. 1
PROJECT LOCATION MAPS
CDP APPLICATION NO. 1-21-0653
(Humboldt Bay Harbor District)

Humboldt Bay Harbor District
Sea Chest Intake Screens
Samoa, California

April 2020 | 016240-003-LOC

\\Eureka\Projects\2016\016240-Engr-HBHRCD\003-RMT-II-EPA-TB\Dwgs, SAVED: 4/27/2020 4:26 PM CSWANSON, PLOTTED: 4/27/2020 4:26 PM, CHUCK SWANSON

Pile Removal Mitigation Site

Humboldt County Planning and Building Department

0 0.275 0.55 1.1 mi

0 0.275 0.55 1.1 mi

RF= 1:36,112 1 in = 3,009 ft

N W E S

4/21/2024, 12:52:04 PM Web AppBuilder 2.0 for ArcGIS

Map Disclaimer:
While every effort has been made to assure the accuracy of this information, it should be understood that it does not have the force & effect of law, rule, or regulation. Should any difference or error occur, the law will take precedence.

Source: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community, Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

Areas

Override 1

Path: \\Eureka\Projects\2016\016240-Engr-HBHRCD\005-Intake-Screen\GIS\PROJ_MXD\BayIntake_Piping_SitePlan.mxd User Name: cswanson DATE: 1/12/22, 3:25PM

HBHRCD
Humboldt Bay Intake Screens
Samoa, California

January 2022 | BayIntake_Piping_SitePlan

EXHIBIT NO. 2
SITE PLAN
CDP APPLICATION NO. 1-21-0653
(Humboldt Bay Harbor District)

Paper Size ANSI A

0 75 150 225 300

Feet

Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

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Baywater Intake CDP Application No. 1-21-0653

Compensatory Off-site Restoration Areas at Kramer Dock

Project No. 11225550
Revision No. 5
Date Jan 2022

Exhibit 2
CDP 1-21-0653
EXHIBIT 1
Page 2 of 2

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Print date: 26 Jan 2022 - 14:23

Data source: Humboldt County, AirPhoto_2019_MapService: . Created by: jlopez4

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Humboldt Bay Master Water Intakes: Project Description (v8; updated 12/9/22)

Note: This document updates and replaces the Project Description dated 10/21/22.

1. Overview

The Humboldt Bay Harbor, Recreation and Conservation District (District) proposes to modernize and operate two formerly used bay-water intake systems in Humboldt Bay and install new pumps, piping, and meters to deliver bay water to existing and future District tenants. Improvement of the water intakes is part of a long-term District program to develop facilities for use by aquaculture tenants. The water intakes are located approximately one-half mile apart along the Samoa Channel at the Redwood Marine Terminal II (RMT II) Dock and Red Tank Dock (Figure 1). The intake systems were operated by a pulp mill from around 1966 until the mill was closed in 2008. Salt water from the intakes will be used by District tenants and other entities for aquaculture and other allowable uses. The proposed project includes bay water withdrawal and pumping to manifolds at specific upland points that will be connected to by future water users. The two intakes will be operated and managed as a single system as they both feed into a common manifold and distribution system. They will be designed such that one intake can operate alone while the other intake is offline for maintenance. However, under typical conditions both intakes will be operated continuously and simultaneously, cooperatively feeding into the common distribution system.

Figure 1: Location of proposed water intakes in Humboldt Bay, California.

Currently, industrial water (raw untreated water from the Mad River) is supplied to the area by Humboldt Bay Municipal Water District through the Town of Samoa. However, it is expected that the Town of Samoa industrial water connection will be discontinued in 2022. The proposed project includes installation of industrial water lines. Water from the industrial lines could also be used for fire suppression. As described below, the industrial water lines will share a trench with the bay water lines.

Based on informal consultation with agencies, the Harbor District has identified habitat restoration opportunities to offset any reduction in the bay's biological productivity that will result from water withdrawal and entrainment of aquatic larvae. Habitat restoration work will be phased in conjunction with the phasing of water withdrawal quantities.

The proposed bay water intake upgrades, industrial water line, and habitat restoration projects are further described below.

2. Water Intake Uses and Controls of Water Intake Volumes

Water will only be supplied to users that operate in compliance with approved permits. This could be users with existing approved permits or future users that receive approved permits. For instance, the Harbor District has existing Coastal Development Permits CDP-16-049 and 17-041 that are approved by the County of Humboldt for Redwood Marine Terminal II, each of which could withdrawal water once the intake system is permitted and constructed. As outlined in those Coastal Development Permits, Coastal Dependent Industrial Uses, Aquaculture, and Coastal Related Uses have priority over interim uses. The process for reviewing potential new uses is outlined in the RMT II Permit Compliance Flowchart (see Attachment A).

The volume of water to withdrawn will occur in three phases:

- Phase I: Intake of bay water between 0 to 694 gpm.
- Phase II: Intake of bay water between 695 to 1,250 gpm.
- Phase III: Intake of bay water between 1,251 to 8,250 gpm.

For those tenants that require baywater, the District will require each of those tenant to pay for a specific set amount of intake water in their lease. They will not be required to use the total volume of water that they pay for, but they will be required to reserve and pay for that set amount. The District will then manage each subsequent lease to ensure that the District never leases more water than the total permitted amount. For example, tenant #1 could lease 90% of the total permitted amount, tenant #2 could lease 6% of the total permitted amount, and tenant #3 could lease 4% of the total permitted amount. Each tenant will reserve and pay for their allocated volume and no tenant will be given access to water beyond their allocation. Thus, in this example, the only way that the intake system could possibly reach the maximum intake volume would be if all three tenants simultaneously utilized their respective maximum intake allocations. Also, continuing with this example, imagine a scenario in which tenant #2 terminates their lease. This would leave 6% of the total permitted volume available for the District to reallocate to a new tenant. If a new tenant only wanted 1% instead of 6%, then there would be capacity for a fourth tenant to use 5% of the total permitted volume.

It is important to note that if any one tenant does not fully utilize their allocated maximum amount in any given period of time, then the overall system will not reach the maximum permitted amount during that specific period of time. Tenants will not be able to exceed their own allocated amount regardless of how much water their neighboring tenants happen to be utilizing at the time. If tenant #1 stops operations for one week, their unused portion of water will not automatically become available to tenant #2. Instead, that portion of water would not be withdrawn that week. It is possible that a tenant will seek to adjust their lease to reserve a smaller amount of water, which could be followed by a different tenant seeking to adjust their lease to reserve an equivalent larger amount of water. But, such adjustments will require lease adjustments and explicit adjustments to allocated volumes of water within each lease.

Under any scenario of combinations of users, the District will manage the collective suite of leases to ensure that the District never leases more water than the total permitted amount. In other words, each tenant’s connection to the intake system will be metered and monitored by the District and no tenant will be allowed by the District to exceed the allocation assigned to them in their respective lease agreement. In addition, the District will require each tenant to acquire all required permits (including CDPs) prior to initiating operations. This is all consistent with how the District manages the outfall system.

Regarding control of water volume through mechanical systems: The combination of pumps at either intake will be manifolded together and discharged into a single pipe. The pipe will have a flow meter that will provide information back to a programmable logic controller (PLC) set to control the variable frequency drives on each pump and adjust the speed of the pumps to keep the flow rate below the maximum design flow for the intake screens, thereby limiting the flow rates.

3. Improvements to Water Lines

A bay water line will provide water from the RMT II Dock and Red Tank Dock water intakes to manifolds directly south of Red Tank Dock, at RMT II and at the proposed Nordic Aquafarms[1] project site. Aquaculturists and other users will connect to the manifolds to receive bay water. Potential users include shellfish, seaweed, and finfish farmers. The bay water line and industrial water line will be buried in trenches except at one location where they will surface to cross a stormwater feature and also where the bay water line will be mounted on the edges of Red Tank Dock and RMT II Dock. The industrial water line will extend from the Red Tank to the RMT I manifold then south to the Nordic Aquafarms manifold (Figure 2). Hydrants will be installed along the line approximately every 500'. For details regarding the trench alignment and proximity to ESHA, see Figures 3 through 6 and Attachment B.

Figure 2: Location of bay water intakes, bay water piping and industrial water piping.

4. Bridge Across Stormwater Feature

As shown in Figure 2, the water lines cross an existing drainage swale ("stormwater feature") that drains stormwater runoff to Humboldt Bay (see Image 1 and Figure 6). The swale is connected to the bay through a culvert that passes through a small earthen berm. There are two structures on the landward side of the berm including a small metal pedestrian bridge crossing. This small crossing bridge is degraded and will be removed. There is also a larger metal pedestrian bridge and piping manifold with associated platform. The bridge associated with the stormwater feature is shown in the image on right. The Coastal Commission approved a replacement of this bridge through CDP E-11-029 for Taylor Mariculture. Per page 8 of the staff report associated with that CDP, the approved project description includes "…the installation of a pre-fabricated 80-foot long one-lane vehicle bridge across the culvert to the north of the Berth Two pier. Bridge installation requires several small footings in areas of existing asphalt." In compliance with that approved CDP, the District intends to install a new one-lane vehicle bridge (see Figure 6 and Attachment B). The new bay water piping and new industrial water piping will be attached to the new bridge in a similar setup as the existing piping manifold.

Image 1: Existing stormwater feature to be replaced

[1] Nordic Aquafarms (a private company) is proposing a finfish aquaculture facility at the site and would likely be one of the bay water users.

5. Trench Details

The industrial water line will have a maximum outside diameter of 12”. The bay water line will range from 18”-36” maximum outside diameter. Diagrams 1 through 3 the outside pipe diameter and volume of water that will travel through different sections of the bay water line. Diagrams 1 through 3 show the design for different trench segments (i.e., areas where there are two pipes or one pipe in the trench). The maximum width of ground impacts will be 19’ in sections where both pipes occur and 17’ where only one pipe occurs.

There is an existing walkway across the stormwater feature (see Figure 2 and Image 1). The two pipes will be attached to the replacement structure described above and in Attachment B.

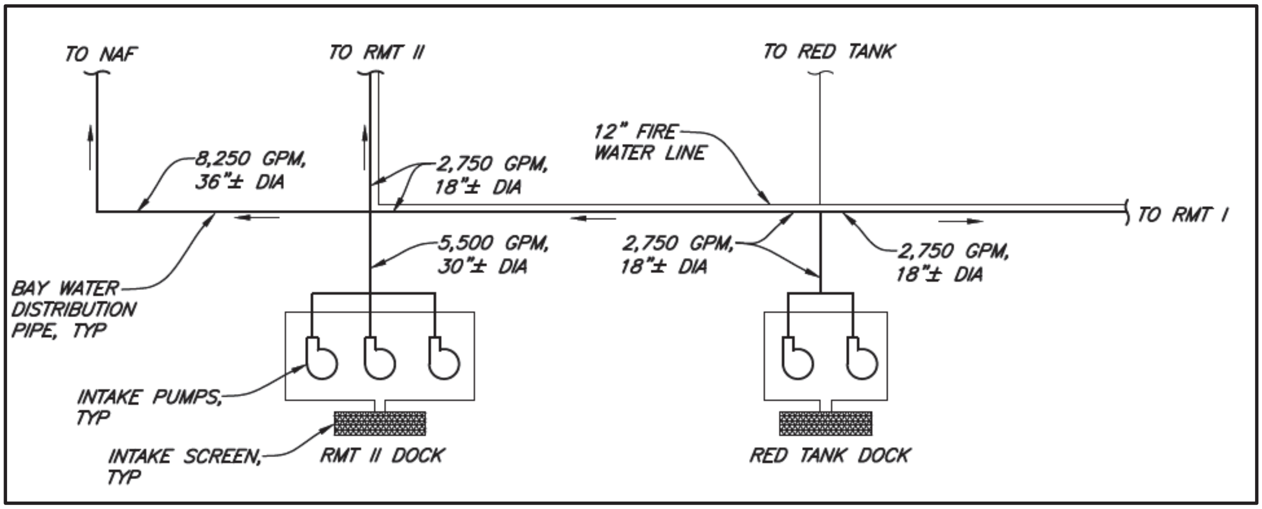

Diagram 1: Pipe diameter and volume of water that will travel through different sections of the bay water line.

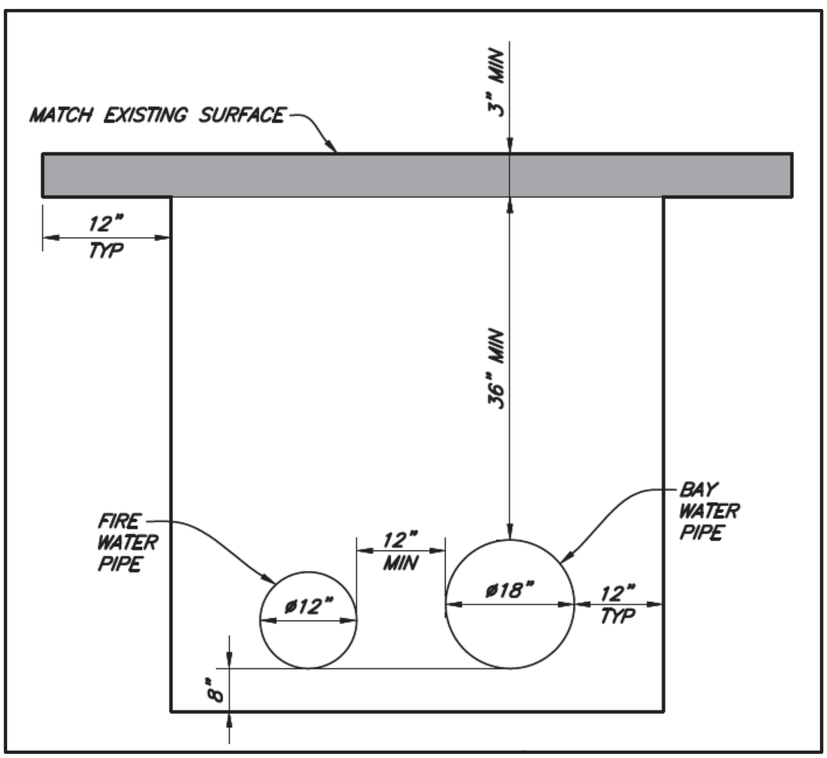

Diagram 2: Conceptual trench details in areas where the bay water line and industrial water line will occur.

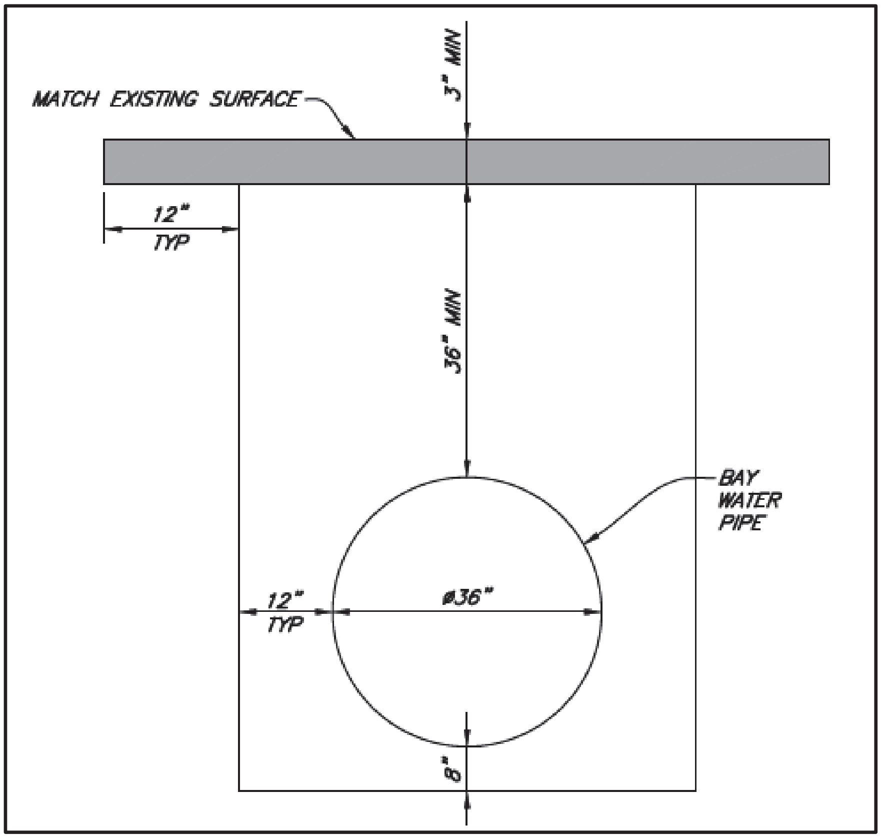

Diagram 3: Conceptual trench detail in the area where only the 36" bay water line will occur.

6. Improvements to Water Intakes

Existing water intake structures ("sea chests") at the two sites will be improved. Appendix R of the DEIR ("Humboldt Bay Intake Screen Conceptual Designs, Redwood Marine Terminal II and Red Tank Dock, Samoa, California – Revision 03.") describes the water intakes, pumps, intake screens, and overall structure orientations that will be used to minimize impacts to aquatic resources. Figures 1 and 2 above show the location of the intakes and proposed bay water and industrial water piping. Images 2 through 6 below are pictures of existing infrastructure that will be modified at each intake site.

Image 2: Existing water intake pumps at the Redwood Marine Terminal II Dock. These will be replaced.

Image 3: Existing wooden sea chest at the Redwood Marine Terminal II Dock. This sea chest will continue to be utilized.

Image 4: Existing water intake screen at the Redwood Marine Terminal II Dock. This screen will be replaced.

Image 5: Existing concrete sea-chest and screens at the Red Tank Dock. This sea chest will continue to be utilized; the screens will be replaced.

Image 6: Existing concrete sea-chest at the Red Tank Dock. This sea chest will continue to be utilized.

7. Intake Screens Cleaning and Maintenance

The bay water intake screens will be periodically cleaned and maintained per the "Preliminary Baywater Intake Cleaning and Maintenance Plan" (see Attachment C).

8. Avoiding Potential Eelgrass Impacts

Eelgrass will be avoided during installation and maintenance of the intake systems. A qualified biologist will be present on-site to help monitor and avoid impacts to eelgrass while work is being performed in areas that may impact eelgrass habitat. Installation and maintenance activities shall comply with the "Eelgrass Protection Plan" associated with Coastal Development Permit 9-16-0204 (Humboldt Bay Mariculture Pre-Permitting Project, Starbird Mariculture).

Gilkerson (2008) found the maximum depth capable of supporting eelgrass in north Humboldt Bay was -1.3 m MLLW. The depths at the proposed RMT II and Red Tank dock water intakes are -4.5 m MLLW and -1.8 m MLLW, respectively. The depth of the RMT II intake prohibits growth of eelgrass, but the depth at Red Tank dock is only slightly greater than the maximum growing depth. The intake at Red Tank is within the area evaluated under the Humboldt Bay Harbor District Coastal Development Permit 9-16-0204 Subtidal Mariculture Pre-permitting project. An associated Environmental Impact Report (SCH #2013062068) was certified by the Harbor District which included eel grass surveys prepared by Thomas Gast and Associates and impact analysis. An active mariculture lease (Starbird) with a site-specific eel grass protection plan includes the area where the Red Tank intake is proposed to be located. Condition 8 of this permit requires:

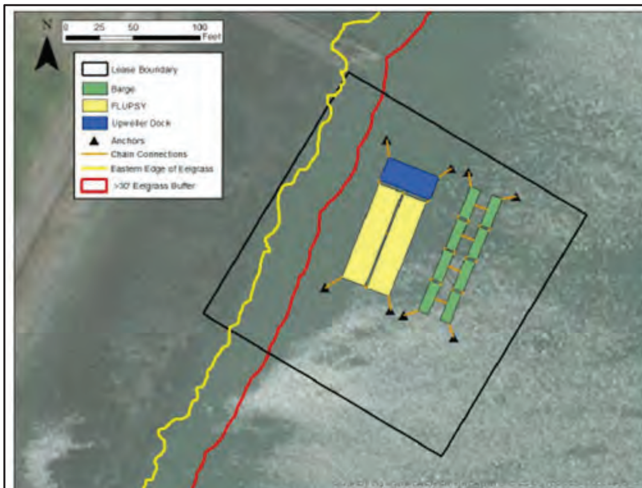

Figure 2. Proposed layout of Starbird Mariculture operations in relation to mapped eelgrass. Eelgrass mapping was conducted by Thomas Gast and Associates (see Attachment 1).

Figure 7: A copy of Figure 2 from the "Humboldt Bay Mariculture Pre-Permitting Project Eelgrass Protection Plan" associated with CDP 9-16-0204

> *Eelgrass Protection. Prior to the initiation of installation activities for aquaculture gear or mooring piles, the Harbor District shall submit for Executive Director review and approval a plan showing that all such activities and associated structures or infrastructure (including pilings,*

moorings, anchors, longlines, surface rafts, FLUPSYs) shall remain a minimum of 30-feet away from the outside edge of any eelgrass bed within or adjacent to the three subtidal aquaculture sites. This report shall include a map of all eelgrass within each subtidal site and a 50-foot perimeter outside. The map shall be based on the results of an eelgrass survey carried out consistent with the timing and methodology guidelines of the National Marine Fisheries Service's California Eelgrass Management Program. Areas with depths greater than twice the minimum expected eelgrass growing depth in Humboldt Bay are exempt from this survey requirement.

To implement that Condition 8, the District prepared the "Humboldt Bay Mariculture Pre-Permitting Project Eelgrass Protection Plan" (see Attachment D). The Red Tank intake will be required to comply with this same Eel Grass Projection Plan. Also note from Figure 2 of that Plan (see Figure 7 of this Project Description) that the end of Red Tank Dock is beyond the "eastern edge of eelgrass" and therefore the intake structure will be outside of mapped eel grass.

In addition to the information outlined above, the District has prepared a custom Eelgrass protection plan for this project (see Attachment E).

9. Aquatic Species Entrainment and Habitat Restoration

Harbor District staff has had informal consultations with staff from agencies regarding potential environmental effects of the proposed water intakes. Based on the consultations, the Harbor District will implement habitat restoration to offset the reduction in biological productivity that will be caused by entrainment of aquatic larvae from water withdrawal. The need to offset the impact on biological productivity is based on California Ocean Plan[2] requirements for desalination plant water intakes. For more information on this topic, see:

- The following Appendices of the "Draft Environmental Impact Report: Samoa Peninsula Land-based Aquaculture Project, County of Humboldt, Planning Department, 17 December 2021" (a.k.a. "DEIR for Nordic Aquafarms"):
  - Appendix N: Tenera Environmental (12/13/21). The Use of Piling Removal for Mitigating Effects of Entrainment Losses to Longfin Smelt and Other Fishes Resulting from Operation of the Proposed Samoa Peninsula Intakes in Humboldt Bay.
  - Appendix P: Tenera Environmental (5/13/21). Empirical Transport Modeling of Potential Effects on Ichthyoplankton Due to Entrainment at the Proposed Samoa Peninsula Master Bay Water Intakes.
  - Appendix Q: Tenera Environmental (7/14/21). Empirical Transport Modeling of Potential Effects on Ichthyoplankton Due to Entrainment at the Proposed Samoa Peninsula Bay Water Intakes: Addendum 1: Longfin Smelt.
- Attachments to this Project Description:
  - Attachment F: CDFW (1/3/22). Memorandum of Understanding: Section 2081(A) Take Permit for The Humboldt Bay Intake Entrainment Study.
  - Attachment G: Tenera Environmental (1/5/22). Project Implementation Plan for Ichthyoplankton Collection at the Samoa Peninsula Water Intakes.

10. Entrainment

The water intakes are designed to avoid impingement of all aquatic species and entrainment of juvenile and adult aquatic species, by meeting design criteria related to screen mesh, water approach velocity and other parameters. It is expected that only non-special status aquatic larvae will be entrained. Tenera (Attachments G and H) developed a model to estimate entrainment impacts of the proposed water intakes on larvae. Tenera predicts that the portion of larvae in Humboldt Bay that will be entrained is 0.0207% or less (see Attachment H). However, Tenera likely provides an overestimate of larval impacts because:

[2]State Water Resources Control Board (2015). California Ocean Plan as amended effective January 28, 2016, to address desalination facility water intakes.

1. The model assumes even distribution of larvae throughout Humboldt Bay. However, the intakes are located at a site with strong currents and high salinity near the entrance of the bay. It is expected that larvae of most fish species are more concentrated in parts of the bay where they are subject to less tidal action and currents. Additionally, larvae of some species (e.g., longfin smelt (*Spirinchus thaleichthys*)) are not associated with the high water salinities at the water intakes.
2. The model was developed based on a water intake screen slot (mesh) size of 1.75 mm, but based on comments received from the California Coastal Commission the slot size has been reduced to 1.0 mm. The 1.0 mm slot size will further reduce larvae entrainment.

As requested by Coastal Commission staff, the Harbor District has begun to collect field data on larvae abundance in Humboldt Bay to validate the Tenera (5/13/21) model's assumption that larvae are evenly distributed in the bay (or less concentrated near the water intakes). This one-year study will be completed in December of 2022 with the complete report anticipated to be available in January or February of 2023 (see Attachment G). The Harbor District is actively pursuing a Coastal Development Permit, Clean Water Act Permits and a Harbor District Permit before conducting the field work. The permit(s) may include conditions that, prior to exceeding 1,250 gallons per minute (gpm) of water withdrawal, larvae sampling in the bay will be conducted to validate model assumptions regarding larvae distribution. On 1/3/22, CDFW entered into an MOU with Tenera to conduct sampling for this purpose (see Attachments F and G).

11. <u>Habitat Restoration</u>

Habitat mitigation will occur as outlined in section 2.4.7 (page 2-56) of the DEIR, Mitigation Measure BIO-6a (Protection of Longfin Smelt) of the DEIR, and as supported by Appendix J (below).

The Harbor District will complete compensatory off-site habitat restoration activities to (1) offset a small reduction in the Humboldt Bay's biological productivity as a result of entrainment of non-special status larval species, and (2) compensate for the potential take of longfin smelt (LFS) larvae during the operation of the two sea chests. Compensatory off-site habitat restoration will include pile removal. Compensatory off-site habitat restoration will be implemented in associated with the phased withdrawal of water through the two water intakes as follows:

- Phase I.
    - Volume: This Phase includes intakes between 0 to 694 gpm.
    - Impact Mitigation: Consistent with other intake permits to withdraw Bay water, and with the project design features incorporated into the project, the effects of this small amount of water withdrawal are considered de minimis and habitat restoration to offset impacts to bio-productivity are not necessary.
    - Timing: Water withdrawal for up 694 gpm is expected to begin after all permits are approved and all conditions of approval of all agencies are met.
- Phase II.
    - Volume: This Phase includes intakes between 695 to 1,250 gpm.
    - Impact Mitigation: The Harbor District will compensate for project-related impacts to Longfin Smelt (LFS) by implementing the revised FEIR version of Mitigation Measure BIO-6a (Longfin Smelt Mitigation), which consists of "habitat creation or enhancement to provide Longfin Smelt spawning, rearing, or nursery habitat capable of producing the number of Longfin Smelt larvae lost to entrainment." The mitigation measure goes on to provide an estimate of impact and a formula for calculating the area of mitigation required.
    - Timing: Water withdrawal at this level will not begin until after Phase II mitigation is completed and Phase II Conditions of Approval are satisfied.
    - Timing: Regardless of tenant/user, the District will not initiate this Phase II of withdrawal until the associated mitigation and conditions of approval are met. In addition, the District will not allow any collective combination of tenant(s)/user(s) to exceed 1,250 gpm unless/until additional permits are acquired.
- Phase III.

- Volume: This Phase includes intakes between 1,251 to 8,250 gpm.
- Pre-mitigation Studies: Prior to withdrawing bay water at Phase III levels, the District will complete an Entrainment Study as approved by CDFW via MOU (see Attachment F and G) and as outlined in:
  - CDFW (1/3/22). Memorandum of Understanding: Section 2081(A) Take Permit for The Humboldt Bay Intake Entrainment Study. See Attachment F.
  - Tenera Environmental (1/5/22). Project Implementation Plan for Ichthyoplankton Collection at the Samoa Peninsula Water Intakes. See Attachment G.
- Impact Mitigation:
  - The Harbor District will compensate for project-related impacts to biological productivity by removing up to 988 creosote piles and 151 crossbeam supports attached to the pilings.
  - The location of these piles/crossbeams is the Kramer Dock site as outlined in Attachment E (Humboldt Bay Master Water Intakes Project, Kramer Dock Pile Removal, Eelgrass Protection Plan and Compensation for Potential Loss of Biological Productivity; 8/15/22).
  - The pile/crossbeam removal will serve as compensatory restoration for biological productivity foregone as a result of the water intakes. This is intended to create space for eelgrass (Zostera marina) habitat while enhancing a larger tidal habitat area, and in turn, supporting biological productivity. Per Attachment K, this will also remove an estimated 308 tons of potentially toxic creosote-soaked wood from the bay. The piles collectively have a surface area of 30,660 square feet that is exposed daily to the water column of the bay. As outlined in Attachment I, the total habitat restoration area is 2.69 acres.
  - Benefits from reduced light penetration and replacement of natural substrate are subsequent beneficial impacts to submerged aquatic vegetation. There will also be more natural bay substrate for benthic organisms that live in the bay mud. In addition, some aquatic species such as Pacific herring spawn on hard surfaces, including old dock pilings. Studies performed on creosote coated pilings have shown detrimental effects on embryonic development of herring eggs, even on pilings that were 40 years old (Vines, 2000). For more information on the benefits of pile removal, see EIR appendix N by Tenera as it builds on previously developed rational for why piling removal is appropriate for APF mitigation. Therefore, removal of the pilings would eliminate any potential impacts to organisms that may come in contact with the pilings. Therefore, removal of the pilings would eliminate any potential impacts to organisms that may come in contact with the pilings. Accordingly, the removal of the Kramer Dock pilings and restoration to more natural conditions will improve the biological productivity of the Bay.
  - Removal of the creosote treated piles is expected to have water quality benefits. The removal of creosote piles and braces is proposed to offset the small reduction in the Humboldt Bay's biological productivity as a result of entrainment of non-special-status larval species. This is consistent with Appendix N of the Nordic EIR (The Use of Piling Removal as Method for Mitigating Effects of Entrainment Losses to Longfin Smelt and Other Fishes Resulting from Operation of the Proposed Samoa Peninsula Intakes in Humboldt Bay, Tenera December 13, 2021; Tenera Environmental 2021c, DEIR Appendix N).
  - This action is consistent with the "compensatory off-site restoration" outlined in the Final EIR for the Nordic project.
- Impact Mitigation Location: The District will utilize the location described in Attachment I for the off-site restoration and will utilize the BMPs outlined in Attachment J. These BMPs are designed to avoid impacts to eelgrass as well as to prevent the potential mobilization of contaminants into the Bay.
- Secondary Use of Impact Mitigation Site:
  - Exhibit 1 of Attachment I (Kramer Dock Habitat Restoration Memorandum) displays "Piling removal areas 2 and 4," both of which are reserved for use as "barge landing sites" after pile removal.

- The planned barge landing sites are each 150 ft wide locations reserved to be used as barge access to South Depot Road. The District forecasts that these sites can be used periodically as barge access landing sites without disturbing eelgrass. Note that the methodology used to removal the piles includes the use of equipment operating from a barge. Per Attachment J (Pile Removal Methods and Best Management Practices), the barge associated with the removal of piles would be approximately 80' X 100' with a 4' draft and would be moved with a small tugboat and "neither the barge nor the tug will anchor during the removal process." During the pile removal process, the barge will operate "…at a tide of sufficient elevation to float the barge and tugboat… without scarring the mudflats or injuring eelgrass." In addition, "grounding of the barge will not be permitted."
- The District anticipates that the same methodology and Best Management Practices may be deployed in the future (following pile removal) to allow for barge landings at these two sites. The restored eelgrass beds will not be affected by future barges as they would be floating above the eelgrass beds.
- This same concept of barge unloading in this same location was applied for in CDP Application 04-12-19S for the TerraGen Humboldt Onshore Wind Project. In that application, the applicant sought to use this site to unload large wind turbine components (such as wind turbine blades). The barges were to have shallow drafts and to be deployed at the site at tides that were sufficiently high enough to float the barge above eelgrass beds. The components would have been unloaded onto the land, where they would have been shipped by vehicle to their destination. This site was selected because it is the only feasible location to unload large loads south of Eureka. For instance, unloading a two-hundred-foot-long wind turbine blade in Eureka may be feasible, but transporting such a long load through the streets of Eureka to get to the Fortuna area would be impractical. Such a route would also require transiting under (or around) the US 101 underpasses and on/off ramps in southern Eureka, which could be impractical for large/tall loads. However, unloading long/large/tall loads at the Kramer Dock site provides a much more reasonable access point and transport corridor to US 101 south and avoids the underpasses and on/off ramps in southern Eureka. The plan was to use this site for these purposes using barges in such a way as to have no impact to eelgrass.
- The District is anticipating that similar demands may occur in the future and that similar methodologies may be utilized without any impacts to eelgrass. Thus, the District is anticipating full mitigation credit for pile removal in "Piling removal areas 2 and 4," both of which are reserved for use as "barge landing sites" after pile removal. Note that the District does not have any specific planned barge landings and is not aware of any planned or forecasted uses, though the District does intend to reserve these areas for such use if the need ever arises.
- Other than mitigation and two limited barge landing sites, the District does not have any planned uses for the proposed mitigation area. As explained above, any barge landings would be conducted in such a way that impacts to eelgrass would be avoided. Thus, the District expects that the site will effectively function as mitigation.

o BMPs to Avoid Mobilization of Contaminants at Mitigation Site:

- To minimize the potential for impacts, the District has developed the document “Pile Removal Methods and Best Management Practices to Avoid Impacts to Eelgrass and to Avoid Mobilization of Contaminants” (Attachment J).
- To reduce the risk of mobilizing sediment and any potential contaminants that may be present during creosote-treated wood pile removal, the District will use methods designed to minimize disturbance and implement industry-established best management practices (BMPs). Vibratory extraction is the preferred method of piling removal because it causes the least disturbance to the seabed and it typically results in the complete removal of the piling from the aquatic environment (EPA 2016). BMPs to be implemented include but are not limited to: use of a floating

boom to control debris, having proper containment on the barge for removed piles, controlling sediments and turbidity and preventing them from re-entering the water column, and characterization of piles for proper disposal. A detailed summary of methods and BMPs for the Kramer Dock piling removal is provided in Appendix J.

- Creosote is a registered pesticide mixture that is comprised primarily of Polycyclic Aromatic Hydrocarbons (PAHs) by weight (90%). Creosote on the surface of the pilings leach contaminants to the aquatic environment through a weathering process in which individual chemical constituents are adsorbed, evaporated, photo-oxidized or dissolved. Leaching rates of contaminants from creosote-treated wood are variable and greatest during the first few years after placement (SFEI, 2010).
- The accumulation of PAHs in sediment tends to be localized and is subject to degradation that varies based on site specific conditions. Factors that influence the rate of contaminant degradation include saline content in water, water exchange through currents, and bioavailability. Previous studies have demonstrated over time that PAH concentrations do not reach a problematic level in sediment (SFEI, 2010).
- The Kramer Dock piles are over 50 years old. Leached contaminants previously present in the sediment are further expected to have degraded to levels of insignificance. The District is unable to identify sediment testing as part of EPA or NOAA guidance, and has not been made aware of this requirement for other California port piling removal projects. Based on these conditions, current findings, and modeling completed for aquatic impacts from treated wood pile In San Francisco Bay, the District does not intend to conduct sediment testing following piling removal.

- Timing: If necessary, the Harbor District will consult with other regulatory agencies to further develop details of the habitat restoration prior issuance of permits required for pile removal.
- Timing: Water withdrawal at this level will not begin until after Phase III restoration is completed and Phase III Conditions of Approval are satisfied.
- Timing: Regardless of tenant/user, the District will not initiate this Phase III of withdrawal until the associated mitigation and conditions of approval are met. In addition, the District will not allow any collective combination of tenant(s)/user(s) to exceed 8,250 gpm unless/until additional permits are acquired.

Attachments

A. HBHRCD (2/2/19). RMT II Permit Compliance Flowchart.
B. SHN (7/19/22). Baywater Intake System Pipeline Trench and EHSA Analysis; Response to Continued Review of Coastal Development Permit (CDP) Application No. 1-21-0653.
C. SHN (1/13/21). Humboldt Bay Intake Screens Preliminary Operation and Maintenance Description, Redwood Marine Terminal II and Red Tank Dock, Samoa, California.
D. HBHRCD (1/30/18). Eelgrass Protection Plan (from Humboldt Bay Mariculture Pre-Permitting Project Starbird Mariculture).
E. SHN (8/15/22). Humboldt Bay Master Water Intakes Project, Kramer Dock Pile Removal, Eelgrass Protection Plan and Compensation for Potential Loss of Biological Productivity.
F. CDFW (1/3/22). Memorandum of Understanding: Section 2081(A) Take Permit for The Humboldt Bay Intake Entrainment Study.
G. Tenera Environmental (1/5/22). Project Implementation Plan for Ichthyoplankton Collection at the Samoa Peninsula Water Intakes.
H. SHN and Tenera Environmental (7/18/22). Humboldt Bay Water Intakes and Tidal Dynamics.
I. GHD (1/27/22). Kramer Dock Habitat Restoration Memorandum.
J. HBHRCD (1/16/22). Pile Removal Methods and Best Management Practices to Avoid Impacts to Eelgrass and to Avoid Mobilization of Contaminants.
K. GHD (4/5/22). Kramer Dock Pile Removal Quantities.

L. County of Humboldt (9/29/22). CEQA Notice of Determination: Environmental Impact Report – Nordic Aquafarms California, LLC – Land-based Aquaculture Project & Coastal Development Permit & Special Permit.

M. SHN (11/15/22). Mitigation and Monitoring Plan for the Humboldt Bay Master Water Intakes Project.

N. H.T. Harvey Associates (12/92/22). Memorandum in response to concerns about effects of water intake operations by the Sea Chests on juvenile salmonid critical habitat.

Other Studies/Reports That Can Be Provided Under Separate Cover Upon Request

- Biological Assessment (SHN 2022).
- Phase I reports.
- SHN (9/20/20). Biological and Habitat Assessment report.
- SHN (9/20/20). Wetland Assessment.

Referenced Studies/Reports from the "Samoa Peninsula Land-based Aquaculture Project DEIR and FEIR"

- Link to FEIR and DEIR: https://humboldtgov.org/3218/Nordic-Aquafarms-Project
- Appendix R of the DEIR
  - SHN (8/6/21). Humboldt Bay Intake Screen Conceptual Designs, Redwood Marine Terminal II and Red Tank Dock, Samoa, California – Revision 03. *[For a copy of this report, see: "Draft Environmental Impact Report: Samoa Peninsula Land-based Aquaculture Project, County of Humboldt, Planning Department, 17 December 2021" Appendix R.]*
  - Link: https://humboldtgov.org/DocumentCenter/View/102332/Appendix-R---Sea-Chest-Screen-Conceptual-Design-PDF
- Appendix N of the DEIR
  - Tenera Environmental (12/13/21). The Use of Piling Removal for Mitigating Effects of Entrainment Losses to Longfin Smelt and Other Fishes Resulting from Operation of the Proposed Samoa Peninsula Intakes in Humboldt Bay.
  - Link: https://humboldtgov.org/DocumentCenter/View/102328/Appendix-N---Tenera-Piling-Removal-Mitigation-PDF
- Appendix P of the DEIR
  - Tenera Environmental (5/13/21). Empirical Transport Modeling of Potential Effects on Ichthyoplankton Due to Entrainment at the Proposed Samoa Peninsula Master Bay Water Intakes.
  - Link: https://humboldtgov.org/DocumentCenter/View/102330/Appendix-P---Tenera-Final-Report-PDF
- Appendix Q of the DEIR
  - Tenera Environmental (7/14/21). Empirical Transport Modeling of Potential Effects on Ichthyoplankton Due to Entrainment at the Proposed Samoa Peninsula Bay Water Intakes: Addendum 1: Longfin Smelt.
  - Link: https://humboldtgov.org/DocumentCenter/View/102331/Appendix-Q---Tenera-Addendum-PDF

Other References

- EPA (2016). Region 10 EPA, Best Management Practices for Piling Removal and Placement in Washington State
- Humboldt Bay Harbor, Recreation and Conservation District (2021). "Humboldt Bay Master Water Intakes Project Description.
- NOAA (October 12, 2009). The Use of Treated Wood Products in Aquatic Environments: Guidelines to West Coast NOAA Fisheries Staff for Endangered Species Act and Essential Fish Habitat Consultations in Alaska, Northwest and Southwest Regions.
- San Francisco Estuary Institute (December 2010). Removal of Creosote-Treated Pilings and Structures from San Francisco Bay.
- Vines et al. (2000). The Effects of creosote-derived compounds on development of Pacific Herring. Aquatic Toxicology 51.

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812 W. Wabash Avenue, Eureka, CA 95501-2138

Reference: 016240.005

August 6, 2021

Adam Wagschal
Humboldt Bay Harbor, Recreation, and Conservation District
601 Startare Dr.
Eureka, CA 95501

Subject: **Humboldt Bay Intake Screen Conceptual Designs, Redwood Marine Terminal II and Red Tank Dock, Samoa, California–Revision 03**

Adam Wagschal:

SHN is submitting this revised letter, at your request, describing proposed intake screen designs for two intake locations: Redwood Marine Terminal II (RMT II), and "Red Tank" Dock in Samoa, California, owned and operated by the Humboldt Bay Harbor, Recreation, and Conservation District (District). Existing intake structures located at each dock (RMT II and Red Tank Dock) require new intake screens capable of supplying bay water to potential industrial tenants while meeting design criteria to prevent fish entrapment and impingement. Appendix 1, Figure 1 includes a site location map identifying the location of the RMT II dock and Red Tank dock.

Design Criteria

General intake screen design criteria are outlined in the National Marine Fisheries Service (NMFS) document: *Fish Screening Criteria for Anadromous Salmonids* (NMFS, 1997). Through consultation with the California Department of Fish and Wildlife (CDFW; personal communication with Arn Aarreberg, Environmental Scientist, CDFW–Marine Region), it has been determined that intake screens must meet the design criteria assuming the presence of anadromous salmonid fry and juvenile longfin smelt. Applicable design criteria for fish screens from NMFS (1997) are summarized below.

A. Flow Rate
Maximum Intake Flow Rate:
RMT II Dock intake Screen: 5,500 gallons per minute (gpm)
Red Tank Dock Intake Screen: 2,750 gpm
Total: 8,250 gpm

B. Structure Placement

a. The screened intake shall be designed to withdraw water from the most appropriate elevation, considering juvenile fish attraction, appropriate water temperature control downstream, or a combination thereof. The design must [obscured] of water surface elevations.

EXHIBIT NO. 4
PRELIM. INTAKE SCREEN PLANS
CDP APPLICATION NO. 1-21-0653
(Humboldt Bay Harbor District)

b. Where possible, intakes should be located off shore to minimize fish contact with the facility. Water velocity from any direction toward the screen shall not exceed the allowable approach velocity. Where possible, locate intakes where sufficient sweeping velocity exists. This minimizes sediment accumulation in and around the screen, facilitates debris removal, and encourages fish movement away from the screen face.

C. Maximum Approach Velocity

a. Self-cleaning screens: 0.2 feet per second (fps)

b. Non self-cleaning screens: 0.05 fps

c. The screen design must provide for uniform flow distribution over the surface of the screen, thereby minimizing approach velocity.

D. Screen Orientation
For screen lengths greater than six feet, screen-to-flow angle must be less than 45 degrees.

E. Screen Face Material

a. Perforated plate: screen openings shall not exceed 3/32 inches (2.38 millimeters [mm]), measured in diameter.

b. Profile bar: screen openings shall not exceed 0.0689 inches (1.75 mm) in width.

c. Woven wire: screen openings shall not exceed 3/32 inches (2.38 mm), measured diagonally. (e.g.: 6-14 mesh).

d. Screen material shall provide a minimum of 27% open area.

e. The screen material shall be corrosion resistant and sufficiently durable to maintain a smooth and uniform surface with long term use.

F. Civil Works and Structural Features

a. The face of all screen surfaces shall be placed flush with any adjacent screen bay, pier noses, and walls, allowing fish unimpeded movement parallel to the screen face.

b. Structural features shall be provided to protect the integrity of the fish screens from large debris. Trash racks, log booms, sediment sluices, or other measures may be needed. A reliable on-going preventive maintenance and repair program is necessary to ensure facilities are kept free of debris and the screen mesh, seals, drive units, and other components are functioning correctly.

G. Operations and Maintenance

a. Fish Screens shall be automatically cleaned as frequently as necessary to prevent accumulation of debris. The cleaning system and protocol must be effective, reliable, and satisfactory to NMFS. Proven cleaning technologies are preferred.

b. The head differential to trigger screen cleaning for intermittent type systems shall be a maximum of 0.1 feet (0.03 m), unless otherwise agreed to by NMFS.

c. The completed screen and bypass facility shall be made available for inspection by NMFS, to verify compliance with design and operational criteria.

d. Screen and bypass facilities shall be evaluated for biological effectiveness and to verify that hydraulic design objectives are achieved.

Following consultation with CDFW, the District contracted with Tenera Environmental (May 2021) to complete an entrainment study evaluating the potential for the proposed screens to entrain marine organisms. This study suggests that decreasing the slot opening width of a woven wire screen mesh material from 1.75 mm (the NMFS maximum slot opening specified above for profile bar material) to 1.0 mm would reduce the potential for entrainment. Therefore, it is recommended that 1.0 mm be used as the maximum allowable slot opening width for profile bar or woven wire screen materials.

Design Conditions

Site-specific design conditions include minimum and maximum water depths; and elevation of the pier where the pumps, blowers, and mounting equipment will be located. Appendix 1 presents figures with conceptual site plans and elevations of each intake structure. Elevations reported below in Table 1 for the RMT II dock intake structure are from the original design drawing included in Appendix 2 (Georgia-Pacific Corporation, 1966). Elevations reported below in Table 1 for the Red Tank dock intake structure are from manual measurements collected April 1, 2020, at 8:15 a.m. in reference to the tidal water surface elevation reported from the NOAA North Spit tide station (9418767).

Table 1. Tidal Data[a] and Intake Structure Elevations RMT II Dock and Red Tank Dock, Samoa, California

Description	Abbreviation	RMT II Dock Elevation (feet, NAVD88) [b]	Red Tank Dock Elevation (feet, NAVD88)
Existing Pump Base Elevation	N/A[c]	13.68	11.20 +/-
Existing Pump Discharge Pipe Center Line Elevation	N/A	9.93	N/A
Highest Astronomical Tide, December 31, 1986	HAT	8.52	8.52
Mean Higher High Water	MHHW	6.51	6.51
Mean High Water	MHW	5.80	5.80
Mean Sea Level	MSL	3.36	3.36
Mean Low Water	MLW	0.91	0.91
North American Vertical Datum of 1988	NAVD88	0.00	0.00
Mean Lower Low Water	MLLW	-0.34	-0.34
Lowest Astronomical Tide, May 25, 1990	LAT	-2.73	-2.73
National Geodetic Vertical Datum of 1929	NGVD29	-3.32[d]	-3.32

Table 1. Tidal Data[a] and Intake Structure Elevations
RMT II Dock and Red Tank Dock, Samoa, California

Description	Abbreviation	RMT II Dock Elevation (feet, NAVD88) [b]	Red Tank Dock Elevation (feet, NAVD88)
Existing Intake Structure Invert Elevation	N/A	-8.82	-4.38 +/-
Bay Bottom Adjacent to Intake Structure	N/A	-14.82	-5.90 +/-

[a] National Oceanic and Atmospheric Administration (NOAA) Station 9418767 North Spit, CA
[b] NAVD88: North American vertical datum, 1988
[c] N/A: not applicable
[d] NGVD29 is 1.013 meters (3.32 feet) lower than NAVD88 according to the NOAA VERTCON orthometric height conversion tool (https://www.ngs.noaa.gov/cgi-bin/VERTCON/vert_con.prl) for 40.804624 North Latitude, 124.193127 West Longitude.

Original design elevations for the RMT II dock were given in reference to the National Geodetic Vertical Datum of 1929 (NGVD29). Current design elevations are typically in reference to the North American Vertical Datum of 1988 (NAVD88). NGVD29 is 1.013 meters (3.32 feet) lower than NAVD88 at RMT II (NOAA, 2019); that is, NAVD88 = NGVD29 – 3.32 feet. Table 1 includes tide elevations and existing intake structure elevations.

Proposed Intake Screen Design

The RMT II dock and Red Tank dock intake structures are currently designed with openings on the face of the structures with vertical guide channels to hold flat screens over the intake openings. Based on the required intake flow rates, flat screens will not be of sufficient surface area to provide the required intake flow rates. Therefore, the District is proposing to install tee-style intake screens over the intake openings. The tee screens would be mounted to flat plates that can be slid down into place over the intake openings, providing significantly greater screen surface area. The proposed intake screens also include an automated air burst self-cleaning system, which greatly increases the allowable approach velocity and, thus, the intake flow rates.

Appendix 3 includes a product information sheet for a tee screen manufacturer (Hendrick Screen Company) that specializes in intake screen design. The manufacturer has provided a preliminary design for an intake screen that meets the design criteria described above (Appendix 4 includes a preliminary design drawing of the intake screen). A similar intake screen design is proposed for both locations with the exception that the RMT II Dock screen will be 36-inch diameter with a maximum intake flow rate of 5,500 gpm, and the Red Tank Dock screen will be 24-inch diameter with a maximum intake flow rate of 2,750 gpm.

The proposed screens include the following features:

- 316 stainless steel woven wire screen material; 1.0 mm spacing between bars
- 36% open area on screen material
- 0.2-feet per second (fps) maximum approach velocity at maximum intake flow rate
- Compressed air automatic self-cleaning system
- Flow modifier to evenly distribute intake flow rates and velocities over the entire screen face

The screen manufacturer indicates head loss through the screen will be approximately 0.17 pounds per square inch (psi) at design conditions; 0.44 feet. Therefore, the water level inside the intake structure will be a minimum of 0.44 feet lower than the tidal water level outside the structure. As material builds up on the screen, head loss will increase, and the water level inside the intake structure will decrease accordingly, until the air burst cleaning system clears the screen of obstructions. The setpoint for when the air burst cleaning system actuates will be manually adjusted to clean the screen when the head difference inside and outside the intake structure is a maximum of 0.1 feet greater than the design head difference of 0.44 feet, for a total maximum head difference of 0.54 feet prior to automated screen cleaning.

Proposed RMT II Dock Intake Structure Conceptual Design

The existing RMT II dock intake structure is constructed of wood that has become deteriorated. The wooden structure will likely need repairs to seal cracks that would allow flow into the intake structure other than through the intake screen. Appendix 1, Figure 2 includes a proposed plan view of the new intake screen location. The direction of tidal flow in the bay channel varies 180-degrees, four times per day. The proposed orientation of the new screen is parallel to the direction of tidal flow.

Appendix 1, Figure 3 includes an elevation view of the proposed RMT II dock intake screen relative to tidal elevations and the existing intake structure. The proposed design puts the intake screen approximately 3 feet above the invert elevation of the existing intake structure. The bottom elevation of the bay outside of the intake structure is approximately 6 feet below the bottom of the intake structure, and may vary over time as sediment moves; however, there is sufficient depth between the invert of the existing structure and the mean lower low water (MLLW) elevation to provide 3 feet of clearance between the bottom of the new screen and the invert of the existing intake structure. This will provide room for sediment accumulation and prevent the new screen from drawing sediment from the bottom of the bay while maintaining complete submergence during all tides. The manufacturer recommends a minimum of 18 inches clear water be maintained above and below the top and bottom of the screen. Note the proposed intake elevation is also below the lowest astronomical tide level, which is the lowest expected water level at this location.

The proposed RMT II dock intake structure design will include up to four vertical turbine pumps, with a maximum combined flow rate of 5,500 gpm. The existing wood and concrete pump pad will likely need to be replaced to accommodate additional vertical turbine pumps. The pumps will operate on variable speed drives in order to provide a variable flow rate depending on demand and pipe pressure. The four intake pumps will include redundant/backup pumps and duty pumps. The new compressor can be installed on the dock, adjacent to the new pumps. The compressor should be located as close as possible to the intake screen to minimize headloss through the compressed air piping. A new pump house is recommended to house all of the new equipment and protect it from the harsh marine environment.

New discharge piping will be required. SHN recommends that stainless steel and PVC piping be used for this application due to the severe marine environment.

The new intake screen will be bolted to a large, square steel plate that will slide into the vertical guide channels, creating a seal to cover the 8-foot-tall by 3-foot-2-inch-wide structure opening, restricting the opening to the inner diameter of the intake screen flange. This will allow the new tee screen to be lowered and raised using a crane or hoist located above on the pier.

The RMT II dock intake screen is located between the pier and the shore of the bay such that large logs and debris that may damage the screen are unlikely to occur at this location. However, if it is determined that large debris is of concern, piles or other protective measures may be placed around the outside of the screen to prevent damage.

Proposed Red Tank Dock Intake Structure Conceptual Design

The existing Red Tank dock intake structure is concrete and appears to be in functional condition. Minor maintenance repairs or cleaning may be necessary to bring this structure back into service. Red Tank dock is located approximately 0.5 miles north of the RMT II dock. Up to two water pipes may be used to supply bay water from Red Tank dock to land to support various uses. A conceptual site plan is included in Appendix 1, Figure 4. The direction of tidal flow in the bay channel varies 180-degrees, four times per day. The proposed orientation of the new screen is parallel to the direction of tidal flow.

Appendix 1, Figure 5 includes a conceptual elevation view of the proposed Red Tank dock intake structure and screen. Accumulated sediment inside the structure that is higher than the sediment outside of the structure. Approximately 3 feet of sediment (approximately 6.3 cubic yards) will be removed prior to placing pumps into the structure to allow sufficient depth for placing the pumps to prevent sediment from damaging the pumps.

The new intake screen will be placed approximately 1 foot off of the existing bay bottom which will put the top of the screen near the lowest astronomical tide elevation. The manufacturer recommends a minimum of 12 inches clear water be maintained above and below the top and bottom of the screen. The tidal water level will need to be monitored to ensure the intake pumps do not operate if the water level drops below 12 inches above the top of the screen. Leaving 1 foot between the bottom of the intake screen and the bay bottom will reduce the potential for pumps to draw sediment into the interior of the intake structure.

The Red Tank dock intake structure is currently configured to house up to two intake pumps mounted above the intake structure on a concrete pad. The proposed design includes up to two new vertical turbine pumps, providing up to a maximum of 2,750 gpm. The pumps will operate on variable speed drives in order to provide a variable flow rate depending on demand and pipe pressure.

The new compressor can be installed on the dock, adjacent to the new pumps. The compressor should be located as close as possible to the intake screen to minimize headloss through the compressed air piping. A new pump house is recommended to house all of the new equipment and protect it from the harsh marine environment.

New intake piping will be required. SHN recommends that stainless steel and PVC piping be used for this application due to the severe marine environment.

The new intake screen will be bolted to a large, square steel plate that will slide into the vertical guide channels, creating a seal to cover the 4-foot-tall by 2-foot-wide structure opening, restricting the opening to the inner diameter of the intake screen flange. This will allow the new tee screen to be lowered and raised using a crane or hoist located above on the pier. Red Tank dock intake structure currently includes two openings: one opening is proposed to be used for the new screen, and the second opening will be sealed off using a blank steel plate.

The Red Tank dock intake screen is located on the open channel side of the dock, exposed to possible damage from large logs and debris that may flow by the structure in the channel of the bay. It may be necessary to place piles or other protective measures around the perimeter of the intake screen to prevent impacts and damage from logs and debris floating by, or from vessels unaware of the location of the screen.

Please call us at (707) 441-8855 if you have any questions.

Sincerely,

SHN

Mike Foget, PE
Senior Engineer

Chuck Swanson, EIT
Staff Engineer

MKF:CRS:lam

c. w/Attach.: Larry Oetker, HBHRCD
Chris Mikkelsen, HBHRCD

Appendices:
1. Figures
2. Sea Chest Drawing D-12-226
3. Tee Screen Data Sheet
4. Tee Screen Drawing

References

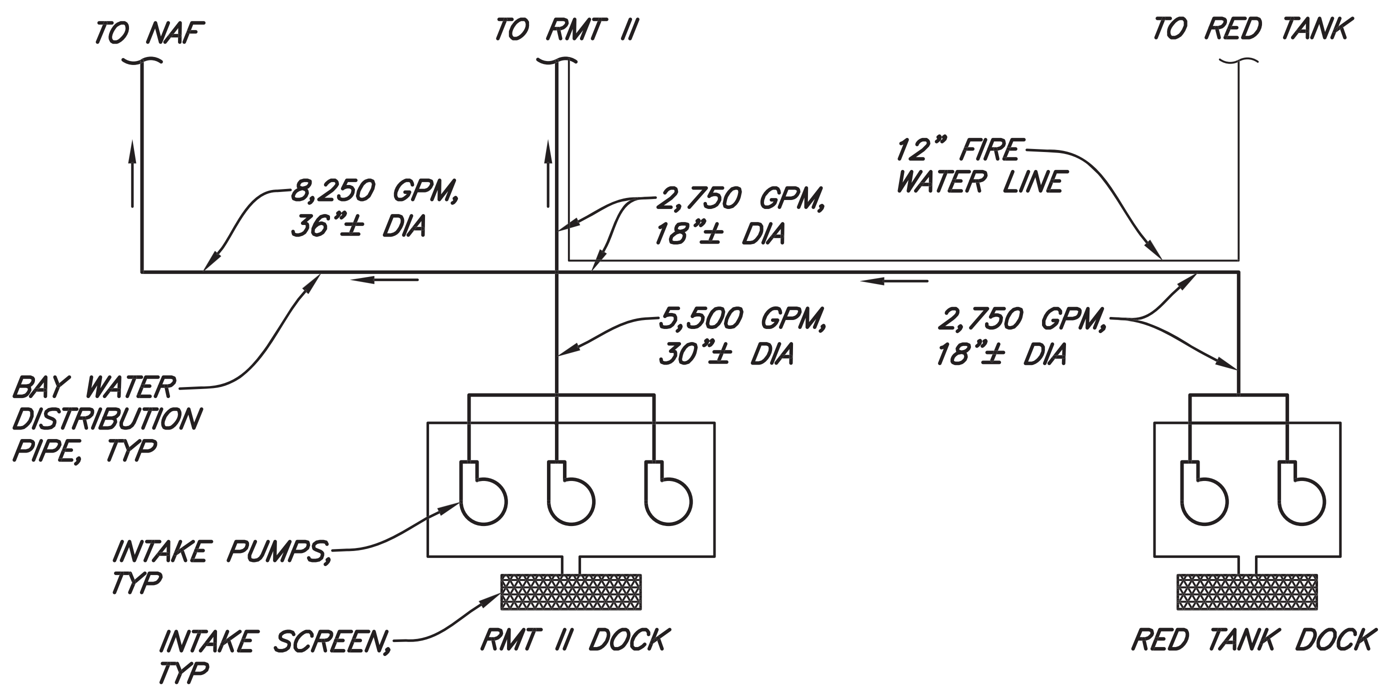
Aarreberg, Arn, Environmental Scientist, CDFW–Marine Region. (2020). Consultation with the California Department of Fish and Wildlife regarding intake structure design criteria.

Georgia-Pacific Corporation. (1966). *Water Supply and Distribution Water Treatment Plant Sea Water Intake; Drawing Number D-12-226*. Georgia-Pacific Corporation, Paper Division-Samoa, California. Eureka, CA:Georgia Pacific Corp.

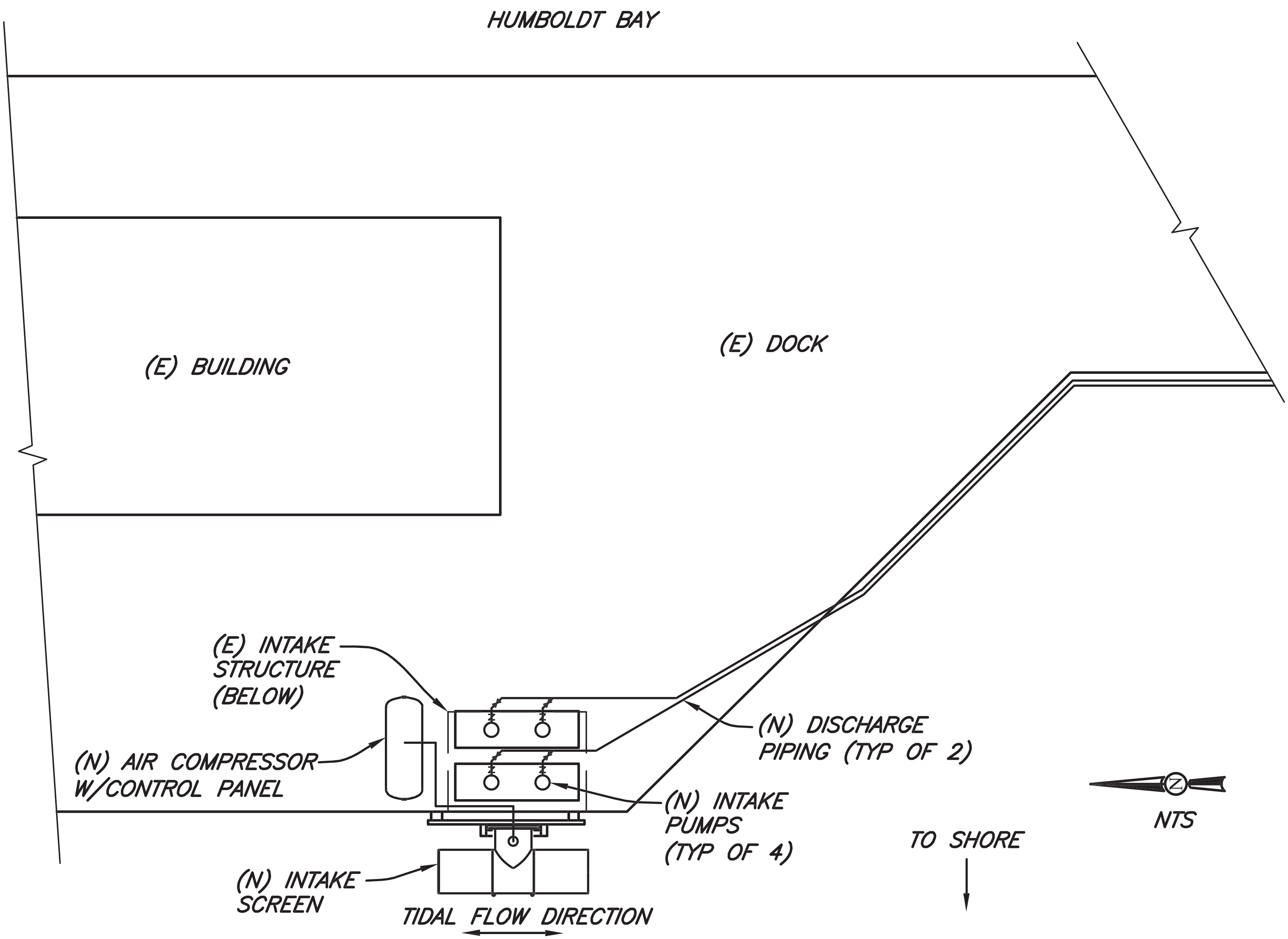
National Marine Fisheries Service. (1997) *Fish Screening Criteria for Anadromous Salmonids*. NR:NMFS.

National Oceanic and Atmospheric Administration. (2019). *NOAA VERTCON orthometric height conversion tool for 40.804624 North Latitude, 124.193127 West Longitude*. Accessed at: https://www.ngs.noaa.gov/cgi-bin/VERTCON/vert_con.prl.

Tenera Environmental. (May 13, 2021). *Empirical Transport Modeling of Potential Effects on Ichthyoplankton Due to Entrainment at the Proposed Samoa Peninsula Master Bay Water Intakes*. San Luis Obispo, CA: Tenera Environmental.



SHN	HBHRCD Humboldt Bay Intake Screens Samoa, California	Humboldt Bay Intake Piping Diagram SHN 016240
	November 2021 / 016240-005-INTAKE-WATER-DIAG	Figure 2



SHN	Humboldt Bay Harbor District Sea Chest Intake Screens Samoa, California	RMT II Intake Screen Conceptual Site Plan SHN 016240.003
	April 2020	016240-003-SEA-CHEST

Figure 2

Exhibit 4
CDP 1-21-0653
Page 10 of 20

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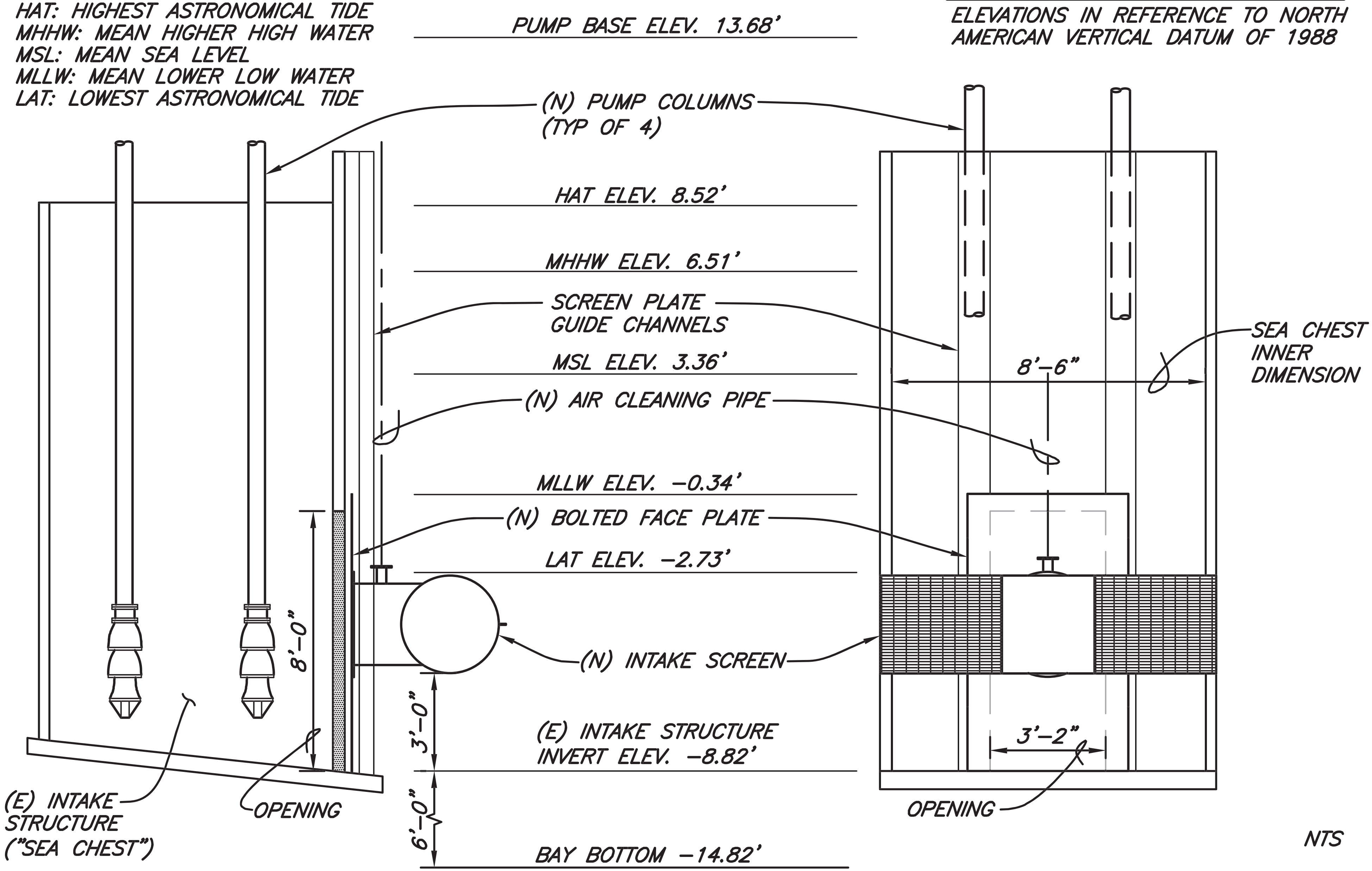
DEFINITIONS

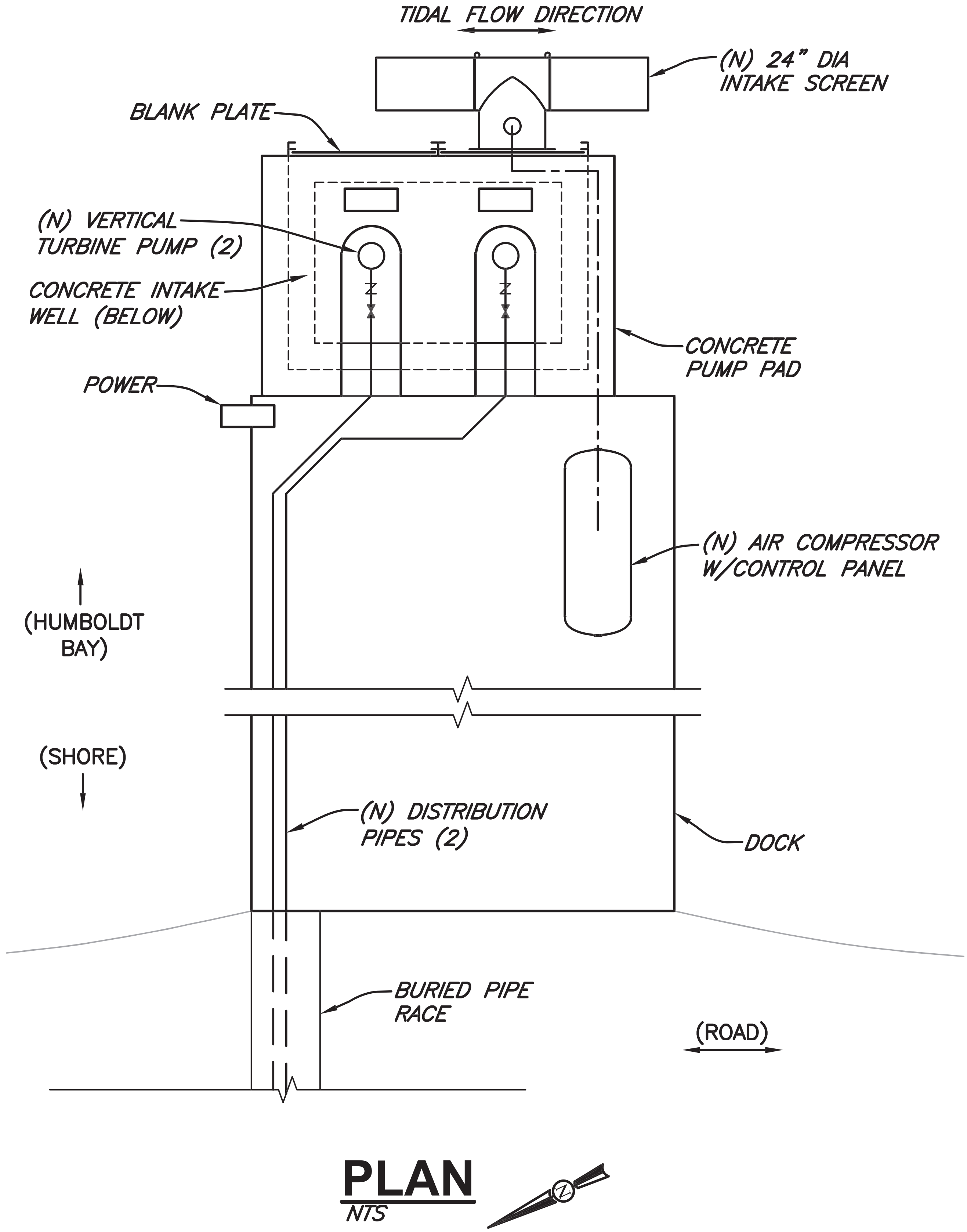
HAT: HIGHEST ASTRONOMICAL TIDE
MHHW: MEAN HIGHER HIGH WATER
MSL: MEAN SEA LEVEL
MLLW: MEAN LOWER LOW WATER
LAT: LOWEST ASTRONOMICAL TIDE

NOTES

ELEVATIONS IN REFERENCE TO NORTH AMERICAN VERTICAL DATUM OF 1988



SHN	Humboldt Bay Harbor District Sea Chest Intake Screens Samoa, California	RMT II Intake Screen Conceptual Elevations SHN 016240.003
	March 2020 / 016240-003-SEA-CHEST	Figure 3



SHN	Humboldt Bay Harbor District Sea Chest Intake Screens Samoa, California	Red Tank Dock Intake Screen Conceptual Site Plan SHN 016240.003
May 2020	016240-REDTANKDOCK	Figure 4

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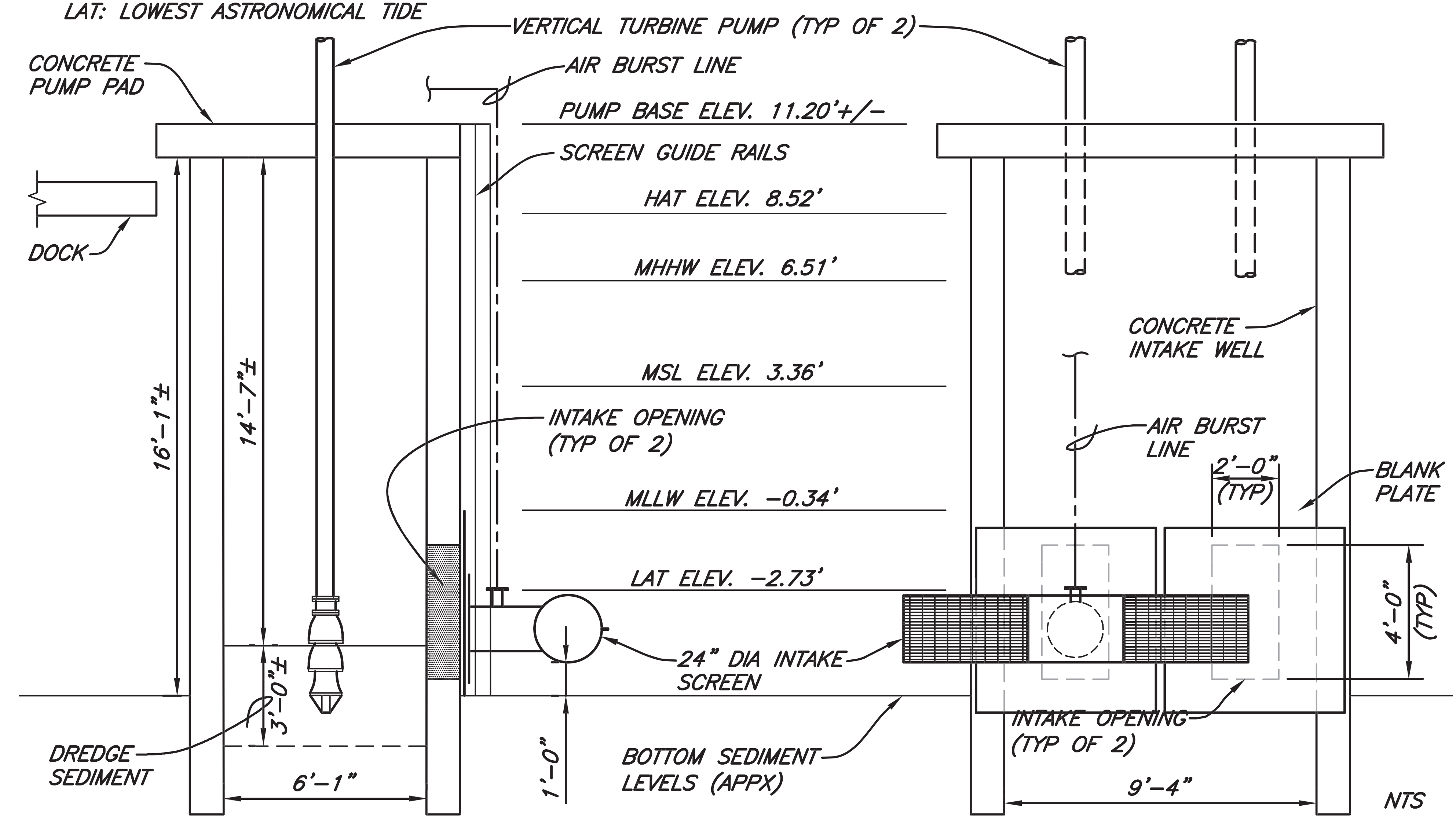
DEFINITIONS

HAT: HIGHEST ASTRONOMICAL TIDE
MHHW: MEAN HIGHER HIGH WATER
MSL: MEAN SEA LEVEL
MLLW: MEAN LOWER LOW WATER
LAT: LOWEST ASTRONOMICAL TIDE

NOTES

ELEVATIONS IN REFERENCE TO NORTH AMERICAN VERTICAL DATUM OF 1988



Humboldt Bay Harbor District Sea Chest Intake Screens Samoa, California	Red Tank Dock Intake Screen Conceptual Elevation SHN 016240.003	
May 2020	016240-REDTANKDOCK	Figure 5

Exhibit 4
CDP 1-21-0653

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812 W. Wabash Avenue, Eureka, CA 95501-2138

Reference: 016240.005

March 9, 2022

Larry Oetker
Humboldt Bay Harbor, Recreation, and Conservation District
601 Startare Dr.
Eureka, CA 95501

Subject: Humboldt Bay Intake Screens Preliminary Operation and Maintenance Description, Revision 1, Redwood Marine Terminal II and Red Tank Dock, Samoa, California

Larry Oetker:

SHN is submitting this preliminary operation and maintenance (O&M) description, at your request, describing proposed/recommended O&M for two intake screens located at Redwood Marine Terminal II (RMT II) and "Red Tank" Dock (RTD) in Samoa, California. The screens will be owned and operated by the Humboldt Bay Harbor, Recreation, and Conservation District (District).

This document is intended to serve as a preliminary description of O&M tasks and should be updated once the project design has been completed and again when operation of the system has begun and actual conditions are better understood. For additional detail on the proposed design conditions, please see letter dated August 6, 2021, entitled *Humboldt Bay Intake Screen Conceptual Designs, Redwood Marine Terminal II and Red Tank Dock, Samoa, California–Revision 03* by SHN.

This revision (Revision 1) to the O&M description includes updated elevations for RMT II Dock based on recent field survey.

System Description

Two similar intake screen systems will be installed at RMT II and Red Tank Dock (Appendix 1, Figures 1-6). The screens must be constructed and operated to meet or exceed requirements to prevent entrainment and impingement (E&I) of wildlife. Each screen will consist of a cylindrical screen face constructed of stainless steel or other corrosion resistant material. The screen mesh will be permanently attached to a flange that will mount to a flat plate and will create a seal around the intake structure openings. The intake structures must be sealed to prevent E&I through orifices and openings other than the intake screen faces. Water will be drawn out of each intake structure by vertical turbine pumps, and the screens will prevent wildlife from entering the structure and being captured by the pumps.

Each screen will include a self-cleaning mechanism consisting of either pressurized air or mechanical brushes (see Attachment 2 for an example manufacturer's O&M for a tee screen with pressurized air cleaning system). Pressurized air systems will introduce short bursts of pressurized air into the interior of the screens, pushing debris and material that has accumulated on the screen faces off into the surrounding water. Mechanical brush screens will continuously or periodically scrape the screen face surface either by rotating the brushes around the outer face of the screen, or by rotating the screen with the brushes fixed in one position.

The flat plate the screens are mounted to, which creates a seal around the intake structure openings, will rest inside of two vertical c-channels. The screens will have lifting lugs attached that will allow the screens to be raised up out of the water from a lifting crane located on top of the structure. Screens can be lifted up to the surface of the dock and intake structure for inspection and maintenance.

Vertical turbine intake pumps will consist of motors that will be installed on top of the intake structure at the dock level, a vertical driveline and intake pipe, and pump intake bowls (impellers) located beneath the water surface inside the intake structures. The discharge pipe from each pump will be connected to a distribution system for distribution to various locations along the waterfront.

Pump motors, air compressors, screen brush motors, lifting hoists, and sensors will require power at each site.

Operational Constraints

Flow Rate

See Appendix 1, Figure 2 for conceptual flow diagram.

- RMT II: The maximum design flow rate of 5,500 gallons per minute (gpm) shall not be exceeded at any time.
- RTD: The maximum design flow rate of 2,750 gpm shall not be exceeded at any time.

Vertical Position

See Appendix 1, Figures 4 and 6 for conceptual elevations of each intake.

Note: All elevations are in reference to the North American vertical datum, 1988 (NAVD88).

RMT II

- The RMT II Sea Chest is a wooden structure supported by vertical wood piles and horizontal 6 inch (in.) by 16 in. horizontal members, and enclosed by 4 in. by 12 in. wood planks. The structure inside dimensions are approximately 8 ft. 2 in. wide by 8 ft. 6 in. long, and approximately 17 ft. 6 in. deep.
- Top Clearance: Maintain 18 inches (in.) clear water above the screen face during operation, at a minimum (unless otherwise specified by screen manufacturer). MLLW elevation is -0.34 feet (ft) such that, at a minimum, the top face of the screen should be located below -1.84 ft.

- Bottom Clearance: maintain 18 in. clear water below the screen face during operation, at a minimum (unless otherwise specified by screen manufacturer). The bottom of the existing intake structure is located at an elevation of approximately -5.1 ft. The bay bottom measured near the face of the intake structure at the time of this writing is approximately -11.1 ft. With the new screen mounted at the lowest elevation of the intake structure, approximately 6.0 ft of clear water will remain below the bottom of the new screen.

RTD

- The Red Tank Dock intake structure is a concrete sea chest approximately 6 ft. 1 in. wide by 9 ft. 4 in. long, and 16 ft. deep to the bay mud. It is uncertain as to whether the bottom of the interior of the structure is concrete or bay mud. When measured, the mud accumulated inside the structure was approximately 1 ft. 6 in. higher than the bay mud outside the structure. The concrete walls and top slab are approximately 12 in. thick.
- Top Clearance: Maintain 12 inches of clear water above the screen face during operation, at a minimum (unless otherwise specified by screen manufacturer). MLLW elevation is -0.34 ft such that, at a minimum, the top face of the screen should be located below -1.34 ft.
- Bottom Clearance: maintain 12 inches of clear water below the screen face during operation, at a minimum (unless otherwise specified by screen manufacturer). The bay bottom measured near the face of the intake structure at the time of this writing is approximately -5.9 ft such that the bottom of the screen should be located at or above -4.9 ft.

Head (Water Level) Differential

The self-cleaning mechanisms shall be initiated when the head differential measured as the difference in water level inside and outside the structures exceeds 0.1 ft above the baseline differential. The baseline differential shall be established as the difference in water level inside and outside the structures when the pumps are operating at full design capacity with the screen completely clean and free of any pore obstructions. Screen manufacturers should provide an estimate of what the baseline differential will be and what can be field verified.

There will be headloss due to friction as water passes through the screens such that the water level will be lower inside the intake structures compared with the ambient bay water level outside the structures. As material builds up on the screens and the pores decrease in opening size, the head differential will increase (the level inside the structures will decrease compared with outside the structures due to increased friction). Once this differential increases to 0.1 ft or more above the baseline, the self-cleaning mechanism must be initiated.

As the frequency of self-cleaning increases because the screens cannot be cleaned sufficiently by the self-cleaning mechanisms and the 0.1 ft head differential is exceeded more frequently, manual cleaning should be initiated. The frequency of manual cleaning may need to be adjusted after the screens have become operational.

Operation

Startup Pre-Inspection

1. Inspect and Clean Screen
    a. Visually inspect the screen for debris or excessive obstruction of pores by aquatic growth or eelgrass.
    b. Remove loose debris manually prior to proceeding with startup.
    c. Raise screen and remove attached growth if necessary prior to proceeding with startup.
    d. Ensure that the screen is in place over the opening of the intake structure and that all seals are in place and seated securely. Record and repair any deficiencies.
    e. Ensure that the screen is securely attached to pressurized air piping (if applicable).
2. Inspect and Service the Air Compressor (if applicable)
    a. Visually inspect the air compressor, pressure tank, and pressurized air piping and valves. Record and repair any deficiencies.
    b. Drain water from compressor pressure tank.
    c. Check lubricant levels. Repair any deficiencies.
    d. Visually inspect air cleaner, replace as needed.
3. Inspect and Service Mechanical Brush Mechanisms (if applicable)
    a. Visually inspect the brushes and brush motors. Repair any deficiencies.
    b. Remove any debris from brushes that may reduce the efficiency of the cleaning mechanism.
4. Inspect and Service Pump Motors and Hoist Motors (if applicable)
    a. Visually inspect pump motors. Repair any deficiencies.
    b. Check lubricant levels (if applicable), check inspection service logs, and record frequency of maintenance.
5. Inspect level, pressure, and flow instruments.
    a. Visually inspect water level instrumentation and ensure its free of debris that may affect level measurements. Record water levels. Confirm that water levels are not below the lowest water level recommended.
    b. Visually inspect water pressure sensors and ensure in place and functional.
    c. Visually inspect flow meters and ensure in place and functional. Record totalized flow.
6. Verify that end-user(s) is ready to receive water.
7. Open/close valves as needed to supply water to desired location in distribution system.

Startup

1. Select manual or automatic operation mode on air compressor cleaning system control panel (as applicable).
    a. START air compressor cleaning system.
2. Select manual or automatic operation mode on mechanical brush cleaning control panel (as applicable).
    a. START mechanical brush cleaning system.
3. Select manual or automatic operation mode on pump control panel (as applicable).
    a. START one pump at a time (as applicable). Allow 1-2 minutes after pump start before starting each additional pump for pressure to equalize in the system.
4. Verify that level sensors are functioning and manually record water levels and head differential. Manually verify water levels are correct and accurate. Note whether head differential is greater than previous record and whether manual cleaning may be necessary.
5. Verify that pressure sensors are functioning and manually record pressures.
6. Verify that flow meters are functioning and manually record flow rates once all pumps are running. Confirm that flows do not exceed maximum capacity of screens.

Post-Startup Inspection

1. Inspect pumps; note any abnormal vibration or heat.
2. Inspect pump water seal (if applicable).
3. Inspect piping, valves, and appurtenances for leaks. Note minor leaks. Stop the system and repair major leaks.
4. Confirm with end-user that flow is sufficient.
5. Confirm that pressurized air or mechanical brush cleaning systems are functioning properly.

Shutdown

1. STOP pumps.
2. STOP pressurized air or mechanical brush cleaning system.
3. Record date/time of shutdown and totalized flow rate.

Maintenance

Manual Screen Cleaning

1. Lockout/tagout pumps and air compressor or mechanical brush systems.

2. Visually inspect lifting chain(s) and/or cable(s). Confirm that they are connected to the appropriate lifting lugs and secured to the lifting hoist. Confirm that they are not corroded or loose. Manually pull on chains and/or cables to test for strength. Confirm that hoist is secured to overhead support.
3. Lift screen very slowly ensuring that the screen does not bind in the vertical guide rails. If binding occurs, adjust tension on lifting chains/cables until screen raises smoothly. Do not exert excessive force on screen or damage to guide rails may occur and will have to be manually removed and repaired.
4. Raise screen until accessible for manual cleaning. Photograph and record accumulation on screen and note time since last service.
5. Use pressure washer to remove debris and growth on screen. If pressure washing is not sufficient, use manual scrapers or brushes to remove remaining material until screen is free of debris and growth and all pores are clear.
6. Inspect interior of screen for additional debris/growth and clean as above.
7. Inspect pressurized air distribution system or mechanical brush system and service as needed.
8. Lower screen back into place slowly. Prevent binding as above.

Intake Structure Integrity Test

Note: this test should be performed at high tide.

1. Lift and remove screen from structure.
2. Place blank face plate in vertical guide channels and lower into place, sealing the intake structure opening.
3. Pump water from intake structure as low as possible. This may be accomplished with a small submersible pump.
4. Observe and note any leakage of bay water into structure. Repair any deficiencies.

Intake Structure Cleaning

Note: This should be done periodically to remove accumulated sediment from the structures prior to when sediment rises to within 1 ft below the bottom of the pumps. This may be done by following the instructions above for "Intake Structure Integrity Test," removing sediment from the interior after the blank face plate is in place and water has been removed. Or this may be accomplished with the screen in place, using a small suction dredge.

Cleaning with water removed:

1. Pull pump motors and pumps.
2. Remove sediment using a vacuum suction system by lowering the vacuum suction hose into the holes for the pumps (similar to a vactor truck system).
3. Replace pumps and motors.

Cleaning with screens in place:

1. Pull pump motors and pumps.
2. Remove sediment using a small dredge suction pump by lowering the suction hose into the holes for the pumps.
3. Note that suction flow rate must be recorded to ensure it does not exceed the maximum design capacity of the screens.

Please call us at (707) 441-8855 if you have any questions.

Sincerely,

SHN

Mike Foget, PE
Senior Engineer

Chuck Swanson, EIT
Staff Engineer

MKF:CRS:ame

c. w/Attach.: Rob Holmlund, HBHRCD
Chris Mikkelsen, HBHRCD

Appendices: 1. Figures
2. Manufacturer O&M

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1062 G Street, Suite I, Arcata, CA 95521-5800

Reference: 016240.005

August 15, 2022

Rob Holmlund, AICP
Humboldt Bay Harbor, Recreation, and Conservation District
601 Startare Drive
Eureka, CA 95501

Subject: Humboldt Bay Master Water Intakes Project, Kramer Dock Pile Removal, Eelgrass Protection Plan and Compensation for Potential Loss of Biological Productivity

Dear Rob Holmlund:

Introduction and Project Objectives

The Humboldt Bay Water Intakes Project is being implemented by the Humboldt Bay Harbor, Recreation, and Conservation District (Harbor District; County of Humboldt, 2022). This project will modernize and operate two former bay-water intake systems in Humboldt Bay and will install new piping to deliver bay water to existing and future Harbor District tenants, as described in the Draft Environmental Impact Report (DEIR; SCH 2021040532; County of Humboldt, 2021), which includes this pile removal project conditioned by the project's regulatory approvals from the Harbor District, California Coastal Commission, North Coast Regional Water Quality Control Board, and U.S. Army Corps of Engineers. These conditions include the removal of 988 piles at the previous Kramer Dock along the Humboldt Bay shoreline near Fields Landing. Removal of these piles will create new benthic habitat that will mitigate for loss of biological productivity caused by fish species entrainment, as a result of the operation of the water intake systems as outlined in Section 2.4.7 (pages 2-56) of the DEIR. The EIR was certified by the Humboldt County Planning Commission on August 4, 2022.

The need to offset the impact on biological productivity is based on Section 30231 of the California Coastal Act, California Ocean Plan requirements for desalination plant water intakes, and a Memorandum of Agreement among regulatory agencies during environmental review of applications for proposed seawater desalination facilities. Additionally, Section 3.14 of the Humboldt Bay Area Plan (consistent with Section 13142.5 (b) of the Ocean Plan) outlines requirements that the best available site, design, technology, and mitigation measures feasible shall be used to minimize the intake and mortality of all forms of marine life. The water intakes are designed to avoid impingement of all aquatic species and entrainment of juvenile and adult aquatic species, by meeting design criteria related to screen mesh, water approach velocity, and other parameters and avoiding potential significant impacts to biological productivity. It is expected that only non-special status aquatic larvae will be entrained, except a small amount of Longfin Smelt larvae is estimated at up to 200 larvae

EXHIBIT NO. 5
PILE REMOVAL MITIGATION PLAN
CDP APPLICATION NO. 1-21-0653
(Humboldt Bay Harbor District)

SHN, Tenera Environmental, and the Harbor District prepared a technical memorandum for the Humboldt Bay Water Intakes. According to that technical memorandum, based on daily tidal dynamics and using the source water volume estimates, the daily losses to any larval populations in Humboldt Bay subject to entrainment would be expected to be less than 0.018%, even under maximum intake flow during Phase III of its operation and the most conservative source water volume estimate at Mean Sea Level (SHN, Tenera, Harbor District, 2022). As explained in this technical memorandum, entrainment losses estimated based solely on the ratio of the intake volume to source water volume are likely to be highly conservative, especially due to the design of the intake screens and their placement in an area of Humboldt Bay where they will be subject to strong sweeping velocities on ebb and flood tides.

Nine hundred eighty-eight (988) creosote-treated pilings and 151 creosote-treated cross-beam supports, attached to the pilings, are proposed for removal at Kramer Dock as compensatory restoration for biological productivity foregone as a result of the water intakes project. This is intended to create space for eelgrass (*Zostera marina*) habitat while enhancing a larger tidal habitat area, and in turn, supporting biological productivity. The removal of creosote piles and braces is proposed to offset a small reduction in the Humboldt Bay's biological productivity as a result of entrainment of non-special-status larval species. Following implementation, the Harbor District intends to maintain ownership of the property and oversee follow-up monitoring and maintenance activities associated with the restoration.

The California Regional Water Quality Control Board (RWQCB) requires submittal and approval of a plan describing mitigation for the mortality of all forms of marine life. Plans shall include project objectives, site selection, site protection instrument (the legal arrangement or instrument that will be used to ensure the long-term protection of the compensatory mitigation project site), baseline site conditions, a mitigation work plan, a maintenance plan, a long-term management plan, an adaptive management plan, performance standards and success criteria, monitoring requirements, and financial assurances. This document has been organized in the same format as is required by the RWQCB.

This Plan is not a mitigation plan but is rather a companion document for the pile removal effort developed to compensate for the loss of biological productivity and is intended to minimize impacts to eelgrass that might otherwise occur during pile removal activities for habitat improvement. This will ensure no net loss in eelgrass function consistent with the California Eelgrass Mitigation Policy (NOAA, 2014).

Project Location, Site Selection, and Baseline Site Conditions

The piling removal project proposed by the Harbor District as compensatory restoration for the reduction of biological productivity is located along the eastern shore of the South Bay portion of Humboldt Bay (See Exhibit 1 in Attachment 1). The abandoned pilings were previously part of a structure referred to as the Kramer Dock and extend over an area of approximately 2 acres of shoreline.
At the upcoast end of the abandoned dock, the pilings are more numerous and extend further out from the shoreline, while at the downcoast end they only extend a short distance from the shore. All of the pilings have been cut off and extend various lengths above the surface of the water.

Eelgrass is a sensitive, natural community that occurs in Humboldt Bay and in proximity to the pile removal location. According to an eelgrass mapping study in Humboldt Bay, the vicinity of the Kramer Dock had continuous eelgrass bed coverage (Gilkerson, 2008); however, eelgrass distribution fluctuates and can expand, contract, disappear, and recolonize areas within suitable environments (NOAA, 2014). Pile removal would benefit eelgrass in Humboldt Bay by creating additional eelgrass habitat and would, therefore, self-mitigate for temporary impacts to eelgrass that may occur during pile removal activities.

Within the overall 2.69-acre habitat restoration area, there are two, 150-foot-wide sections that will be used as barge access. Barge access locations were selected based on a previously used location and access to South Depot Road. Eelgrass exists among some of the wood piles at elevations ranging from approximately -2 feet to 1 foot (North American vertical datum, 1988 [NAVD88]; See Attachment 1, Figure 3).

At the request of California Department of Fish and Wildlife (CDFW), field measurements and desktop analyses were conducted to evaluate the weight, surface area, and volume of piles and cross beams to be removed at the Kramer Dock site. The proposed mitigation and compensatory restoration results in the removal and disposal of 1,139 creosote-treated piles and beams, totalling 23,650 cubic feet (ft^3); 308 tons; and 96,530 square feet (ft^2) from Humboldt Bay (GHD, 2022).

The piles and cross beams exhibited a faint smell of petroleum product and are all assumed to have been treated with creosote, as was common for piers, docks, and floats for more than a century. Creosote is derived from coal tars and is made up of hundreds of thousands of chemical compounds with various forms of polynuclear aromatic hydrocarbons (PAHs) accounting for up to 90% of the creosote mixture. Even very low levels of leaching of PAHs from the weathered pilings in Humboldt Bay may still represent a risk to fishes and other marine organisms (Tenera, 2021). These toxins can accumulate in tissues of mollusks and other benthic invertebrates that do not metabolize as efficiently. An increase in concentration can result within organisms with higher fat content, this phenomenon is known as bioaccumulation. Reproduction may be inhibited, or death may occur. For some fish species, sediment contamination is linked to adverse impacts such as reproductive impairment, suppressed immune function, liver lesions, and fin abnormalities. In addition, embryonic development of the Pacific herring has been shown to be negatively affected by diffusible components of weathered creosote pilings (Washington State Department of Natural Resources, 2019).

Site Protection Instrument and Financial Assurance

Regulatory requirements of the California Coastal Commission, North Coast Regional Water Quality Control Board, California Department of Fish and Wildlife, and U.S. Army Corps of Engineers ensure the long-term protection of the compensatory restoration and mitigation project site.

The Harbor District is a public agency and subject to public agency regulations. Once permits are approved, the Harbor District will work within its overall budget to commit funds to the construction of the project. The Harbor District will not begin the bidding process until project funds are committed. Then, the Harbor District will conduct a standard public-agency competitive construction bid process. Through that bid process, the Harbor District will be able to confirm the actual project costs and will reconcile those costs with committed Harbor District funds. As per all standard public agency contracting procedures, the Harbor District will require a bid bond, a performance bond, and 10% retention of all progress payments until project completion.

Mitigation Work Plan

Pile removal will be conducted from shore and/or from a barge. A crane with a boom carrying a vibratory hammer and timber clamp will be used to remove the piles. Piles that break off above the bottom will be reattached to the vibratory hammer and removed. If a pile cannot be fully extracted, it will be cut off 1 foot below the mudline using a saw. Piles located closer to shore would likely be removed using equipment on land during low tidal periods, whereas piles further offshore would likely require removal with equipment operating from a barge. Under current conditions, the pilings likely provide some wave energy dissipation along the shoreline and the existing eelgrass beds have adapted to these conditions. Unarmored portions of the adjacent shoreline show varying degrees of erosion likely caused by tide and wind waves. Pile removal may alter the nearshore hydraulic characteristics of shoreline erosion, but the project does not include removal of the old retaining wood wall, which will continue to protect the shoreline (County of Humboldt, 2022).

Removal with barge: The crane referenced above would be on a barge. The barge would be approximately 80 feet X 100 feet with a 4-foot draft and would be moved with a small tugboat. After being placed on the barge, the piles would be transferred to land and then transported to and disposed of at an appropriate upland location.

Removal from shore: The crane referenced above would operate from the shore immediately adjacent to the bay. The piles would be transported to and disposed of at an appropriate upland location.

Schedule: The Harbor District will complete the mitigation and restoration projects prior to operation of the intake structures. This is anticipated to be within 2 years of permit approval.

Maintenance Plan and Best Management Practices

The following best management practices (BMP) will be followed:

PART 1 A Harbor District staff member or representative will be present to ensure that these BMPs are adhered to.

PART 2 Neither the barge nor the tug will anchor during the project. The barge may attach to existing piles to maintain its position.

a. Piles will be removed during a tide of sufficient elevation to float the barge and tugboat adjacent to the piles being removed without scarring the mudflats or injuring eelgrass.

b. Grounding of the barge is not permitted.

c. A floating containment boom shall be installed and maintained around each pile being removed to collect any debris, including debris floating below the surface but not sinking to the bottom, and weighted plastic mesh (similar to orange construction fencing) will be attached to the boom and extended across the area surrounding the pile. If debris sinks to the bottom, then it shall be removed by a diver.

d. Any equipment used shall be without leaks of any coolant, hydraulic fluid, transmission fluid, or petroleum products. All equipment shall be checked before use in order to certify that there are no fluid leaks. A spill response kit, including oil absorbent pads, shall be onsite to collect any petroleum product accidently released.

e. Crane excavator and tug operators shall be experienced with vibratory pile removal.

f. The crane or excavator operator shall break the soil/pile bond prior to pulling in order to minimize pile breakage and sediment adhesion.

g. Piles shall be removed slowly to limit sediment disturbance.

h. Piles shall not be hosed off, scraped, or otherwise cleaned once they are removed from the sediment.

i. Piles shall be placed in a containment area on the barge to capture sediment attached to the piles.

j. The containment area shall include a structure around the perimeter, which precludes sediment or contaminated water from reentering the bay.

k. Holes left in the sediment by the removed pilings will not be filled. They are expected to naturally fill.

l. Piles and debris shall be removed from the barge and moved to a designated site for disposal preparation in such a manner as to prevent water quality impacts. Prior to disposal, the piles and debris will be stored on paved areas, covered with tarps, and surrounded by a soil erosion boom in order to prevent potential leaching or discharge of debris or contaminated material.

m. All removed piles or portions of piles shall be disposed of at an authorized facility. Piles or portions of piles shall not be re-used in Humboldt Bay or along shoreline areas.

n. Land operations shall not be conducted in wetlands in proximity to the staging site.

Long-Term Management Plan

A long-term management plan is not required as part of this Plan. Pile removal is intended to allow for the natural re-colonization of aquatic organisms, including eelgrass, in the space created by the removal of the piles, compensating for the potential loss of biological productivity resulting from the water intake project. Eelgrass will be avoided using the measures described above to minimize impacts to eelgrass during pile removal.

Adaptive Management Plan

Working with tidal fluctuation, equipment will work from land when possible and from a floating barge when land access is not possible. Piles that break off above the bottom will be reattached to the vibratory hammer and removed. If a pile cannot be fully extracted, it will be cut off one foot below the mudline using a saw. If debris sinks to the bottom, then it shall be removed by a diver. Any eelgrass observed within the vicinity of a broken pile will be avoided during mud removal and cutting of the pile one foot below the soil surface. This includes avoiding trampling eelgrass during on the ground work when access the broken piles and when conducting the actual removal. The contractor shall provide the location of all the broken and cut piles using a GPS unit.

Performance Standards

In addition to the BMPs listed above, performance standards will be consistent with requirements of the California Coastal Commission, North Coast Regional Water Quality Control Board, and U.S. Army Corps of Engineers. Implementation of compensatory restoration would be consistent with the North Coast Regional Water Quality Control Board Basin Plan and would not conflict with the 303(d) listing for Humboldt Bay. Removal of creosote piles is supported by both the Basin Plan and 303(d) listing, as pollutant removal would occur (County of Humboldt, 2021). Benefits to the removal of old and derelict pilings reported by Tenera (2021) will include:

- reduced substrate for introduced species;
- reduced shading of the bottom of the water column;
- reduced toxic effects of creosote and other contaminants;
- reduced restrictions to flow and sediment movement;
- restoration, re-creation, or realignment of intertidal mudflats, sand flats, rock, and shellfish, eelgrass, and macroalgal beds;
- reduced navigational hazards; and
- improved aesthetics.

Monitoring Requirements

The Harbor District proposes to monitor eelgrass in the pile removal areas using photo documentation before and after pile removal efforts with a combination of drone and ground-based photo points at low tide approximately one week before pile removal and again in the same photo point locations approximately one week after pile removal.

Success will be reported based on visual representation of the listed benefits above. Additionally, a minimum of 10 before and after photos from the same location shall be taken of eelgrass populations within the action area. These photos will be used to document the success of the Eelgrass Protection Plan and the avoidance of impacts to eelgrass for submittal to the RWQCB.

Conclusion

Depressions around the base of piles are common and are most likely the result of increases in the speeds of ambient currents around the piles that pull away sediment. In an area where there are numerous piles closely spaced, such as the abandoned Kramer Dock, this effect would likely be expected to severely limit growth of eelgrass and submerged vegetation in the area with the piles in place. Therefore, the removal of a piling results in the restoration of a much larger area than just the area occupied by the piling (Tenera, 2021). Pile removal is intended to provide creation of available space for eel grass habitat while enhancing a larger tidal habitat area with the removal of creosote piles and braces. Removal of the piles in the water will restore the habitat to support aquatic vegetation, such as eelgrass, and associated invertebrates and fishes and result in the removal of creosote-laden piles out of Humboldt Bay.

Implementation of this Plan will result in reduced impacts to eelgrass currently occurring within the action area and will allow for the documentation of the avoidance of eelgrass during pile removal. The enhanced habitat and expansion of area available for eelgrass growth should more than compensate for minor impacts to eelgrass occurring during the pile removal effort. Following pile removal, eelgrass currently occurring within the action area will be able to freely colonize the newly available habitat and will support increased biological productivity in this area of Humboldt Bay.

If you have any questions or comments, please call me at 707-822-5785 or email me at gobrien@shn-engr.com.

Sincerely,

SHN

Gretchen O'Brien

Gretchen A. O'Brien
Senior Wildlife Biologist

GAO:ame

Attachment

1. Kramer Dock Memo

References

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---. (January 28, 2022). "Humboldt Bay Master Water Intakes: Project Description. V5". County of Humboldt:Eureka, CA.

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Kramer Dock Memo

1

Memorandum

27 January 2022

To	Rob Holmlund (Humboldt Bay Harbor, Recreation and Conservation District)		
From	Brett Vivyan & Jeremy Svehla (GHD)		
Reviewed By	Misha Schwarz	**Tel**	707 267 2275
Subject	Suitability of Kramer Dock Site for Bay Water Intake Project Compensatory Off-site Restoration and Mitigation	**Project no.**	11225550

Introduction

The Humboldt Bay Harbor, Recreation and Conservation District (HBHRCD) parcel APN 307-101-002 is located along the shoreline in Fields Landing, at the end of South Bay Depot Road (Exhibit 1). The property extends into the bay, north and south of South Bay Depot Road. The northern section includes a parking lot, boat ramp, structures and the southern section is largely undeveloped with a gravel trail along the shoreline. Rows of in-water pilings that historically supported the Kramer Dock (Figure 1) and a retaining wall span the shoreline of the parcel (Figure 2).

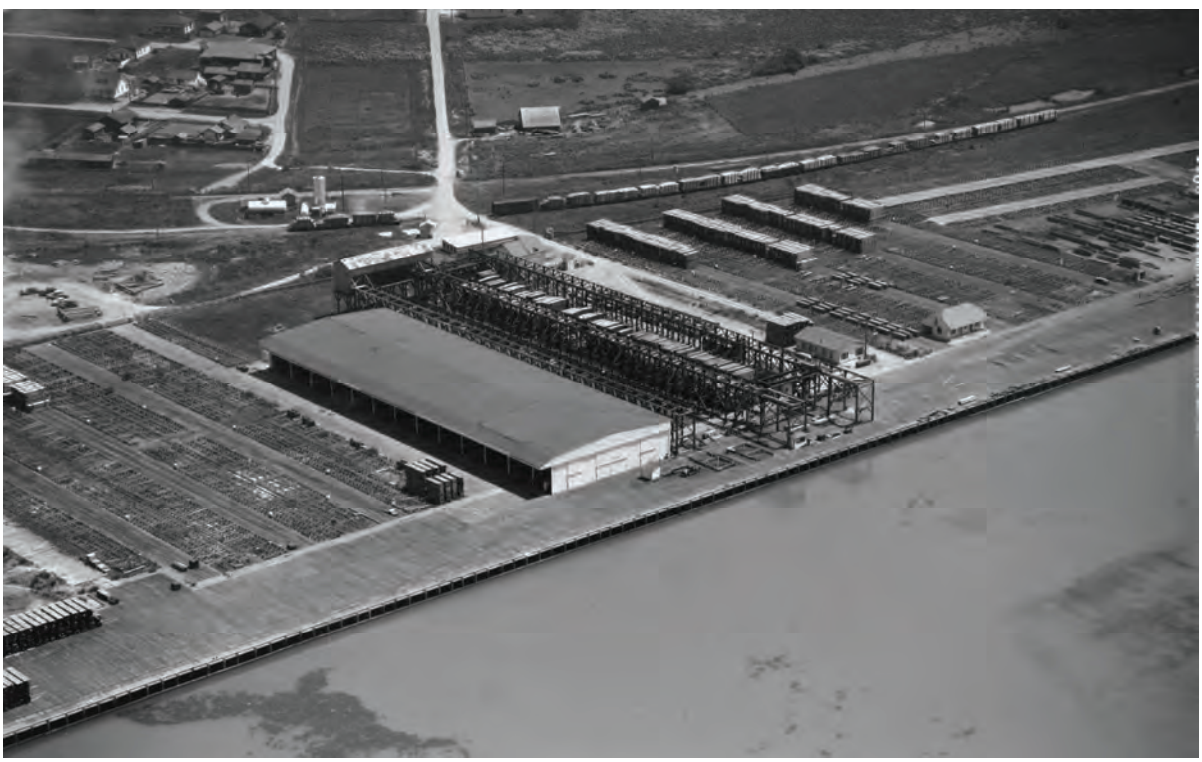

Figure 1. 1947 aerial photo showing former Kramer Dock and supporting piles (Humboldt Room 1947).

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Figure 2. Photo of representative shoreline erosion at project site. Photo source: Stillwater Sciences, 2016

As a part of the eel grass mitigation planning process for the Fisherman's Channel Dredging Project in 2016, mitigation concepts were developed for the project shoreline that included measures to create eel grass habitat (Stillwater Sciences, 2016). The Fisherman's Channel Dredging Project did not move forward, as such the 2016 design concepts were not implemented. Since 2016, the HBHRCD has considered other multi-benefit approaches to habitat enhancement at the site.

The purpose of this memo is to present a habitat enhancement concept that builds on previous efforts and address feedback received from the California Coastal Commission. HBHRCD intends to implement eel grass and habitat enhancements along the shoreline of APN 307-101-002 to restore and improve natural processes and ecosystem functions that will provide habitat for essential fish habitat (EFH). Following implementation, HBHRCD intends to maintain ownership of the property and oversee follow-up monitoring and maintenance activities associated with the restoration.

Proposed Enhancements

Eel grass and habitat enhancements may be achieved through the removal of creosote pilings and associated support structures used for the former Kramer dock. As shown in Exhibit 1, the total habitat restoration areas is 2.69 acres, and contains a total of 988 creosote treated pilings, and 151 cross beam supports, attached to the pilings. The pilings and cross beam supports were part the former Kramer dock have been identified along the shoreline (Exhibit 1).

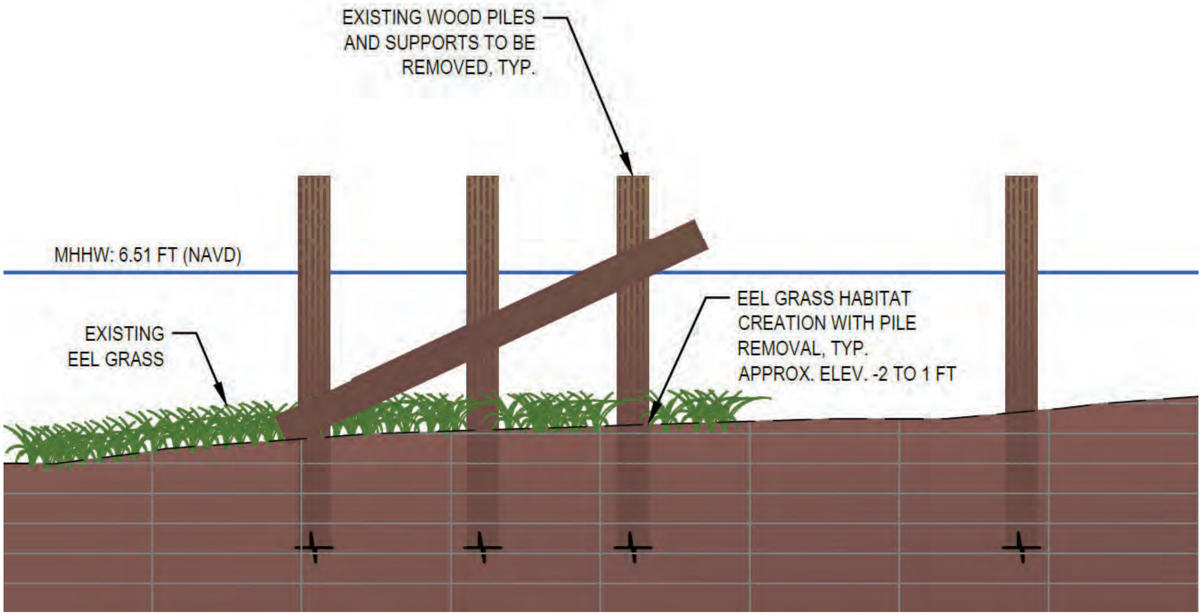

Figure 3 *Typical pile removal section.*

The general area containing pilings in which habitat restoration will occur is comprised of five sub-areas. Within the overall 2.69 habitat restoration area are two 150 ft wide sections that will be used as barge access. Barge access locations were selected based on a previously used location and access to South Depot Road. Existing eel grass exists among the some of the existing wood piles at elevations ranging from approximately -2 ft to 1 ft (NAVD 88).

Pilings would be removed using various methods including but not limited to a vibratory hammer, excavator, or cut-off at a minimum of 1 foot below bed elevation. Pilings located closer to shore would likely be removed from equipment operation on land during low tidal periods whereas piles further off-shore would likely require removal with equipment operating from a barge. Under current conditions, the pilings likely provide some wind wave energy dissipation along the shoreline and the existing eel grass beds have adapted to these conditions. Unarmoured portions of the adjacent shoreline show varying degrees of erosion likely caused by tide and wind waves. Piling removal may alter the nearshore hydraulic characteristics of shoreline erosion, but the project does not include removal of the old retaining wood wall which will continue to protect the shoreline.

Conclusions and Next Steps

The concept presented in this memo provides creation of available space for eel grass habitat while enhancing a larger tidal habitat area with the removal of creosote piles and braces. The following next steps are recommended:

- Obtain Agency concurrence with this plan
- Develop Construction Documents for the removal of piles
- Develop Regulatory Approval Documents and Monitoring/Maintenance Plan

References

1. Stillwater Sciences, 2016. Fields Landing Shoreline Stabilization – Preferred Approach and Alternatives Descriptions. Technical Memorandum. Arcata, CA
2. Humboldt State University Library, Humboldt Room Historic Photos

Paper Size ANSI A

0 75 150 225 300

Feet

Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

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GHD

Baywater Intake CDP Application No. 1-21-0653

Compensatory Off-site Restoration Areas at Kramer Dock

Project No. 11225550
Revision No. 5
Date Jan 2022

EXHIBIT 1

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Print date: 26 Jan 2022 - 14:23

Data source: Humboldt County, AirPhoto_2019_MapService: . Created by: jlopez4

COMMISSIONERS:
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Harbor, Recreation and Conservation
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Methods and Best Management Practices for Pile Removal at Kramer Dock Site (10/21/22)

Objectives

The objectives of these Best Management Practices (BMPs) are to avoid impacts to eelgrass, to avoid the mobilization of contaminants, and to control turbidity and sediments re-entering the water column during the process of removing piles from the Kramer Dock site.

Methods

Pile removal will be conducted from shore and/or from a barge. A crane with a boom carrying a vibratory hammer and timber clamp will be used to remove the piles. Piles that break off above the bottom will be reattached to the vibratory hammer and removed. If a pile cannot be fully extracted, it will be cut off one foot below the mudline using a saw.

Removal with barge: The crane referenced above would be on a barge. The barge would be approximately 80' X 100' with a 4' draft and would be moved with a small tugboat. After being placed on the barge, the piles would be transferred to land and then transported to and disposed of at an appropriate upland location.

Removal from shore: The crane referenced above would operate from the shore immediately adjacent to the bay. The piles would be transported to and disposed of at an appropriate upland location.

Best Management Practices

The following best management practices (BMP) will be followed:

Best Management Practices	BMPs to Avoid Impacts to Eelgrass	BMPs to Minimize Sediment and Contaminant Mobilization
Harbor District staff or a designated representative will be present to ensure that these BMPs are adhered to.	X	X
Neither the barge nor the tug will anchor during the project. The barge may attach to existing piles to maintain its position.	X	X
During the barge method, piles will be removed at a tide of sufficient elevation to float the barge and tugboat adjacent to the piles being removed without scarring the mudflats or injuring eelgrass.	X	X
Grounding of the barge will not be permitted.	X	X
A floating containment boom will surround each pile being removed to collect any debris. To collect debris that floats below the surface but does not sink to the bottom, weighted plastic mesh (similar to orange construction fencing) will be attached to the boom and extended across the area surrounding the pile. If debris sinks to the bottom, then it will be removed by a diver.	X	X
All equipment will be checked before use to minimize risk of petroleum product releasing to the bay. A spill response kit, including oil absorbent pads will be on-site to collect any petroleum product that is accidently released.	X	X

Methods and Best Management Practices for Pile Removal at Kramer Dock

Best Management Practices	BMPs to Avoid Impacts to Eelgrass	BMPs to Minimize Sediment and Contaminant Mobilization
The crane and tug operators will be experienced with vibratory pile removal.	X	X
The crane operator will break the soil/pile bond prior to pulling to limit pile breakage and sediment adhesion.	X	X
All work should be confined to within the floating containment boom.		X
Piles will be removed slowly to limit sediment disturbance.	X	X
Piles will not be hosed off, scraped, or otherwise cleaned once they are removed from the sediment.	X	X
Piles will be placed in a containment area on the barge to capture sediment attached to the piles.	X	X
The containment area will be lined with plastic sheeting to not allow sediment or residual water to reenter the bay.	X	X
Sawdust or woody debris generated from pilings that are cut 1 foot below the mudline using a saw are to be retrieved and placed in the containment area	X	X
Holes left in the sediment by the pilings will not be filled. They are expected to naturally fill.	X	
Piles and debris will be removed from the barge carefully and moved to a designated site for disposal preparation. Prior to disposal, the piles and debris will be stored on a paved surface, covered with tarps, and surrounded by an erosion boom, straw waddle, or hay bale perimeter.	X	X
All removed piles or portions of piles will be disposed of at an authorized facility. No piles or portions of piles will be re-used in Humboldt Bay or along shoreline areas.	X	X
Land operations will avoid wetlands mapped at the site.		

Technical Memorandum

April 5, 2022

To	Larry Oetker	**Tel**	707.267.2275
Copy to	Misha Schwarz, Rob Holmlund	**Email**	Brett.Vivyan@ghd.com
From	Brett Vivyan PE	**Ref. No.**	11205607
Subject	Pile and Cross Beam Removal Quantities		

This memorandum summarizes the field methods and estimated quantities of pile and cross beam removal of the remnant Kramer Dock, in support of the Humboldt Bay Master Baywater Intake Offsite Compensatory Restoration. At the request of California Department of Fish and Wildlife (CDFW), field measurements and desktop analyses were conducted to evaluate the weight, surface area and volume of and cross beam removal at the Kramer Dock site in Humboldt Bay (Fields Landing, California). A total of 988 creosote-treated pilings and 151 creosote-treated cross beam supports, attached to the pilings are proposed for removal.

On March 25, 2022 GHD staff visited the site to confirm creosote treatment and measure pile and cross beam dimensions. Piles were partially submerged at the time of observation and a combination of desktop assessments and field measurements were used to determine ground elevations. Pile dimensions are provided in Table 1 and cross beam dimensions are provided in Table 2. Typical pile and cross beam configuration is shown in Figure 1. The piles and cross beams exhibited a faint smell of petroleum product and are all assumed to have been treated with creosote, as was common for piers, docks and floats for more than a century[1].

Table 1 Typical pile dimensions.

Description	Cross Section	Average Ground Elevation at Pile[2]	Top of Pile Elevation	Length Above Ground	Length Below Ground[3]
Pile	12-inch Diameter	-1.8 feet (NAVD)	7.5 feet (NAVD)	9.3 feet	20 feet

[1] www.dnr.wa.gov/publications/aqr_rest_creosote_factsheet_1019.pdf

[2] Ground elevation at the piles was determined based on the water depth measurements and tidal water levels, as reported at Station 9418723 Fields Landing, Humboldt Bay, CA and 9418767 North Spit, CA and then cross referenced to available LiDAR elevation data. Predicted tidal water levels at Fields Landing were -0.25 ft (NAVD88). Measured tidal water levels at the North Spit were shown to be 0.197 ft higher than predicted at 12:00 pm PDT, resulting in a water level of 0.07 feet (NAVD) at the Kramer Dock site. Water depth at the closest pile was measured to be 1.16 feet (14 inches), resulting in an approximate ground elevation of approximately -1.1 feet (NAVD). Ground elevation, was also evaluated using the 2019 Humboldt Bay LiDAR data set. At the time of LiDAR data collection, the piles were submerged and hydroflattening (water surface elevation captured) occurred at a water level of -0.4 feet. The adjacent ground, approximately 5 feet from the piles was not affected by hydroflattenting. The slope of the adjacent ground, over a length of 30 feet was used to extrapolate elevations, resulting in a ground elevation of -1.05 feet (NAVD) at the same measurement location. Using this same method, the two piles located at approximately 6-foot spacing further west, resulted in ground elevations of -1.8 feet and -2.6 feet. Resulting average ground elevation is -1.8 feet.

[3] Based on personal communication with Larry Oetker (Harbor District Executive Director) noting approximate length of piles below mud line during previous pile removal activities.

Table 2 Typical cross beam dimensions

Description	Cross Section	Length	Top Elevation	Bottom Elevation
Cross Beam	6-inch by 12-inch	12 feet	7.5 feet (NAVD)	0.5 feet (NAVD)

Figure 1 Typical piles and cross beams at mitigation site.

The resulting volume weight, and surface area of piles proposed for removal is summarized in Table 3. The proposed mitigation results in the removal and disposal of 1,139 creosote-treated piles and beams, totalling 23,650 ft^3, 308 tons, and 96,530 ft^2 from Humboldt Bay.

Table 3. Resulting weight, surface area and volume calculations.

Description	Number Removed	Volume (ft^3)	Weight[4] (tons)	Surface Area Exposed to Average Daily Water Column[5] (ft^2)	Surface Area Above MHHW (ft^2)	Surface Area Below Ground (ft^2)
Piles	988	22,740	296	25,760	3,100	62,080
Cross Beams	151	910	12	4,900	690	NA
Totals	1,139	23,650	308	30,660	3,790	62,080

[4] Assumed Coast Redwood with density of 26 lbs/ft^3 (https://www.wood-database.com/coast-redwood/)
[5] Based on ground elevation of -1.8 feet (NAVD) and Mean Higher High Water (MHHW) of 6.51 feet (NAVD) at Station 9418767 North Spit, CA

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1062 G Street, Suite I, Arcata, CA 95521-5800

Reference: 016240.005

July 19, 2022

Rob Holmlund, Development Director
Humboldt Bay Harbor, Recreation, and Conservation District
601 Startare Drive
Eureka, CA 95501

Subject: **Baywater Intake System Pipeline Trench and ESHA Analysis; Response to Continued Review of Coastal Development Permit (CDP) Application No. 1-21-0653**

Dear Rob Holmlund:

SHN has developed this response to the California Coastal Commission (CCC) letter dated February 22, 2022, regarding impacts to Environmentally Sensitive Habitat Areas (ESHA), and other biological resources within the alignment for a proposed water intake pipeline. The CDP application is part of the Humboldt Bay Harbor, Recreation, and Conservation District project to modernize and operate two formerly used bay water intake systems at Redwood Marine Terminal II and Red Tank Dock.

Introduction

A Biological and Habitat Assessment report (SHN, 2020a) and a Wetland Assessment (SHN, 2020b) were previously prepared for a majority of the project site in September 2020, prior to the development of a project description. ESHA and sensitive species habitat have been identified and mapped adjacent to the proposed water intake piping alignment (Figures 1, 2, and 3). The following information is intended to satisfy the CCC request for a biological report that:

(i) evaluates the proposed pipeline infrastructure project in relation to sensitive species and habitats in the project area;

(ii) provides a biological determination of minimum buffers necessary to protect the resources of the sensitive habitat areas from significant disruption of habitat values;

(iii) evaluates the adequacy of any proposed buffers less than the recommended minimum buffers;

(iv) provides a description of the specific mitigation measures and BMPs that will be provided to avoid and/or minimize adverse environmental effects of construction of the proposed pipeline infrastructure adjacent to sensitive habitats and coastal waters; and
provides a description/map of the proposed bridge infrastructure relative to sensitive habitats, evaluates impacts, and describe BMPs, avoidance, and minimization measures to limit adverse environmental effects of construction of the
adjacent to sensitive habitats and coastal waters.

EXHIBIT NO. 6
ESHA ANALYSIS & MAPS
CDP APPLICATION NO. 1-21-0653
(Humboldt Bay Harbor District)

Methods

Existing documentation of special-status species and sensitive habits were used to analyze the temporary impacts of the proposed project implementation. Sources include the previously prepared Biological and Habitat Assessment (SHN, 2020a) and Wetland Assessment (SHN, 2020b); the Nordic Aquafarms California, LLC Land-based Aquaculture Project Draft EIR (Humboldt County, 2021); and the Humboldt Bay Master Water Intakes Project Description (HBHRCD, 2022). In addition, a field visit was conducted on March 4, 2022 by SHN Senior Biologists Joseph Saler and Gretchen O'Brien to verify current site conditions within the pipeline infrastructure footprint.

Results

Existing Conditions

The majority of the pipeline alignment will be sited within asphalt and concrete paved vacant industrial land (Figure 1). These areas consist of large expanses of asphalt with little to no vegetation. Cracks in pavement or old foundations are typically dominated by invasive species, the most common being pampas grass (*Cortaderia jubata*). The southern portion of the alignment occurs immediately east and south of the former pulp mill infrastructure (Attachment 1, photos 1, 2, 4 and 5). This area is characterized by compacted gravel and invasive herbaceous species cover (Appendix 1, photo 3). As such, the majority of the pipeline installation and construction-related activities will not result in impacts to sensitive species or ESHA. Two ESHA were identified within the vicinity of the proposed pipeline alignment. Both of the ESHA consisted of coast willow thickets and are described below.

ESHA

Coastal dune willow thickets (*Salix hookeriana* Shrubland Alliance) occupy two isolated locations adjacent to the proposed water intake piping alignment. The coast dune willow thickets are composed of a mix of coast willow, wax myrtle, and to a lesser extent, Pacific willow. Areas with a higher dominance of wax myrtle greater than 50 percent cover in the canopy more closely resemble wax myrtle scrub (*Morella californica* Shrubland Alliance). These areas are intermixed with the more widespread dominance of coast willow and are mapped as wax myrtle/coast willow shrublands (Figures 2, 3, and 4).

Coastal dune willow thickets and mixed wax myrtle scrub are closely associated with old foundations, concrete low spots with drainage inlets, debris and soil spoil piles, and industrial stormwater features. Many of the areas with wax myrtle and coast willow canopy cover do not meet the one-parameter wetland definition on account of dominance by invasive upland species in the understory, concrete in the soil, and the well-drained nature of the site. It is well documented that coast willow dune thickets are a "disturbance-related" vegetation community (Sawyer, 2009), and the occurrences of this vegetation community within the project area reflect past disturbance rather than natural conditions (SHN, 2020a).

The proposed pipeline trench will not result in direct impacts to coastal willow thickets or other ESHA as proposed. The proposed pipeline will pass adjacent to two coast willow thickets along the length of the pipeline. The coast willow thicket adjacent to the proposed alignment in the south is restricted to an excavated swale constructed for stormwater conveyance from surrounding industrial lands. Soils are mostly intact and uncompacted, and invasive species dominance is restricted to the edge of the feature. The coast dune willow thicket follows the stormwater swale into the paved industrial areas and may represent a wildlife movement corridor into areas that would otherwise be inaccessible.

The majority of this stormwater feature is dominated by coast willow thicket (see Figures 2 and 4 and Appendix 1, photo 6); however, the easternmost portion of the feature contains weirs, pedestrian bridges, and retaining walls, and does not have willow cover and is not considered ESHA (Appendix 1, photos 7-9). It is in this area that the proposed pipeline will be sited and will be attached to a bridge for support. The stormwater detention feature at this location is between 33 and 36 feet from top of bank to top of bank. The proposed pipeline and bridge over the existing stormwater feature will be positioned outside of the ESHA boundaries. No tree removal or disturbance of soil within the coast willow thicket would occur as a result of the proposed pipeline. In addition, appropriate avoidance measures and BMPs, as described below in BMPs, Avoidance, and Mitigation Measures, will be in place during construction. The nearest disturbance will be at the location of the proposed bridge abutment within existing pavement approximately 75 feet from the edge of the coast willow and approximately 15 feet back from the top of bank. The banks of this feature are predominantly vegetated with non-native species and are not classified as ESHA. The functionality of the ESHA for wildlife movement is not expected to change post-construction, as access to the potential movement corridor will not be restricted after the proposed construction is complete; therefore, the 75-foot setback from coast willow is considered adequate.

The coast willow thicket in the northern portion of the alignment exists within the footprint of former milling facilities and has developed in the years since closure (see Figure 3 and Appendix 1, photos 10 and 11). The proposed pipeline will be sited within the footprint of an existing asphalt road that exists 10 feet east of the coast willow thicket. No tree removal or disturbance of soil within the coast willow thicket would occur as a result of the proposed pipeline. In addition, appropriate avoidance measures and BMPs, as described below in BMPs, Avoidance, and Mitigation Measures, will be in place during construction. The habitat value of the ESHA along the proposed pipeline alignment is degraded on account of the past use, current industrial remnants, invasive species dominance, and isolation from intact habitat. It is restricted to the former mill foundation with asphalt and compacted soils present. English ivy and other invasive plant species are present in the understory. The willow thicket is isolated from other vegetated areas by vast areas of asphalt, which limits wildlife movement into the willow thicket. There is no functional relationship of the proposed area for the piping and the adjacent patches of ESHA; therefore, the 10-foot setback is considered adequate to avoid impacts to the ESHA.

The two ESHAs present within the immediate vicinity of the proposed pipeline alignment will not be directly impacted by the project. As proposed, the pipeline will remain outside of ESHA and will stay within the footprint of existing hard surfaces. The recommended buffer for this project is to maintain the same setback as exists between the hard surfaces and the ESHA, with no encroachment allowed into the adjacent ESHA, including any soil, stormwater, worker, or equipment incursion, that could occur during construction. High-visibility temporary construction fencing should be installed prior to the commencement of construction to clearly demarcate the edge of ESHA and act as a barrier to accidental incursion. Proper soil containment and stormwater BMPs will ensure that ESHA remains unimpacted during construction.

The following measures are recommended to minimize potential impacts associated with the installation of the proposed pipeline:

- Install high visibility temporary construction fencing along the edge of ESHA where it is adjacent to the proposed pipeline.
- Post construction, grade disturbed soils to pre-project condition,
- Use native herbaceous seed mix in areas where soils are not gravel or asphalt.
- Use weed-free straw to cover exposed spoils
- Follow BMPs detailed the end of this report to reduce erosion and habitat degradation.

Proposed Set-back Justification

With the establishment of a temporary construction fence and implementation of proper soil and stormwater BMPs, the existing development setbacks are deemed adequate for the following reasons:

- The ESHA adjacent to the proposed pipeline alignment are low-quality examples of coast dune willow thickets and their occurrence is dependent on anthropogenic disturbance and manipulation of the site.
- Past use and legacy development from past industrial use isolates the ESHA on site and invasive species occurrences further reduce the habitat value of these features. Coast willow is a disturbance-adapted species and not expected to be affected by the installation of the pipeline.
- The ESHA adjacent to the proposed pipeline alignment is surrounded by development, and the pipeline will not encroach any closer to the ESHA than the existing asphalt and hard surfaces.
- Following completion of construction, the location of the pipeline should be indistinguishable from the surrounding area at the northern ESHA, and the proposed new bridge will be constructed outside of the swale and extent of coast willow, with bridge abutments to be sited within existing pavement. Furthermore, the pipeline and supporting bridge will improve conditions within the stormwater swale by removing industrial equipment from the swale, allowing for better wildlife movement as the proposed bridge will be constructed above the top of bank.
- Installation of temporary construction fencing will minimize incursion into the ESHA during construction and maintain the coast willow thickets in the same condition as they are prior to construction.
- Implementation of the mitigation measures described below will further reduce impacts to adjacent coast willow thicket ESHA.

Throughout the entire extended project area with the associated Nordic Aquafarms proposed development, mitigation measures are in place for any loss of Sensitive Natural Communities, as detailed in BIO-7a in the Mitigated Negative Declaration prepared for the projects (County of Humboldt, 2021).

Special-status species

Plants

Seasonally appropriate surveys for special-status plants occurred in April, May, and June 2020 (SHN 2020a). No special-status plants were detected in the Humboldt Bay Water Intakes Study Area. This is likely a result of intensive historical development and use of the site and the remaining impacts from that development, as well as the dominance of exotic herbaceous species within large portions of the study area. Special-status plant species will not be impacted by the proposed water intake piping project.

Animals

Construction and ground disturbance required for the piping infrastructure is within proximity to existing Osprey nests. Construction within 500 feet of the osprey nests, as well as nests of other bird species, would occur outside the nesting bird season if feasible. If construction within 500 feet the osprey nests or other nests were to occur during the nesting bird season, a buffer and biological plan would be required with the approval of the Planning and Building Department and in consultation with California Department of Fish and Wildlife (DFW; County of Humboldt, 2021).

BMPs, Avoidance, and Minimization Measures

As described in Mitigation Measure BIO-7b in the DEIR prepared for the projects (Humboldt County, 2021), prior to issuance of any permits, the following BMPs will be applied:

- Orange net or other appropriate fencing shall be placed around the 35-foot ESHA setback or at the limit of the Fire Road encroachment. The fencing shall remain in place throughout the construction period to prevent vehicles, equipment, or materials from entering the ESHA.
- The grading plans for the project site shall design finished pad grades to not result in grade changes at the edge of the buffer or fire road within the ESHA buffer.
- Erosion control materials (for example, silt fencing) shall be utilized to isolate the area of ground disturbance from the Humboldt Bay shoreline during construction.

In addition, the project shall be required to obtain a General Construction Stormwater Discharge stormwater pollution prevention plan (SWPPP; see Mitigation Measure HWQ-1). SWPPP requirements would minimize and avoid water quality impacts to Humboldt Bay from construction-generated erosion and stormwater by establishing erosion control measures during construction (for example, silt fences), minimization of vegetation removal, and avoidance of work during heavy rainfall. These requirements include the following:

- Construction activities shall be scheduled and sequenced to minimize the areal extent and duration of site disturbance at any time.
- Drainage from outside the construction area shall be directed away from or around the site through use of berms, ditches, or other structures to divert surface runoff.
- Install weed-free fiber rolls, straw-wattles, coir logs, silt fences, or other effective devices along locations where water drains off the construction site.

- All graded slopes shall receive slope protection measures such as fiber rolls, drainage ditches, or erosion control fabrics to minimize the potential for concentrated surface runoff to cause erosion.
- Implement wind erosion or dust control procedures consisting of applying water or other dust palliatives as necessary to prevent or alleviate dust nuisance generated by construction activities. The contractor may choose to cover small stockpiles or areas as an alternative to applying water or other dust palliatives.
- Control water application rates to prevent runoff and ponding. Repair leaks from water trucks and equipment immediately.
- Hazardous materials shall be stored in areas protected from rain, provide secondary containment and must be a minimum of 100 feet from any wetland or Environmentally Sensitive Habitat Area.
- Implement the following hazardous materials handling, storage, and spill response practices to reduce the possibility of adverse impacts from use or accidental spills or releases of contaminants:
    - Conduct all refueling and servicing of equipment more than 100 feet from any wetland or Environmentally Sensitive Habitat Area with absorbent material or drip pans underneath to contain spilled fuel. Collect any fluid drained from machinery during servicing in leak-proof containers and deliver to an appropriate disposal or recycling facility.
    - Prevent raw cement; concrete or concrete washings; asphalt, paint, or other coating material; oil or other petroleum products; or any other substances that could be hazardous to aquatic life from contaminating the soil or surface water.
- In the event dewatering is determined to be necessary, the following steps shall be taken:
    - Prepare a dewatering plan prior to excavation.
    - Impound dewatering discharges in sediment retention basins or other holding facilities to settle the solids and provide treatment prior to discharge to receiving waters as necessary to meet Basin Plan water quality objectives.

Conclusion

The proposed project is sited with the least environmental impact possible to ESHA and sensitive species. Consistent with the Humboldt Bay Area Plan—Local Coastal Plan, the project will not disrupt habitat value or significantly degrade habitat in the area with the above BMPs, avoidance, and mitigation measures in place.

Please call me at 707-822-5785 or email me at gobrien@shn-engr.com if you have any questions.

Sincerely,

SHN

Gretchen O'Brien
Senior Wildlife Biologist

GAO:ame:cet

Attachments: 1. Project Site Photos, March 2022

c. w/Attach.: Rob Holmlund, Development Director, HBHRCD

References

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Sawyer, G. O., T. Keeler-Wolf, and J. Evans. (2009). A Manual of California Vegetation, Second Edition. Sacramento, CA:CNPS Press.

SHN. (2020a). Biological and Habitat Assessment Redwood Marine Terminal 1, Samoa Peninsula. September 2020.

---. (2020b). Wetland Assessment, Redwood Marine Terminal 1, Samoa Peninsula. September 2020.

Photos 1

Photo 1: Looking northeast across the southern extend of the proposed pipeline. Compacted gravel soils and non-native species dominant. Does not meet dune mat vegetation community at this location. Photo taken March 4, 2022.

Photo 2: Looking east within area of southern pipeline alignment. Compacted gravel soils and non-native species dominant. Does not meet dune mat vegetation community at this location.

Photo taken March 4, 2022.

Photo 3: Representative vegetation composition within the southern portion of the proposed alignment. No asphalt, but highly compacted gravels present with high invasive species cover (English plantain (*Plantago lanceolata*), six weeks grass (*Festuca myuros*), and subterranean clover (*Trifolium subterraneum*)). Photo taken March 4, 2022.

Photo 4: Southern pipe alignment looking north. Compacted gravel soils. Photo taken March 4, 2022.

Photo 5: Current aiquiculture related use of the southern portion of the pipe alignment looking north. Photo taken March 4, 2022.

Photo 6: Stormwater swale showing one of three pedestrian bridges looking north. Note edge of willow canopy at bridge signifying the edge of ESHA. Photo taken March 4, 2022.

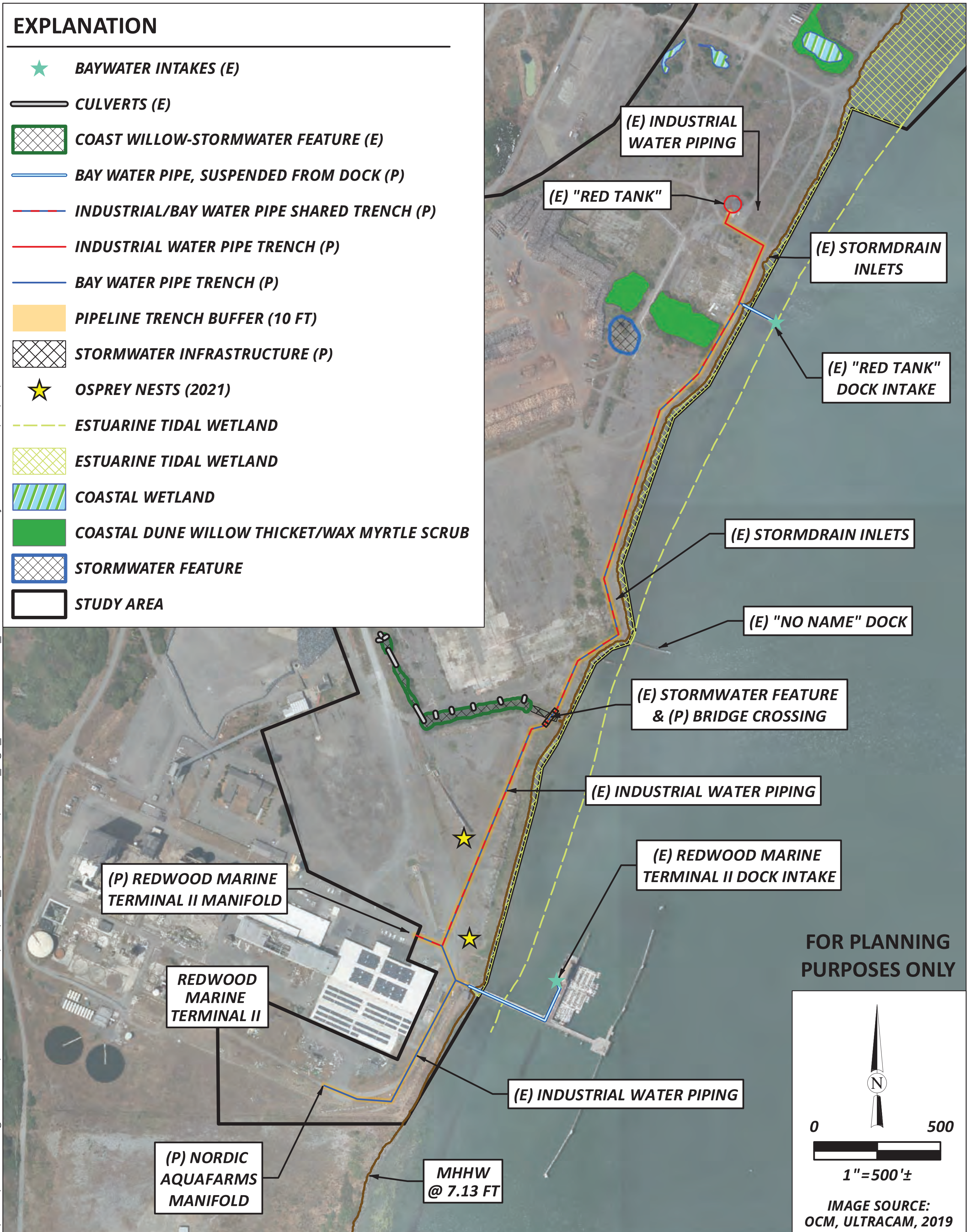
Photo 7: Existing stormwater detention facilities looking northeast. ESHA is not present at this location. Pipeline and bridge alignment would likely pass over here. Photo taken March 4, 2022.

Photo 8: Closeup at existing stormwater detention infrastructure. Note weirs, screening, and overflow pipes. Photo taken March 4, 2022.

Photo 9: Close up at middle pedestrian bridge looking NE. Pipeline and bridge alignment would likely pass between this bridge and overflow pipe visible in the upper right corner. Photo taken March 4, 2022.

Photo 10: Typical conditions throughout the majority of the pipeline alignment. Note expansive areas of asphalt. Photo looking south taken on March 4, 2022.

Photo 11: Looking north at the proposed pipeline alignment as it passes the northern coast dune willow thicket. Note the road which will be the location of the pipeline, passes east of the coast dune willow thicket. Photo taken March 4, 2022.



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SHN

Humboldt Bay Harbor, Recreation, & Conservation District
RMT I Water Intakes CDP, Response to Comments
Eureka, California

Habitat & ESHA Map Overview

July 2022 - 016240.005

Figure 1

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Exhibit 6
CDP 1-21-0653
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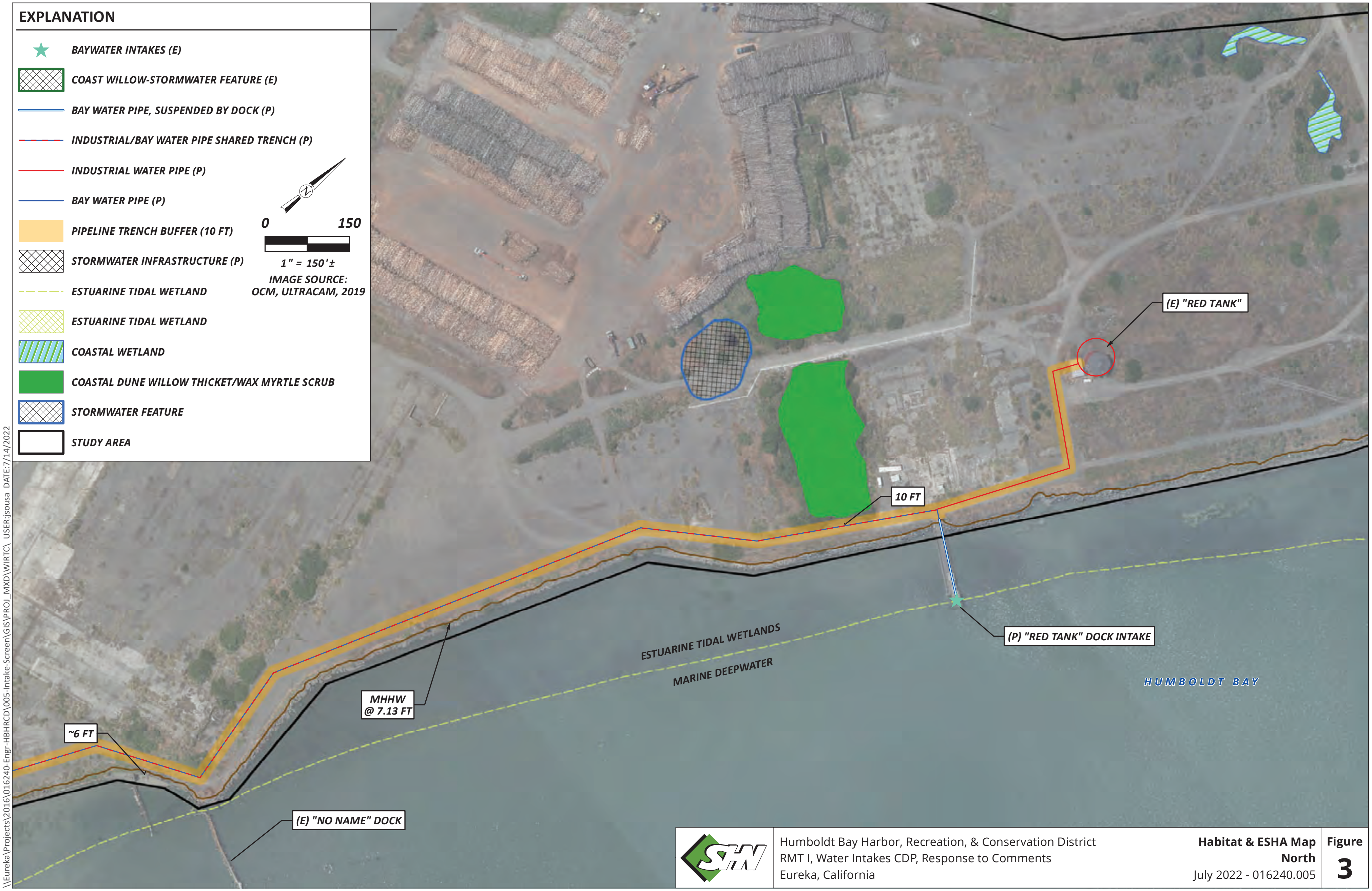

Exhibit 6
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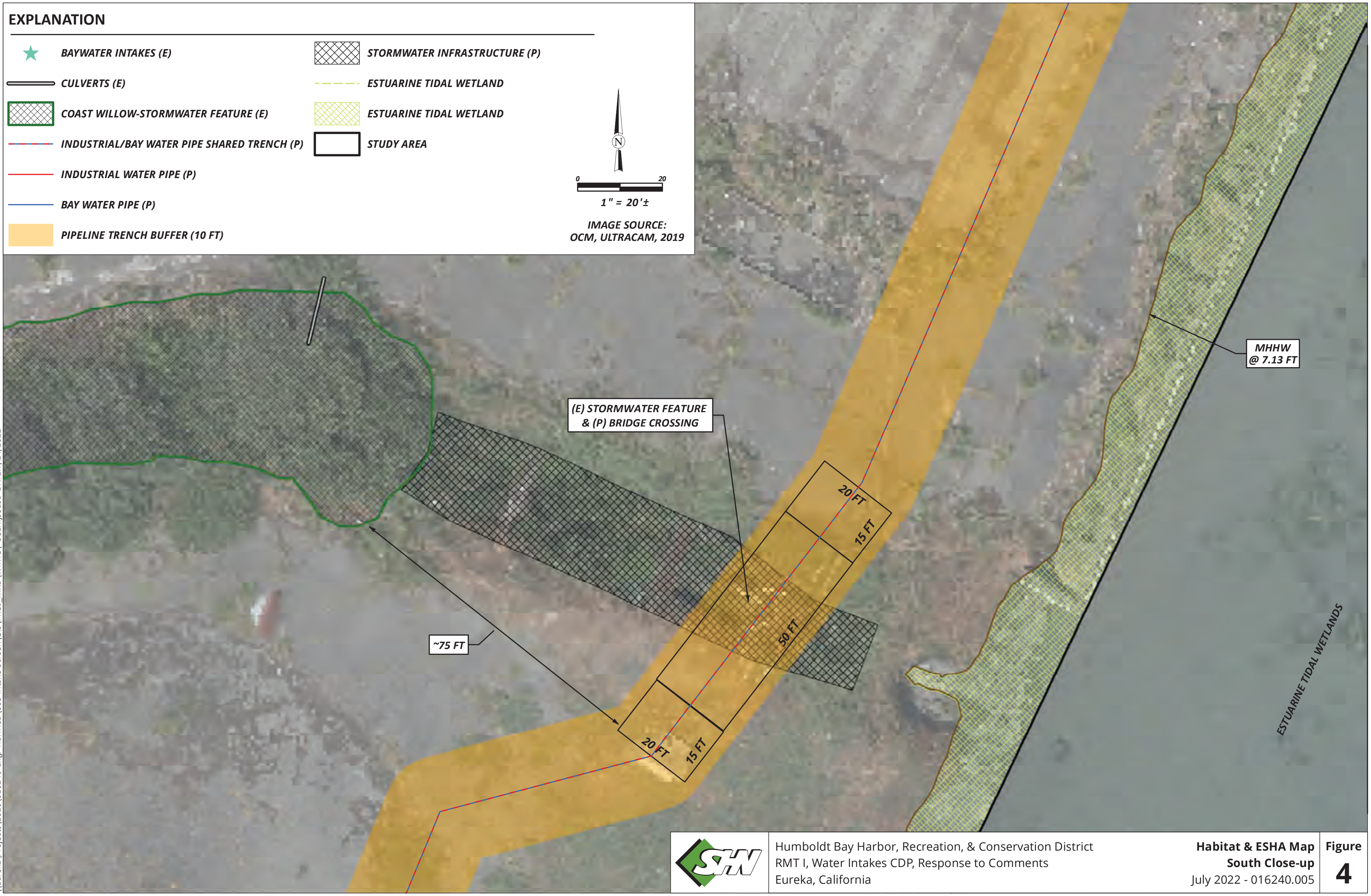

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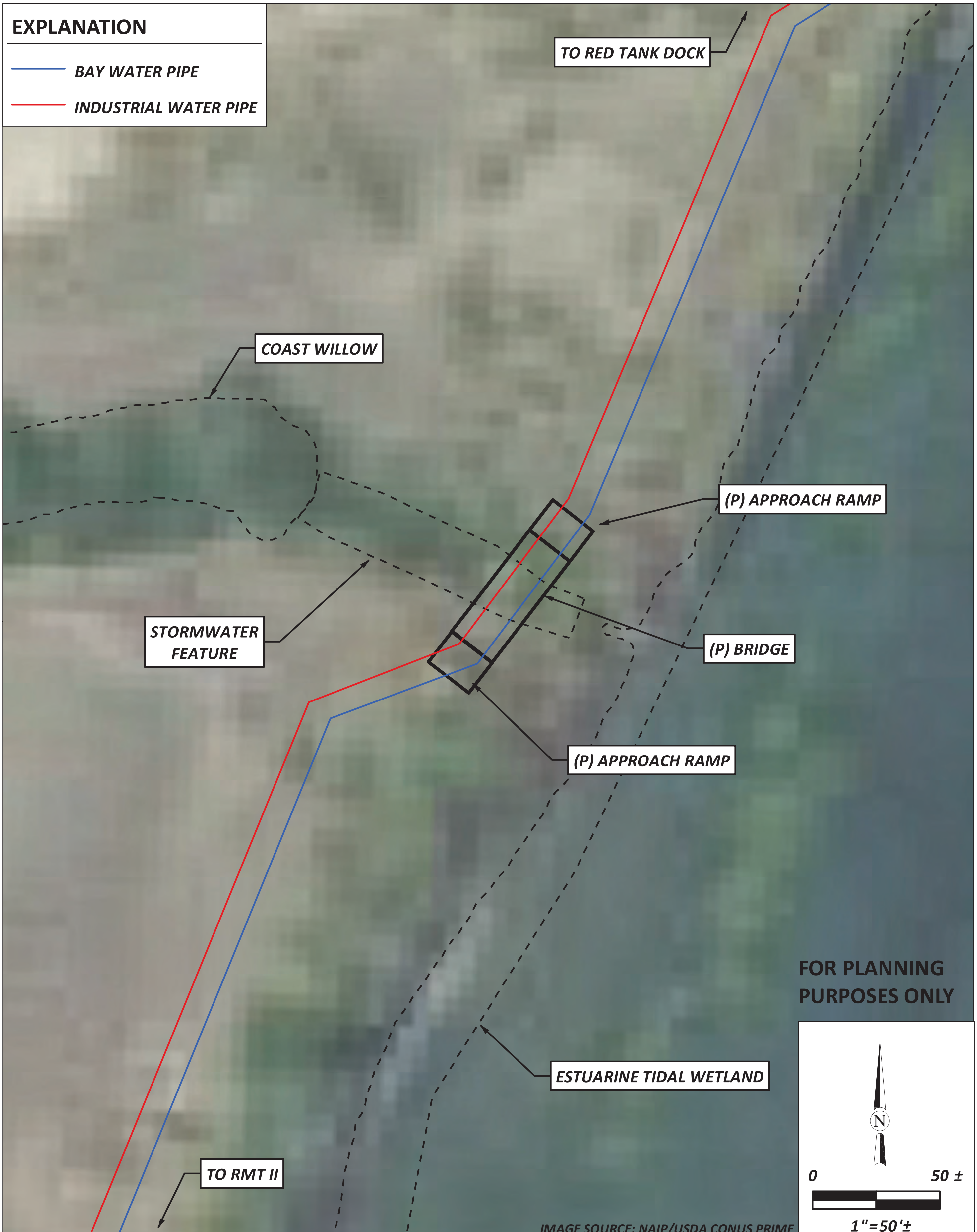
Humboldt Bay Harbor, Recreation, & Conservation District
RMT I, Water Intakes CDP, Response to Comments
Eureka, California

Habitat & ESHA Map
South Close-up
July 2022 - 016240.005

Figure
4



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HBHRCD Humboldt Bay Intake Screens Samoa, California		Preliminary Stormwater Feature Crossing Bridge Layout SHN 016240.005
January 2022	BayIntake_Bridge_Plan	Figure

Technical Memorandum

October 12, 2023

To	Rob Holmlund, HBHRCD	**Contact No.**	(707) 267-2214
Copy to	Misha Schwarz, GHD Jeremy Svehla, GHD Sharon Kramer, H.T. Harvey & Associates (HTH)	**Email**	kolby.lundgren@ghd.com
From	Kolby Lundgren, GHD Sophie Bernstein, HTH	**Project No.**	11205607
Project Name	Humboldt Bay Harbor, Recreation and Conservation District Water Intakes Project		
Subject	Offsite Mitigation Opportunities For APF		

1. Introduction

The Humboldt Bay Master Water Intakes Project (hereafter "Project") is proposing to modernize and operate two bay-water intake systems and develop facilities for future aquaculture tenants. This Project is being proposed by the Humboldt Bay Harbor, Recreation and Conservation District (HBHRCD). The Project may result in the loss of productivity due to larval entrainment in the intakes (i.e., calculated as the Area of Production Foregone [APF]).

An initial estimate of APF associated with the intake pumps was provided for the HBHRCD in Appendix N of the Draft EIR (GHD 2022) based on the results of an initial assessment prepared by Tenera Environmental (2021). A following addendum by Tenera Environmental more precisely calculated the APF to be 34.6 acres (Tenera 2023, **Attachment 1**). To offset the APF impacts at the two proposed intake pumps, compensatory mitigation is required.

The purpose of this memorandum is to (1) summarize the mitigation sites that have been identified for the Project and their associated proposed restoration and/or mitigation actions; and (2) identify compensatory off-site restoration and mitigation opportunities at sites yet to be identified in the greater Humboldt Bay area, which can be used to further inform Project planning and design. This memo addresses feedback from the California Coastal Commission (CCC) regarding the APF from the Project and its required mitigation.

EXHIBIT NO. 7
MEMO RE: OFFSITE MITIGATION
CDP APPLICATION NO. 1-21-0653
(Humboldt Bay Harbor District)

2. Existing Mitigation Sites and Proposed Restoration and/or Mitigation Actions

Three HBHRCD parcels were identified for a number of mitigation actions that provide, in total, 28.77 acres of habitat creation and enhancement to satisfy a portion of the calculated APF (34.6 acres). One parcel (APN 302-101-002) is in Fields Landing, located on the shoreline at the end of South Bay Depot Road and is referred to as the Kramer Dock mitigation site because of the existing (historical) infrastructure that remains along the shoreline. The other two parcels (APNs 002-161-001 and 002-162-001) are located on the north end of Bay Street in Eureka, along Second Slough at the confluence with Eureka Slough. This property is called the Bay Street mitigation site.

Kramer Dock Mitigation Site

The Kramer Dock property extends into the bay, north and south of South Bay Depot Road (**Attachment 2**, Exhibit 1). This site was identified for potential mitigation because it contains rows of in-water pilings that historically supported the Kramer Dock (see Figure 1 and Figure 2 of **Attachment 2**). There is a total of 988 remnant creosote treated pilings and 151 cross beam supports attached to the pilings. Proposed mitigation actions include removing the pilings and associated support structures to restore and improve tidal ecosystem functions, including enhancing potential eelgrass habitat (there are substantial eelgrass populations mapped offshore to the west and north of the old dock footprint) and essential fish habitat, among other trophic benefits to this habitat. See **Table 3** in **Attachment 4** for detailed benefits to aquatic resources from pile pulling. The total area that contains the pilings is 2.69 acres, which at a 1:4 mitigation ratio results in 10.76 acres of compensated APF (**Table 1**).

Table 1. Kramer Dock Mitigation Site Summary of Compensated APF

Mitigation Action	Area Created / Enhanced (Acres)	Ratio	Compensated APF (Acres)
Pile removal	2.69	1:4	10.76
		Total Compensated APF for Site	**10.76 acres**

Bay Street Mitigation Site

The Bay Street property is largely undeveloped and comprised of inter-tidal salt marsh with moderately dense to dense invasive dense-flowered cordgrass (*Spartina densiflora*) (**Attachment 3**, Exhibit 1 and Exhibit 2). The salt marsh has been historically altered: a remnant dike exists in the northeast corner of APN 002-161-001 (assumed to be failed attempt to construct a rail prism) and a soil mound along eastern edge of APN 002-162-001, as well as linear drainage ditches throughout the marsh areas. Man-made structures include the remnants of wood pile foundations from historic buildings and other wood debris along the shoreline, as well as a buried, abandoned sewer line (see Figure 1 and Figure 2 of **Attachment 3**). This site was identified for mitigation based on the aforementioned historic development.

Potential habitat restoration and enhancement activities proposed at Bay Street include construction of new inter-tidal slough channels with tidal ponds and salt marsh pannes, filling of historical drainage ditches, and removal of dense-flowered cordgrass in discrete areas (within limits of grading). These restoration activities will result in approximately 2,820 square feet of salt marsh creation, 1,082 square feet of backfilling and/or removing existing human-made drainage ditches, creation of 10,400 square feet of new tidal channels, 6,200 square feet of tidal pond / salt marsh panne creation, and removal of 30 square feet of piles (**Table 2**, and see Exhibit 1 of **Attachment 3**). Additionally, approximately 3.7 acres of dense-flowered cordgrass will be removed (**Table 2**, and see Exhibit 2 of **Attachment 3**). A deed restriction is proposed to be placed over the parcels, which removes development rights but allows for habitat restoration.

Table 2 summarizes the mitigation actions and area that will be created or enhanced by said action, and proposed ratios to compensate for APF, including a total area of compensated APF by each individual action and the combined actions for this site. Details of construction the benefits to species and habitats within the Bay can be referenced in **Attachment 3**, and detailed benefits of each activity on aquatic resources can be referenced in **Table 3** of **Attachment 4**.

Table 2 Bay Street Mitigation Site Summary of Compensated APF

Mitigation Action	Area Created / Enhanced (square feet / acres)	Ratio	Compensated APF (acres)
Lower dikes / create salt marsh	2,820 / 0.0647	1:10	0.647
Fill existing drainage ditches	1,082 / 0.0248	1:10	0.248
Construct new tidal channels	10,400 / 0.2388	1:10	2.388
Construct tidal ponds / pannes	6,200 / 0.1423	1:10	1.423
Pile removal	30 / 0.0007	1:4	0.0028
Remove dense-flowered cordgrass	161,172 / 3.7	1:3	11.1
Deed restriction: APN 002-162-001	2.53 acres	1:0.5	1.265
Deed restriction: APN 002-161-001	1.88 acres		0.94
		Total Compensated APF for Site	**18.01 acres**

3. Potential Mitigation Actions (Site TBD)

As determined by the Tenera Environmental addendum (2023), APF was calculated at 34.6 acres. The Kramer Dock mitigation site offers 10.76 acres of mitigation for removal of piles and associated support structures at a 1:4 mitigation ratio. The Bay Street mitigation site offers 18.01 acres of mitigation at a 1:10 ratio for numerous restoration and enhancement activities, including: lowering existing dikes and creating salt marsh habitat; filling existing man-made drainage ditches; constructing new tidal channels with tidal ponds / pannes; removal of piles; removal of dense-flowered cordgrass; and a deed restriction on each parcel that restoration and enhancement activities will occur on. Mitigation ratios for these activities vary (**Table 2**). Collectively, the activities at Kramer Dock and Bay Street mitigation sites provide 28.77 acres worth of mitigation. To satisfy the APF associated with the Project (34.6 acres), an additional 5.83 acres of area must be identified.

Further actions to fully mitigate for the APF from the Project have been identified and presented in **Table 3** of **Attachment 4**, with associated benefits to aquatic resources, and specific species and sensitive habitat that would benefit from the action. Sites have not yet been identified for these proposed actions, with the intent that the CCC will include a condition of approval in the CDP that requires the remaining 5.83 acres to be mitigated with a project(s) that meet the parameters outlined in **Table 3** of **Attachment 4**.

References

GHD. 2023. Final Environmental Impact Report Samoa Peninsula Land-based Aquaculture Project. County of Humboldt, Planning and Building Department, June 30, 2022. SCH#: 2021040532.

Prepared by GHD, Eureka, CA. Accessed October 4, 2023 at https://humboldtgov.org/DocumentCenter/View/108020/Nordic-Aquafarms-Final-EIR.

Tenera Environmental. 2021. The Use of Piling Removal for Mitigation Effects of Entrainment Losses for Longfin Smelt and Other Marine Resources Resulting from Operation of the Proposed Samoa Peninsula Intakes in Humboldt Bay. Technical Memorandum prepared for Humboldt Bay Harbor Recreation and Conservation District (HBHRCD). Document SLO2021-019. Appendix N of FEIR, GHD (2022).

Tenera Environmental. 2023. Addendum on APF Estimates to Humboldt Bay Intake Assessment. Technical Memorandum prepared for HBHRCD.

Attachment 1

Tenera Memo

TECHNICAL MEMORANDUM

August 18, 2023

To: Rob Holmlund, Humboldt Bay Harbor, Recreation, and Conservation District

From: John Steinbeck, Tenera Environmental

Subject: Addendum on APF Estimates to Humboldt Bay Intake Assessment

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The technical memorandum is an addendum to the final draft of the Intake Assessment of the Potential Effects on Ichthyoplankton and other Meroplankton Due to Entrainment at Proposed Samoa Peninsula Water Intakes (Intake Assessment) dated May 1, 2023 and provides final estimates of Area of Production Foregone (APF) using the approach specified in the Desalination Amendment to the Statewide Water Quality Control Plan for the Ocean Waters of California (Desalination Amendment).[1] The Intake Assessment provides estimates of APF in **Table 5-9** which is presented below for each of the seven fishes that were analyzed using the Empirical Transport Model (ETM) as specified in the Desalination Amendment.

Table 5-9 from May 2023 Intake Assessment. Summary of ETM results for taxa analyzed from sampling in Humboldt Bay from January–December 2022 with ETM estimates of P_M for the RMT II (Station E1) and RTD (Station E2) intakes. Area Production Foregone (APF) estimates were calculated based on an estimate of the surface area of Humboldt Bay at MSL of 15,098 acres (6,110 hectares). Note: In addition to the average APF estimates (50th percentile estimate) in the original table, the 95th percentile estimates were added to the table.

	P_M Estimates (%)			APF Estimates (acres [hectares])		
Taxa	RMT II Intake (Station E1)	RTD Intake (Station E2)	Total	RMT II Intake	RTD Intake	Total
Arrow Goby	0.3010	0.0747	0.3757	45.4 (18.4)	11.3 (4.6)	56.7 (23.0)
Bay Goby	0.0762	0.0404	0.1166	11.5 (4.7)	6.1 (2.5)	17.6 (7.1)
Whitebait Smelt	0.0323	0.0142	0.0464	4.9 (2.0)	2.1 (0.9)	7.0 (2.8)
Pacific Herring	0.0210	0.0098	0.0308	3.2 (1.3)	1.5 (0.6)	4.7 (1.9)
Pacific Tomcod	0.0754	0.0088	0.0842	11.4 (4.6)	1.3 (0.5)	12.7 (5.1)
Surf Smelt	0.0535	0.0248	0.0783	8.1 (3.3)	3.7 (1.5)	11.8 (4.8)
Pacific Staghorn Sculpin	0.0636	0.0324	0.0960	9.6 (3.9)	4.9 (2.0)	14.5 (5.9)
Average (50th percentile APFs)	0.0890	0.0293	0.1183	13.4 (5.4)	4.4 (1.8)	17.9 (7.2)
95th percentile APF estimates				27.2 (11.0)	7.8 (3.1)	34.6 (14.0)

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[1] Final Staff Report Including the Final Substitute Environmental Documentation for California State Water Resources Control Board Resolution 2015-0033: Amendment to the Statewide Water Quality Control Plan for the Ocean Waters of California Addressing Desalination Facility Intakes, Brine Discharges, and to Incorporate other Nonsubstantive Changes. Adopted May 6, 2015.

TENERA Environmental 141 Suburban Road, Suite A2, San Luis Obispo, CA 93401
TEL 805.541.0310 • FAX 805.541.0421 • www.tenera.com

The average APF for the seven fishes (17.86) in **Table 5-9** is equal to the value at the 50th percentile assuming the seven APF estimates are normally distributed. The average APF is interpreted as having a 50% chance of providing adequate acreage to fully compensate for the estimated losses due to entrainment. The Desalination Amendment requires that the APF be calculated using the 95th percentile to help ensure that the mitigation fully compensates for entrainment losses.

The APF estimate at the 95th percentile for the seven fishes from the study is 34.6 acres (14 hectares) (**Table 5-9**).

The proposed mitigation ratio used in calculating the projects to meet the calculated APF is based on the following:

The May 1, 2023 Tenera Report Intake Assessment of the Potential Effects on Ichthyoplankton and other Meroplankton Due to Entrainment at Proposed Samoa Peninsula Water Intakes on page 6-12 states:

> *An initial estimate of APF was provided for the District in Appendix N of the Draft EIR for the project that was based on the results of the Initial ETM Assessment prepared by Tenera (2021) (Appendix P of the Draft EIR). The APF estimate of 10.4 acres (4.2 hectares) in Appendix N was based on a source water area of 10,000 acres (4,047 hectares) and was intended to be used as an example of how APF was calculated. The source water area based on the data in Swanson (2015) that was used in the APF calculations in the Initial ETM Assessment and in this report was 15,104 acres (6,112 hectares). Therefore, the corrected APF from the Initial ETM Assessment would be 15.7 acres (6.3 hectares), which, as expected, is very close to the APF estimate of 17.9 acres (7.2 hectares) in this report. Using the same 4:1 ratio proposed in Appendix N, an area of piling removal equivalent to 4.5 acres (1.8 hectares) would fully compensate for the losses to marine resources resulting from entrainment at the two intakes.*

Also note that an MOU between regulatory agencies regarding desalination projects cites California Water Code (Water Code) section 13142.5(b) and Water Board Ocean Plan Section M. Those citations state that for out-of-kind mitigation:

- An owner or operator shall evaluate the biological productivity of the impacted open water or softbottom habitat calculated in the Marine Life Mortality Report and the proposed mitigation habitat.
- If the mitigation habitat is a more biologically productive habitat (e.g. wetlands, estuaries, rocky reefs, kelp beds, eelgrass beds, surfgrass beds), then the regional water board may apply a mitigation ratio based on the relative biological productivity of the impacted open water or softbottom habitat and the mitigation habitat.
- The mitigation ratio shall not be less than one acre of mitigation habitat for every ten acres of impacted open water or soft-bottom habitat.

The proposed intake project is impacting open water and mitigating by creating a higher quality habitat (out-of-kind mitigation). For the Kramer Dock pile removal, the mitigation ratio is 1:4.

As described in the Final Environmental Impact Report for the project,[2] the planned restoration of 2.7 acres of bay habitat by the removal of pilings from the old Kramer Dock will be used to account for 10.8 acres of the total required APF mitigation. This approach assumes using the 1:4 mitigation ratio for the Kramer Dock site[3] that was presented in Appendix N of the draft EIR. This is the mitigation ratio used for the Poseidon desalination plant project in Carlsbad, California that is provided in the Final Staff Report for the May 6, 2015 Desalination Amendment to the Water Quality Control Plan for Ocean Waters of California.[4] The remaining acres of mitigation required from the APF (and the associated mitigation ratio) will be determined based on discussions between the resource agencies, and the Humboldt Bay Harbor, Recreation, and Conservation District.

A different mitigation ratio for any additional mitigation at any alternate site may be justifiable.

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[2] Final Environmental Impact Report Samoa Peninsula Land-based Aquaculture Project. County of Humboldt, Planning and Building Department, June 30, 2022. SCH#: 2021040532. Prepared by GHD, Eureka, CA. Accessed August 18, 2023 at https://humboldtgov.org/DocumentCenter/View/108020/Nordic-Aquafarms-Final-EIR.

[3] A different form of mitigation at a different site may require a different mitigation ratio. For instance, a higher ratio may be appropriate for a mitigation project that consists of restoring filled estuarine channels.

[4] Final Staff Report Including the Final Substitute Environmental Documentation. Adopted May 6, 2015 Amendment to the Water Quality Control Plan for Ocean Waters of California addressing Desalination Facility Intakes, Brine Discharges, and the Incorporation of Other Non-Substantive Changes. Accessed August 18, 2023 at https://www.waterboards.ca.gov/board_decisions/adopted_orders/resolutions/2015/rs2015_0033_sr_apx.pdf.

Attachment 2

Kramer Dock Memo

Attachment 3

Bay Street Memo

Memorandum

2 October 2023

To	Rob Holmlund & Doug Saucedo (Humboldt Bay Harbor, Recreation and Conservation District)		
From	Jeremy Svehla & Brett Vivyan (GHD)		
Reviewed By	Misha Schwarz (GHD)	**Tel**	707 267 2246
Subject	Bay Street Conceptual Mitigation Design	**Project no.**	11205607

Introduction

The Humboldt Bay Harbor, Recreation and Conservation District (HBHRCD/District) intend to implement habitat creation and enhancements at their Bay Street property to satisfy mitigation measure BIO-6a in the Final Environmental Impact Report (FEIR) for the Samoa Peninsula Land-based Aquaculture Project and other future mitigation needs. Mitigation measure BIO-6a states: *"The Humboldt Bay Harbor District shall mitigate for the potential loss of Longfin Smelt larvae due to entrainment by the intakes…" and "Mitigation shall consist of… habitat creation or enhancement to provide Longfin Smelt spawning, rearing, or nursery habitat…"* This memo presents a conceptual mitigation design approach for Longfin Smelt (LFS) habitat creation and was based on an assessment of existing site conditions, review of historic aerial maps, and input received from California Department of Fish & Wildlife (CDFW) aquatic biologists during a site visit on March 1, 2023.

Summary of Site Conditions

The HBHRCD properties (APNs 002-161-001 and 002-162-001) are located on the north end of Bay Street, along Second Slough at the confluence with Eureka Slough. The existing parcels are undeveloped, largely comprised of inter-tidal salt marsh with moderately dense (26-60%) to dense (61-100%) invasive *Spartina densiflora* (Spartina) based on mapping conducted by Grazul and Rowland in 2011 and provided by the Redwood Community Action Agency (RCAA 2021). The parcels generally range in elevation from 5 to 9 feet (NAVD 88). Localized areas of higher elevations include a remnant dike in the northeast corner of APN 002-161-001 and a soil mound along the eastern edge of APN 002-162-001 extending into the City of Eureka's Bay Street right-of-way. Linear drainage ditches are present throughout the marsh area. The City of Eureka's Bay Street right-of-way bisects the two parcels and contains a buried, abandoned sewer line. An active sewer line also bisects APN 002-162-001, connecting sewer services for residents on Bay Street to the Hills Street Pump Station, west of Second Slough. PG&E overhead lines extend east-west along the southern boundary of APN 002-162-001. Conservation easements over the parcels have removed the development rights; however, they allow for habitat restoration.

Historical aerial photographs from 1947 (Figures 1 and 2) show four buildings (assumed to be boat houses) along the edge of Second Slough, a series of linear drainage ditches and a partially constructed dike assumed to be a failed attempt to construct a rail prism (Rohde 2020). Remnants of the buildings wood pile foundations and other wood debris remain along the slough shoreline.

Figure 1 *1947 aerial showing historical land use, infrastructure, and structures at project site (Humboldt Room 1947).*

Figure 2 *1947 aerial showing historical land use, infrastructure and structures at project site (Humboldt Room 1947).*

Proposed Longfin Smelt Habitat Creation and Enhancements

The basis for the conceptual design is to satisfy mitigation measure BIO-6a and other District projects by creating inter-tidal aquatic habitat benefiting LFS and would be ecologically appropriate within the existing salt marsh setting. As shown in Exhibit 1 and Exhibit 2, proposed LFS habitat creation and enhancements for the site include Spartina removal in areas of channel widening and pond excavation, filling of the historical drainage ditches, and excavation of meandering inter-tidal channels with tidal ponds and salt marsh pannes. A summary of each feature is provided below and anticipated benefits are summarized in the subsequent section.

New Inter-Tidal Slough Channels

Based on the concept design presented, new meandering inter-tidal slough channels will be excavated to create aquatic habitat and a dendritic tidal channel network. The excavated channels would reoccupy the original tidal channel alignments to the extent practicable and be enlarged from current conditions to better mimic the channel sizes evident in the 1947 photos. The inter-tidal channel width and depth will be developed during final design and will vary based on tidal prism, existing elevations, and historical indicators. In general, the channel width and depth will decrease with an increase in distance from Second Slough and consist of an average depth of 4 ft and top width of 8 ft. The bottom elevations will range from approximately 0 to 4 ft (NAVD88). Where the enhanced channels connect to Second Slough, the bottom elevations will be similar (approximately 0 ft), providing a range of sub- and inter-tidal habitat at the confluences. The top 0.5-1 ft marsh sod layer that is not infested with Spartina will be excavated, stockpiled and transplanted as the top vegetation layer of the drainage ditch filling. The inter-tidal channels are located in close proximity to existing drainage ditches such that the distance between the channel excavation and ditch backfilling can be minimized to avoid marsh impacts which is further described below.

Tidal Ponds / Salt Marsh Pannes

Based on the concept design presented, tidal ponds / salt marsh pannes will be created at the terminus of the inter-tidal channels. To avoid potential aquatic organism entrapment, the ponds / pannes will be designed to inundate and exchange tidal water during high tides and retain water during low tides, providing a diversity in habitat type and salinity stratification relative to the inter-tidal channels. The final pond / panne area and depths will be developed during the final design and will vary based on tidal prism, existing elevations, and historical indicators.

Removal of Existing Linear Drainage Ditches

Approximately 1,082 feet of existing linear drainage ditches will be either removed as part of the new enhanced inter-tidal channel excavation or filled with native marsh soils excavated from constructing the inter-tidal channels. These are unnatural features that have altered tidal circulation and sediment distribution processes on the salt marsh and could create fish entrapment issues. The ditches are approximately 1-1.5 ft wide and range in depths up to 4 ft deep. The backfilled soil will be compacted to the marsh in-situ soil densities and the upper 0.5-1 ft of native marsh vegetative sod removed from inter-tidal channel excavation will be transplanted to adjacent marsh elevation and provide immediate native vegetative cover over the backfilled remanent ditch.

Spartina Removal within Limits of Grading

As previously described, Spartina was previously mapped on both parcels. Moderately dense (26-60% coverage) Spartina was mapped over 2.5 acres and dense (61-100% coverage) Spartina was mapped over 1.2 acres; however, within both the moderately dense and dense areas, native salt marsh species are present. Within the limits of proposed grading (i.e., tidal channels, ponds and lower remanent dikes) described below, Spartina will be removed during the grading operations and either disposed of off-site or buried a minimum of 3 ft below ground elevation in disturbed areas. The removal methods and best management practices will be specified in the final enhancement plan and will be consistent with methods defined in the Humboldt Regional Invasive Spartina Eradication Plan and PEIR.

Benefits

Fish use of salt marshes in Humboldt Bay has not been widely studied; however, salt marshes have been documented to serve as important nursery habitat for numerous fish species including LFS (Barnhart et al. 1992). Additionally, fisheries habitat restoration projects recently completed around Humboldt Bay including Wood Creek Phase 1 and 2 (tributary to Freshwater Slough), Elk River Estuary, Martin Slough, amongst others regionally within the Eel and Mad River Estuaries have observed use of created inter-tidal habitats by multiple aquatic-dependent species including LFS. More advanced studies on LFS abundance and distribution are ongoing in San Francisco Bay including the 2020-2030 San Francisco Bay Longfin Smelt Science Plan (Plan) led by CDFW and a consortium of agencies (CDFW 2020-2030). The Plan references multiple studies and states that LFS use habitat differently by life stage and that larvae have generally been found from the tributaries of San Francisco Bay to the South Delta. The Plan also states that larvae can be found from very shallow waters in tidal marsh to near-bottom of deep channels, and while larvae can be found over a wide geographic distribution, their rearing habitat has been identified to include shallow low salinity marsh habitat. The Plan also acknowledges that suitable rearing habitat is also largely governed by the distribution of low salinity. The diversity of the inter-tidal habitats proposed for the Bay Street mitigation site, in combination with its juxtaposition to perennial tributaries such as Freshwater Creek, is intended to provide spatially and temporally seasonally diverse water quality conditions that would be suitable for various life stages of LFS.

While the primary purpose of the mitigation design is to create LFS spawning, rearing, or nursery habitat to satisfy mitigation measure BIO-6a and other District projects, the design will also provide other ecosystem co-benefits including improved natural processes within the salt marsh, and habitat creation benefiting other special status species (i.e., coho salmon and tidewater goby). The enhanced inter-tidal channels will improve tidal circulation throughout the marsh by increasing sediment delivery to the existing marsh plain, further enhancing resiliency to sea level rise. Additionally, removal of Spartina from the grading limits will prevent further spread and allow for more diverse native salt marsh species to recolonize the marsh (Eicher and Pickart 2011, Pickart 2012).

Following implementation, HBHRCD intends to maintain ownership of the property and oversee follow-on monitoring and maintenance activities associated with the restoration. Adjacent parcels with similar restoration potential could provide expanded enhancement opportunities in the future, thereby providing broader and contiguous habitat benefits.

Next Steps

The following next steps are recommended:

- Request concurrence memorandums from regulatory agencies confirming that the approach outlined in this document will satisfy BIO-6a.
- Confirm location/extent of Rights-of-Ways and Uses
    - City of Eureka's Bay Street
    - Location of existing and abandoned sewer lines
    - PG&E overhead
- Quantify habitat creation, finalize design and develop construction documents
- Develop regulatory approval documents and monitoring/maintenance plan

References

1. Barnhart et al. 1992. The Ecology of Humboldt Bay.
2. Rohde, 2020. Humboldt Bay Shoreline, North Eureka to South Arcata: A History of Cultural Influences
3. Eicher and Pickart, 2011. Impacts of Mechanical Spartina Treatments on Rare Plants in Humboldt Bay Salt Marshes.

4. Grazul and Rowland, 2011. Humboldt Bay Spartina Inventory Mapping provided by Redwood Community Action Agency (RCAA 2021).
5. Humboldt State University Library, Humboldt Room Historic Photos
6. California Department of Fish & Wildlife, Department of Water Resources, State Water Contractors, and United States Department of Fish & Wildlife. 2020-2030 Longfin Smelt Science Plan for San Francisco Bay.
7. Pickart, 2012. Spartina Densiflora Invasion Ecology and the Restoration of Native Salt Marshes at Humboldt Bay National Wildlife Refuge

Attachment 4

Potential Mitigation Activities

Enhancement and restoration activities have been consolidated into primary categories detailed in Table 3. Note CDFW has already recognized a 1:10 ratio as a quality correction between the intake and mitigation sites. Activities will benefit the following listed species, other taxa, and sensitive habitats.

Species

- Juvenile Chinook salmon (*Oncorhynchus tshawytscha*) – California Coastal Evolutionary Significant Unit (ESU), ESA-T
- Juvenile coho salmon (*Oncorhynchus kisutch*) – Southern Oregon-Northern California (SONCC) ESU, ESA-T, CESA-T
- Juvenile steelhead (*Oncorhynchus mykiss*) – Northern California Distinct Population Segment (DPS), ESA-T
- Subadult/adult green sturgeon (*Acipenser medirostris*) – Southern DPS, ESA-T
- Juvenile and adult longfin smelt (LFS; *Spirinchus thaleichthys*), CESA-T
- Tidewater goby (*Eucyclogobius newberryi*) – ESA-E
- Others

Other Taxa

- Shorebirds and waterbirds, benthic invertebrates
- Juvenile Dungeness crab (*Metacarcinus magister*) and other benthic invertebrates
- Commercially valuable fishes and invertebrates
- Others

Sensitive Habitats

- Essential Fish Habitat (EFH) for salmonids, coastal pelagic and groundfish
- Habitat Areas of Particular Concern (HAPC) for estuarine and eelgrass
- ESA-Critical Habitat for salmonids and green sturgeon
- Others

Table 3. Potential Mitigation Activities for Review by Coastal Commission

Action	Details of Action and Success Criteria	Background and Ecotone Benefits
Aquatic Habitat Enhancement & Restoration **Activity Types** *(A combination of some or all of the following depending on the restoration needs of the site.)* Construct Channels Fill Ditches Restore Channels Construct Ponds/Pannes Full Tidal Amplitude Freshwater Pasture to Tidal Wetlands Tide Gate Removal or Enhancement **Proposed Mitigation Ratio[1]** 1:10	***Constructed Channels:*** Construct new or expand estuarine channels (including historic). Excavated channels would reoccupy the original tidal channel alignments to the extent practical. Width and depth may vary based on the project, given the tidal prism, existing elevations, and historical indicators at a given site. ***Fill Ditches:*** Fill in human-constructed ditches in the marsh plain. This may occur as part of new channel excavations. Ditches may also be filled with native marsh soils removed from constructing new intertidal channels. Any offsite dredged sediment used to fill ditches will comply with the Programmatic EIR for Humboldt Bay Sediment Management Plan (ICF 2020). ***Restore Channels:*** Restore dendritic channels (small) in marsh plain to a degree where channels reoccupy the original tidal channel alignments to the extent practical. Width and depth may vary based on the project, given the tidal prism, existing elevations, and historical indicators at a given site. ***Ponds/Pannes:*** Construct estuarine ponds/pannes. These could be in locations including the terminus of intertidal channels and would be constructed concurrently with channel restoration. Ponds/pannes will be designed and constructed to inundate and exchange tidal water during high tides and retain water	***Background:*** Humboldt Bay is a drowned river valley and its land-use has drastically altered its function. Historically, the sloughs around the Bay provided tidal connectivity to coastal marshes. Starting in the late 19^{th} century, settlers diked and drained the coastal marshes around Humboldt Bay to create agriculture land (Schlosser and Eicher 2012). Ditches above the marsh plain and levees along the margins of the marsh (which were built using sediment from ditches) were also constructed to drain water from pastureland. The alterations resulted in channels being cut off from circulation within the Bay and these simplifications prevent the channels from receiving tidal input. Drainage ditches were developed to drain water from upland areas that were historically tidal marsh and remain present in low elevation areas (Schlosser and Eicher 2012). At higher tides, these ditches may be inundated with water from the Bay. Since the existing ditches are not necessarily connected to a breach in the same way as a tidal creek, water may pond in the ditches at lower tide and entrain fishes. The stranding of fishes is particularly problematic once levees are removed. In natural systems, deep channels of estuaries are connected to a dendritic pattern of smaller channels that cover mudflats and extend into tidal marshes (Schlosser and Eicher 2012). Sediment is stored in these channels and throughout the adjacent floodplain, and this sediment is mobilized during periods of high flow. The land reclamation and history of land use in the region has resulted in dendritic channels being blocked off and/or filled. Estuarine pannes and ponds are water retaining depressions that support salt marsh vegetation. They provide foraging and roosting sites for shorebirds and waterbirds, and habitat for invertebrates and some fishes. They are semi-isolated and disconnect from larger water bodies at low tide, but the depression retains water. Estuarine ponds/pannes require a degree of tidal influence: they are not necessarily fully overturned at high tide but retain water and do not fully dry up at low tides. Land use practices in Humboldt Bay have resulted in muted tides in what were historically intertidal coastal marsh habitats. Muted tides are a result of channel constrictions, levees, and tide gates. Muted tides have changed the plant and animal communities compared to habitats that are fully tidal. Over 90% of former intertidal coastal marsh habitat has been lost in Humboldt Bay, much of it converted to agricultural wetlands (Schlosser and Eicher 2012). Areas surrounding Humboldt Bay that have been diked are key elements supporting freshwater agriculture areas and were formerly tidal areas. Much of the historical intertidal coastal marsh and tidal wetland habitat no longer receives tidal input. ***Examples of Positive Impacts:*** The expected benefits differ based on the ecotone. Channel construction will result in the most significant positive effects when this action occurs in the stream estuary ecotone (SEE), which is currently limited compared to other, more marine influenced habitats in Humboldt Bay. The SEE, defined by Wallace et al. 2015, includes the area of low gradient streams extending from stream entrance to the valley floor, through the upper limits of tidal influence, downstream to the region where the channel borders tidal mudflats. It includes all side channels, off channel ponds, tidal channels and fringing marsh habitats that are accessible to fishes for a portion of the tidal cycle.

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Action	Details of Action and Success Criteria	Background and Ecotone Benefits
	during low tides to avoid the entrapment of aquatic organisms. Sites for pond/panne construction will be developed accordingly and on a project-by-project basis, and vary based on the tidal prism, existing elevation, and historical indicators at a proposed site. ***Full Tidal Amplitude:*** Convert area from a muted tide to a non-muted tide. Construction to convert area to non-muted tidal regions will follow BMPs to minimize potential impacts. ***Pasture Conversion:*** Convert diked area (freshwater agricultural area) to muted tidal or full tidal area. Any use of offsite dredged sediment will follow standards in the Programmatic EIR for Humboldt Bay Sediment Management Plan (ICF 2020). ***Success Criteria:*** Channels function as expected based on the proposed design, with periodic monitoring to evaluate channel functioning and performance. Channels function as expected based on the proposed design and do not impede on other natural processes nearby (e.g., if channel restoration occurs near marshes, impacts on the nearby marshes are minimized and avoided). Ponds/pannes function as expected and retain water during low tides and inundate with water at high tides to minimize entrapment of aquatic organisms. Areas function as expected, receives tidal exchange as	All channel restoration actions will result in a landscape that more closely represents its historic configuration. Actions will result in natural processes of erosion and deposition, tidal exchange that creates saline, brackish and freshwater marsh habitat and maintain channel geomorphology, and will improve coastal resiliency to sea level rise. There will be enhanced and expanded tidal prism exchange, and tidal enhancement will enhance wetland habitats. It will support increased productivity through Humboldt Bay and the SEE. Channel construction, especially in the SEE will increase available habitat for fishes and support critical phases of their life history. This holds true for juvenile fishes including Chinook and coho salmon, steelhead, and larval and juvenile longfin smelt that use estuarine channels as rearing habitat (Wallace 2006, Wallace et al. 2015, Garwood 2017, Wallace et al. 2018, Brennan et al. 2022). Channels may also serve as holding and/or feeding grounds for subadult and adult green sturgeon: green sturgeon aggregate and hold seasonally in Humboldt Bay in deeper channels, channel margins, and mudflats (Pinnix 2008, Lindley et al. 2011). The filling of human-constructed ditches will remove unnatural features that have changed tidal circulation and sediment distribution processes around salt marshes. It will restore the historic function of the SEE and create usable space for special-status species. Overall, it increases the area of potential productivity providing food web benefits. The filling of ditches also removes the threat of fish stranding. Channels and their connections to tidal wetlands will improve productivity in the Bay by increasing residence time and more complex, low velocity habitat. This will be particularly beneficial for fishes that have narrow nursery habitat requirements that rear as larvae or juveniles in restored channels, including Chinook and coho salmon, steelhead, and LFS. ***Examples of Positive Impacts:*** Ponds/pannes are highly beneficial when constructed at the end of intertidal channels, estuarine ponds/pannes facilitate water inundation and tidal exchange during high tides and retain water during low tides. This provides diversity in habitat types and salinity stratification relative to intertidal channels and increases residence time for water that can increase productivity and support the food web. More specifically, because water is 'trapped' at low tide, general productivity can increase as the water is not flushed out. Estuarine pannes and ponds provide the habitat with a way to increase primary production because water does not fully dry up. The establishment of estuarine ponds will be an especially beneficial habitat for the tidewater goby with additional indirect benefits for LFS. Tidewater gobies are restricted to upper margins of tidal bays near the entrance of freshwater tributaries, and coastal lagoons, and they require brackish water and occupy shallow sloughs fringing Humboldt Bay. Their preferred habitats are in areas with low velocity tidal currents or stable areas with infrequent tidal exchange (Chamberlain 2006 as cited *in* Schlosser and Eicher 2012). In Humboldt Bay, the upper sloughs and high marsh areas separated from the bay by tide gates or other flow barriers provide habitat for them, including pannes/ponds (McCraney et al. 2010). Indirect benefits of panne/pond habitat can result downstream, because panne/pond habitat has high residence time it may be highly productive and provide benefits to food webs that support LFS and salmonids in downstream channels. Waterbirds and shorebirds are also known to rely on estuarine pannes/ponds for feeding and loafing and can be expected to benefit from this action. Converting muted tidal regions into tidal habitat will result in a landscape that more closely resembles its historic configuration. Actions will result in natural processes of erosion and deposition and tidal exchange and improve coastal resiliency. There will be enhanced and expanded tidal prism exchange that supports natural processes of

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Action	Details of Action and Success Criteria	Background and Ecotone Benefits
	designed, and more closely resembles historic configurations. Areas function as expected, receive tidal exchange, and more closely resemble historic configurations.	erosion and deposition and creates saline, brackish and freshwater marsh and wetland habitats. The primary productivity of the bay itself and the SEE will be enhanced. This action, especially in the SEE, will increase available habitat for fishes and support critical phases of their life history. This holds true for juvenile fishes including Chinook and coho salmon, steelhead, and larval and juvenile LFS that use estuarine areas to rear (Wallace 2006, Wallace et al. 2015, Garwood 2017, Wallace et al. 2018, Brennan et al. 2022). Avian species that use tidal habitats will also have increased available habitat. Land use practices in Humboldt Bay have resulted in muted tides in what were historically intertidal coastal marsh habitats. Restoring these freshwater pastures/agricultural wetlands back to intertidal coastal marsh will provide important habitat for many listed species. Brackish and low-salinity tidal habitats are lacking in Humboldt Bay and likely limiting production, survival and growth of species including LFS and salmonids. Isotope analysis, otolith tracing and evaluating the relative contribution of larvae from waters with different salinities to adult populations suggest that low-salinity waters and brackish habitats are key spawning and rearing habitat (Hobbs et al. 2010, Lewis et al. 2019, Brennan et al. 2022).
Marsh Building **Activity Types** *(A combination of some or all of the following depending on the restoration needs of the site.)* Restore Marsh Plain/Create Create Habitat Variability Restore Historic Marsh Plain Create Living Shoreline **Proposed Mitigation Ratio**[1] 1:10	***Details:*** Place sediment on subsided/muted marsh lands. All sediment from offsite dredging will follow standards in the Programmatic EIR for Humboldt Bay Sediment Management Plan (ICF 2020). Restore historical marsh plain elevations that have subsided, following BMPs to minimize and avoid construction impacts. All sediment from offsite dredging will follow standards in the Programmatic EIR for Humboldt Bay Sediment Management Plan (ICF 2020). Incorporate components of living shorelines at the land-water interface to promote continuity, including features such as, but not limited to vegetation buffers, sills, gradual slopes, native materials, and physical complexity. ***Success Criteria:*** Habitat more closely resembles its historic	***Background:*** The altered ecosystems around Humboldt Bay from historic land use have resulted in muted marshlands and subsided land elevations. Muted marshlands are land that has subsided because the lack of tidal influence prevents sediment from depositing. Land use practices around Humboldt Bay have resulted in subsidence of lands that historically supported tidal marsh habitat. If levees are removed and tidal inundation is restored, these lands would become mudflats because their elevation is too low to support tidal marsh plant and animal communities. There is a need to recover the ecological functions of marsh plain communities, which require increasing the elevation of these lands in restoration projects that restore tidal connectivity. In locations where it is not possible to maintain a natural shoreline, ecosystem-friendly alternatives are becoming common. Such techniques integrate a combination of natural living materials and traditionally built infrastructure. The terminology used to describe these types of (restoration) projects include 'living shorelines' (Smith et al. 2020). Living shorelines generally refer to shoreline protection projects that incorporate elements of habitat restoration alone or in conjunction with infrastructure. They may encompass a range of shoreline stabilization techniques along bays, estuarine coasts, sheltered coastlines, and tributaries and maintain continuity of natural land-water interfaces (NOAA 2015). ***Examples of Positive Impacts:*** Coastal marshes typically provide ecosystem services such as providing habitat for wildlife, regenerating, recycling and export of nutrients, providing a reservoir for organic matter and primary production that serves as the base of the food web, and supporting fisheries (Schlosser and Eicher 2012). These benefits can be expected as marsh plains in Humboldt Bay are restored, and habitat variability is created. There will also be increased species presence with the conversion to tidal marsh with intricate slough/channel and panne formations. The intertidal coastal marshes will become dominated by benthic invertebrates, including gastropods, crustaceans and polychaetes that graze on microalgae on the soil surface. Intertidal coastal marshes will provide increased available habitat for fishes, including larval species covered under coastal pelagic EFH. The avian community may also be expected to benefit because coastal marshes could be used for roosting at high tide

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Action	Details of Action and Success Criteria	Background and Ecotone Benefits
	function and elevation supports natural processes that provide habitat for native plant and animal communities. Elevations are increased to support tidal connectivity. Living shorelines function as expected and provide the expected ecological, social, and economic benefits. Coastal resiliency is improved through stability along the natural land-water interface, reduced erosion, and habitat enhancements.	and/or foraging at low tide. In summary, placing sediments on subsided/muted marshlands to restore the marsh plain and create habitat variability will provide increased available habitat and resources for native communities. Restoring marsh plains to elevations that provide for natural processes and anticipate sea level rise will support coastal native plant communities that provide resiliency to sea level rise. Elevations supporting mudflats are abundant in Humboldt Bay, but elevations supporting tidal marsh are severely impacted by human activities. Restoring marsh plains to elevations that support coastal marshes will provide ecosystem services such as providing habitat for wildlife, regenerating, recycling and export of nutrients, providing a reservoir for organic matter and primary production that serves as the base of the food web, and supporting fisheries (Schlosser and Eicher 2012). The conversion of mudflats to tidal marsh provides other ecosystem services as well. They reduce shoreline erosion and increase resiliency to sea level rise (Zhu et al. 2020). There are ecological, social and economic benefits associated with incorporating living shorelines into infrastructure along the coast in Humboldt Bay. Living shorelines typically provide ecosystem services at the interface between land and water; however, the exact benefits depend on the components used. For example, living shorelines can improve stormwater drainage and water quality during rain events. It can also improve water quality through the removal of creosote treated pilings and structures and reducing erosion. Living shoreline components can be designed in a way that provide for spawning and rearing habitat for coastal-pelagic and groundfish species, or foraging habitat for shorebirds and waterbirds.
Marsh Restoration **Activity Types** *(A combination of some or all of the following depending on the restoration needs of the site.)* Grade Dikes & Uplands Remove Spartina **Proposed Mitigation Ratio**[1] 1:10 Grade Dikes & Uplands 1:3 Remove Spartina	***Details:*** Lower dikes to marsh plain elevation. Lower upland areas juxtaposed to marsh plain to connect more naturally to marsh plain elevations. Remove *Spartina densiflora* per the procedures outlined in the Humboldt Bay Regional Spartina Eradication Plan (H. T. Harvey & Associates 2012) and associated Environmental Impact Review (EIR) (H. T. Harvey & Associates and GHD 2013). ***Success Criteria:*** The lowered surface elevation allows for more natural tidal circulation and functions as designed. Uplands are graded to a degree where they connect to the estuary and function as expected and support natural plant and animal communities.	***Background:*** Dikes are manmade structures that modify natural habitat-forming riverine and tidal processes. The location of dikes provides insight into how the ecosystem functions under natural conditions. The dikes around Humboldt Bay are in locations that were formerly tidal areas but were cut off for agriculture use. Dikes often border the upper margin of intertidal flats and prevent tidal immersion and the presence of salt marshes, and may be made from natural features, or from rock and riprap. Upland areas within the Humboldt Bay watershed are geographic locations that were historically lower in elevation. These upland areas are often associated with land reclamation. In their existing condition, they do not connect to the estuary itself. Spartina is an invasive dense-flowered cordgrass. A bay-wide inventory in 1999 revealed that Spartina was present in 94% of Humboldt Bay's salt marshes (Pickart 2005 as cited *in* Strong and Ayres 2013). Its presence results in dense canopy cover, root mass, and sediment capture and storage, with adverse ecosystem impacts including less light reaching the sediment surface resulting in competition with native plant species, less growth of algae that are important to support food webs (e.g., diatoms), less area for benthic infauna to colonize, and simplification of benthic habitats (e.g., filling of pannes, small channels) due to sediment capture and storage (Strong and Ayres 2013, Augyte and Pickart 2014, Coastal Conservancy 2018, Ren et al. 2021) ***Examples of Positive Impacts:*** By lowering dikes to marsh plain elevation, in combination with filling ditches, the land will be a more even surface. This supports a more natural flow of tidal waters. Productivity will increase as a result and support trophic interactions. There will also be increased available habitat for fishes, invertebrates, birds, and vegetation that rely on marsh plains. By grading uplands and lowering them to improve connectivity with the historic marsh plain elevation, the habitat will reconnect with the estuary and help enhance productivity of the larger landscape. Bay species will, as a result,

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Action	Details of Action and Success Criteria	Background and Ecotone Benefits
	Spartina is removed per the standards established in the Humboldt Bay Regional Spartina Eradication Plan (H. T. Harvey & Associates 2012).	be able to occupy the area and use the available habitat. This is particularly important for ESA and CESA listed salmonid species, as well as LFS. The slope that is developed to reconnect upland areas to the estuary will support natural plant communities, and the slope will provide habitat for native plant communities to rise as sea level rises. The removal of Spartina will provide benefits to salt marsh and mudflat communities and can be expected to have beneficial food web effects. Native marsh species will have the opportunity to recolonize, the benthic macroinvertebrate community will be improved, primary productivity will increase, and mudflats will potentially be transformed into salt marshes. By restoring native marsh communities and increasing productivity of Humboldt Bay, food chains reliant on primary productivity (versus detritus) will be supported, providing forage for juvenile fish-and commercially important invertebrates like juvenile Dungeness crab. Spartina removal will provide improved foraging habitat on mudflats or along channel edges. There will be a subsequent increase in unvegetated mudflat habitats, which will benefit shorebirds (H.T. Harvey & Associates 2012).
Water Quality Enhancements **Activity Types** Treat Stormwater Protect/Enhance Water Quality **Proposed Mitigation Ratio[1]** 1:10	***Details:*** Manage (treat) stormwater entering the bay that may be impacting water quality (contaminants and temperature). Fence off areas around a creek from cattle for creeks that enter the bay. BMPs will be followed to minimize and avoid impacts associated with the fence construction and adverse impacts on riparian areas. ***Success Criteria:*** Stormwater entering the bay meets the intended water quality standards and regulations. Fenced off areas function as intended, whereby all cattle are excluded from access to creeks and adjacent riparian areas. Fencing does not introduce unintended consequences to surrounding ecosystem.	***Background:*** Stormwater entering Humboldt Bay may have adverse effects on water quality. Adverse effects may be from water that is of different temperature or the loading of contaminants, toxins and nutrients (e.g., from surrounding agricultural lands or industrial sites). For example, chemicals from tire wear particles in untreated urban stormwater runoff can cause salmonid die offs (French et al. 2022). Untreated stormwater may also cause sediment loading. Water quality is an important physical component that contributes to the ecosystem function of Humboldt Bay. Reduced water quality can have devastating effects on the ecosystem through trophic interactions. The presence of cattle in the watershed impacts water quality in several ways. When cattle have direct access to riparian margins and water, they can cause adverse effects on stream morphology, increased sedimentation, nutrient additions, and microbial contamination, and removal of vegetation that protects streambanks and filters surface runoff. Cattle indirectly impact water quality because their excrement runs off and introduces microbial loads and nutrients that reduce water quality in downstream habitats (O'Callaghan et al. 2018). The presence of cattle also impacts water quality due to increased sedimentation. Cattle grazing and trampling of stream banks erode banks and mobilize sediment into the creeks (Evans et al. 2006 and Herbst et al. 2012 as cited in O'Callaghan et al. 2018). Cattle presence in-streams can also cause direct disturbance and resuspension of sediment. In addition, cattle presence alters stream morphology: their movement and overgrazing can reduce riparian vegetation and destabilize stream banks. It can cause banks to slump, resulting in widened waterways, which can increase water temperature and degrade aquatic habitat, as well as present barriers to passage for fishes. Cattle grazing inhibits natural regeneration of native vegetation riparian habitat and adversely affects the vertical structure of existing riparian habitat (including understory species), both of which reduce the quality of habitat. Given that much of Humboldt Bay is surrounded by pastureland, the presence of cattle is a constant threat. ***Examples of Positive Impacts:*** By properly managing and treating stormwater that enters Humboldt Bay, the overall quality of the water will be improved and will provide habitat enhancements for all fishes, invertebrates, and avian species using the Bay. The proper treatment of storm water can also prevent algal blooms, which may otherwise have devastating food web effects.

Action	Details of Action and Success Criteria	Background and Ecotone Benefits
		The exclusion of cattle provides ecological benefits. Evidence for the benefits of excluding cattle is strong with regards to sedimentation, pathogens, and riparian margin vegetation. By excluding cattle, water quality is expected to improve, which will positively impact all organisms downstream of the creeks where cattle are being fenced off, including the SEE and Humboldt Bay proper. Cattle exclusion will promote bank stabilization, will allow riparian and wetland plant species (including willows and California sycamores) to recruit and expand from existing habitats. It will result in the closing of canopy gaps, and higher density and cover of native riparian trees and shrubs adjacent to creeks. These effects collectively result in increased stream shading and input of organic matter, providing positive food web effects downstream.
Remove Piles & Anthropogenic Debris **Proposed Mitigation Ratio[1]** 1:4 Pile Removal 1:10 Debris Removal	***Details:*** Remove piles and all structures associated with pilings. Remove anthropogenic debris from the bay or marsh plain. ***Success Criteria:*** Piles and associated structures are removed as expected in the footprint of the area where piles are located. Best management practices (BMPs) are followed to minimize effects of pulling piles and associated structures on water quality (from turbidity and leaching of toxins). Benthic habitat returns to its more natural form and supports aquatic vegetation and associated invertebrates and fishes. Sites return to a more natural form and that all debris is removed from the proposed site in the footprint of the debris and surrounding area impacted by the debris (e.g., erosion, scour, deposition associated with debris).	***Background:*** Throughout Humboldt Bay, there are remnants of old infrastructure, including derelict structures such as piles and docks. The materials used for these piles and docks have historically been treated with creosote, a toxic preservative. Creosote-treated materials that remain leach toxins into the water and have been documented to impact embryonic development of fishes, including Pacific herring (Vines et al. 2000). The presence of pilings also can limit the growth of submerged aquatic vegetation, including eelgrass. This is because depressions around the base of pilings that result from current around the pilings removes sediment and limits the growth of vegetation (Appendix N *in* GHD 2021). Human-placed debris from the bay and marsh plain reduces water quality and affects natural processes. Debris from marsh plains may enter the Bay itself from storms, and stormwater that runs through human-placed debris may pick up contaminants from the materials and be deposited into the Bay itself. Human-placed debris also occupies physical space that would otherwise be available for occupancy by natural habitat. ***Examples Positive Impacts:*** By removing toxic materials from Humboldt Bay, the overall quality of the water will be improved and have positive food web effects. The removal of pilings results in the reestablishment of native substrates (physical). The more natural substrate will allow organisms to recolonize in the benthos and depending on the location, may support native plant communities (e.g., eelgrass). The increased productivity in the benthos and presence of invertebrates and fishes will offer food sources for shorebirds and increase productivity within the Bay. The removal of human-placed debris from the bay and marsh plain can be expected to improve the quality of habitat and water. This is especially important for the SEE, which is severely depleted and may be limiting many of the listed fish species in Humboldt Bay. The improved water quality and habitat will support primary production and have positive feed web effects for all bay species.

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Technical Memorandum

April 05, 2024

To	Melissa Kraemer, California Coastal Commission Matt Goldworth and Jeff Jahn, National Marine Fisheries Service Cori Flannery, California Department of Fish and Wildlife		
Copy to	Rob Holmlund, Harbor District Kasey Sirkin, USACE		
From	Andrea Hilton, GHD Andrea.Hilton@ghd.com 707-267-2262	**Project No.**	11205607
Project Name	Humboldt Bay Harbor, Recreation, and Conservation District Intake Permitting		
Subject	Summary of APF and LFS Mitigation Adjustments Resulting from Measures to Reduce Impacts and Updated APF and LFS Mitigation Calculations Based on the Redesign of Intake Screens and Project Phasing		

Memorandum Objectives

This memo consolidates updated information resulting from the applicant's recent engineering solution to reduce impacts to Longfin Smelt (LFS) and biological productivity, to ease agency review and streamline the document submittal process. Information summarized herein addresses the following:

1. Re-designed screen specifications to further reduce impacts
2. Documented adjustments to APF and Longfin Smelt take since application submittal
3. Project phasing and proportional mitigation requirements
4. Considerations for advanced mitigation

Re-designed Screen Specifications

To reduce the impacts to special status species, including Longfin Smelt (LFS) and Area of Production Foregone (APF), the Harbor District and its tenant, Nordic Aquafarms California LLC (Nordic), have successfully worked with Intake Screens Inc. of Sacramento, California to redesign the intake to further reduce biological impacts resulting from entrainment. The screen mesh of the redesigned intake has been reduced to 0.50 mm from 1.00 mm. Redesign of the screen mesh will not result in ancillary impacts to other resources, as construction and operational parameters remain consistent with those previously analyzed and disclosed to agencies and the public. Technical specifications for the redesigned 0.50 mm intake screen are attached, including details for the proposed antifouling coating (see Attachment 1 – Redesigned Intake Specifications from Manufacturer). The redesigned intake screen will have a lower maximum approach velocity of 0.12 feet/second (reduced from 0.20 feet/second) and will be self-cleaning via a brush system.

EXHIBIT NO. 8
MEMO RE: SCREEN MESH SIZE & MITIGATION ADJUSTMENTS
CDP APPLICATION NO. 1-21-0653
(Humboldt Bay Harbor District)

Table 1 Re-Designed Screen Metrics Overview

Intake	Original vs Updated	Original:	Approach Velocity	Dimensions
Redwood Marine Terminal II Intake	Original 1.00 mm screen	Max intake flow rate of 5,500 gallons per minute (gpm)	0.20 ft/s	36-inch diameter screen
	Updated 0.50 mm screen	Max intake flow rate of 5,500 gpm (unchanged)	0.12 ft/s	42-inch diameter screen
Red Tank Dock Intake	Original 1.00 mm screen	Max intake flow rate of 2,750 gpm	0.20 ft/s	24-inch diameter screen
	Updated 0.50 mm screen	Max intake flow rate of 2,750 gpm (unchanged)	0.12 ft/s	24-inch diameter screen (unchanged)

Documented Adjustments to APF and Longfin Smelt Take

The Coastal Development Permit (CDP) application initially submitted to the California Coastal Commission included an APF[1] impact calculation for a 1.00 mm wedgewire intake screen based on the 95th percentile for seven fishes from the study of combined entrainment effects for the two intakes. Tenera Environmental has reviewed the redesigned intake screen and updated the required value for APF to 7.80 acres (see Attachment 2 – Tenera March 2024). Similarly, H.T. Harvey reviewed the redesigned intake screen and determined LFS take will be reduced to 1,961 larvae, resulting in an updated value of 0.73 acres of LSF mitigation, using the formula previously established with CDFW (see Attachment 3 – H.T. Harvey April 2024).

Given agencies have received several iterations of submittals, this technical memorandum has been developed to summarize adjustments to APF to date, along with corresponding adjustments to LFS larvae entrainment and associated mitigation as regulated by CDFW. Previous submittals for APF and LFS entrainment are summarized in Table 2.

Table 2 Summary of APF Adjustments Subsequent to Application Submittal

Date	APF Value	Justification	Screen Parameters
August 18, 2023 – Tenera	34.60 acres	Original calculation based on entrainment study results. Entrainment estimated at 28,013 LFS larvae.	1.00 mm wedgewire screen
October 2, 2023 – Tenera	N/A	Entrainment adjusted to 15,881 LFS larvae.	1.00 mm wedgewire screen
December 7, 2023 – Tenera	28.80 acres	Correction to the estimate of the standard error used in calculating the value at the 95th percentile of the cumulative probability curve for final APF estimates.	1.00 mm wedgewire screen
March 27, 2024 – CDFW	N/A	Mitigation area determined to be 5.98 acres[2]	1.00 mm wedgewire screen
March 29, 2024 – Tenera	7.80 acres[3]	Updated estimates of APF based on a reduced screen size.	0.50 mm wedgewire screen
April 3, 2024 – H.T. Harvey	N/A	Corresponding memo documenting reduced Longfin Smelt entrainment associated with updated 0.50 mm wedgewire screen at 1,961 LFS larvae. Adjusts LFS mitigation to 0.73 acres using current formula.	0.50 mm wedgewire screen

[1] All APF calculations summarized herein have been completed by Tenera Environmental.
[2] Prior to application of ratios with CDFW
[3] Prior to application of rations with CCC

Project Phasing and Proportional Mitigation

The CEQA EIR reflected a phased approach to water withdrawal. As the applicant's terrestrial design has adjusted, phasing quantities have also adjusted, summarized in Table 3. The Harbor District and tenant Nordic assume commensurate mitigation requirements will also be phased proportionally and that mitigation for each phase will be required to be in-place in advance of water withdrawal through the intakes for the same phase. Table 3 presents proposed mitigatory requirements by phase for both APF with the Coastal Commission and LFS mitigation with CDFW.

Table 3 Proposed Phased Mitigation Obligations Assuming a 1.00 mm Screen

Phase and Estimated Year or Operation	Original Intake Volumes and Mitigation		Proposed Intake Volumes and Mitigation					Estimated Year of Mitigation
	Cumulative Intake Volumes by Phase (MGD)	% of Total	Individual Phase Vol. (MGD)	Cumulative Intake Volumes by Phase (MGD)	% of Total	APF (cumulative acres)[1]	LFS Mitigation (cumulative acres)[1]	
Phase 1 - 2027	0.999	8%	5.05	5.05	43%	12.24	2.50	2025
Phase 2 - 2032	1.800	15%	4.95	10.00	84%	24.24	4.96	2025
Phase 3 - 2034	11.880	100%	1.88	11.88	100%	28.80	5.89	2033
TOTAL	**11.880**	**100%**	**11.88**	**11.88**	**100%**	**28.80**	**5.89**	**N/A**

Notes
1 – Before ratios applied

Established mitigation for APF and LFS based on a 1.00 mm screen (Table 3) have been adjusted proportionally, reflective of an improved 0.50 mm screen in Table 4. As documented by Tenera and H.T. Harvey, the reduction in screen mesh from 1.00 mm to 0.50 mm reduces APF mitigation from 28.80 acres to 7.80 acres; LFS mitigation is commensurately reduced from 5.98 acres to 0.73 acres (see Attachment 2 and Attachment 3). These mitigatory requirements for APF and LFS are further proportioned by withdrawal phase in Table 4.

Note that LFS mitigation accounts for a 11:1 credit provided by CDFW associated with the location of the mitigation site. As the Coastal Commission considers final ratios, the Harbor District and tenant Nordic request the equivalent 11:1 ratio is also applied to aquatic habitat creation in an estuary setting (e.g., Bay Street or equivalent). Based on the conceptual design, the identified Bay Street site will be sufficient to create the required CDFW LFS acreage of aquatic and related habitat for Phases 1 through 3. Mitigation for APF will also occur at Bay Street, with any required balancing occurring at another location to be determined using the ratios defined by the Coastal Commission.

The Harbor District understands that mitigation areas in place of or in addition to the Bay Street project site would need to offer comparable or better habitat benefits to LFS (e.g., estuarine environment directly beneficial to the species). The Harbor District acknowledges that all final mitigation designs, including associated monitoring plans, will require review and approval by jurisdictional agencies, in addition to CEQA and permitting compliance required for the mitigation site(s).

Table 4 Proposed Phased Mitigation Obligations Assuming a 0.50 mm Screen

Phase and Estimated Year or Operation	Proposed Intake Volumes and Mitigation					Estimated Year of Mitigation
	Updated Individual Phase Vol. (MGD)	Cumulative Updated Intake Volumes by Phase (MGD)	% of Total	APF (cumulative acres)[1]	LFS Mitigation (cumulative acres)[1]	
Phase 1 -2027	5.05	5.05	43%	3.32	0.31	2025
Phase 2 -2032	4.95	10.00	84%	6.57	0.61	2025
Phase 3 -2034	1.88	11.88	100%	7.80	0.73	2033
TOTAL	**11.88**	**11.88**	**100%**	**7.80**	**0.73**	**N/A**
Notes 1 – Before ratios applied						

Considerations for Advanced Coastal Commission APF Mitigation

Maximum mitigatory acreages for APF 7.80 acres based on Phase 3 intake volumes (Table 4), which are not estimated to occur until 2034. However, advanced in-place mitigation would further benefit LFS and biological productivity in Humboldt Bay, as additional habitat would be available well before the commensurate impact occurred.

To account for this habitat benefit, the Harbor District proposes a credit for advanced mitigation. The established lifespan of the project is 30 years. The initial approach to estimating a reasonable credit for advanced mitigation divided the life of the project over the ten-year period for mitigation establishment, resulting in a 3% annual credit. However, multiplying 3% by ten years would result in a credit of 30%, which is recognized to be too high to be acceptable.

Thus, the Harbor District proposes a 0.05-acre credit for each year mitigation is in place prior to the withdrawal of Phase 3 volumes, up to a ten-year maximum. Thus, for example, if the Harbor District completes all mitigation project(s) in the year 2025 to address impacts associated withdrawal of the full 11.88 MGD volume, mitigation would be in place nine years prior to the full impact. The full APF mitigation requirement would be reduced by a total of 0.45 acres (0.05 acres x nine years of advanced mitigation).

Attachment 1

Screen Redesign Technical Specifications from the Manufacturer

Redwood Marine Terminal II (RMT II) Dock Intake

Based on a 5,500 gpm (12.25 cfs) design capacity, 0.5-mm slot openings (22% open area with 1.75-mm wire width), and a 0.2 ft/s approach velocity criteria, a minimum of 81.7 ft^2 of screen surface area is needed to meet regulatory requirements at this intake. For operational reliability of 0.5-mm slot screens, ISI recommends that the screens be sized for an approximate 0.5 ft/s through-screen velocity which is equivalent to a 0.11 ft/s approach velocity. ISI therefore recommends a T42-54EC-r screen for RMT II. This is a tee screen ("T") constructed from 2507 super duplex stainless steel ("C") with two 42" diameter, 54" long wedge wire cylinders providing 99 ft^2 of screen surface area. This equates to an approach velocity of 0.12 ft/s and a through-screen velocity of 0.56 ft/s at a 5,500 gpm flow rate. Each cylinder would have an electric drive ("E") to rotate the screen cylinder between internal and external brushes. See a brush cleaning demonstration video **HERE**. The screen manifold and non-brush cleaned surfaces would be coated with a biocide-free fouling release coating (e.g., Intersleek 1100SR or similar; see attached data sheet) to limit marine organism colonization of the equipment. The screen system would be retrievable ("r") with the tee screen rolling central manifold designed to travel on a vertical rail system. The rail system would include vertical rails and horizontal bracing, a docking inlet with bulb seal at the screen operational elevation to provide a fish tight seal between the docking inlet and rolling manifold, and a docking sensor to confirm the screen has docked without obstruction. The rail system would extend vertically above the deck elevation and allow the screens to be pinned in place for ease of inspection and maintenance from the deck level. The screen would be raised using owner supplied lifting equipment (e.g., portable winch, telehandler, or small crane). The lower portion of the rail system would include a blank plate to close off the existing intake opening outside of the docking inlet. The rail system, docking inlet, and blank plate would be constructed from epoxy coated (e.g., Carboline Plastite 4500 or similar; see attached data sheet) A36 carbon steel. The screen system would be supplied with a pressure differential monitoring system which would trigger a "clean now" event if an operator-defined pressure differential was recorded. Pressure transducers and protective still wells would be incorporated into the rail system. The screen would be provided with a main control panel for manual and automatic screen cleaning, processing of pressure transducer data, and system monitoring. A local control panel would be provided and installed near the screen to allow manual screen cleaning and a docking sensor status indicator light. A reverse seating gate would be installed on the downstream side of the docking inlet (i.e., inside the sea chest) to exclude fish from entering the sea chest when the screen is raised for inspection and maintenance. ISI assumes this gate is supplied by others. The ISI screen would be installed with a screen centerline elevation of -4.56' which would place the top of the screen 1" below the Lowest Astronomical Tide elevation of -2.73. The bottom of the screen would be at elevation -6.31' and therefore 2.51' above the intake structure invert and more than 8 feet above the bay bottom.

Red Tank Dock Intake

Based on a 2,750 gpm (6.13 cfs) capacity, 0.5-mm slot openings (22% open area with 1.75-mm wire width), and a 0.2 ft/s approach velocity criteria, a minimum of 30.7 ft^2 of screen surface area is required to meet the regulatory requirements at this intake. Per the above description for RMT II, ISI recommends a target for 0.5 mm slot openings of approximately 0.5 ft/s through-screen velocity. Based on this, we recommend a T24-50EC-r screen for Red Tank Dock. This is a tee screen ("T") constructed from 2507 super duplex stainless steel ("C") with two 24" diameter, 50" long wedge wire cylinders providing 52.4 ft^2 of screen surface area. This equates to an approach velocity of 0.12 ft/s and a through-screen velocity of 0.53 ft/s at a 2,750 gpm flow rate. All of the equipment, material types, and features described for the RMT II intake screen system would apply to this site as well. The screen would be installed with a screen centerline elevation of -3.81' which would place the top of the screen 1" below the Lowest Astronomical Tide elevation of -2.73. The bottom of the screen would be at elevation -4.81' and therefore 5.2" below the intake structure invert and 1.09' above the bay bottom.

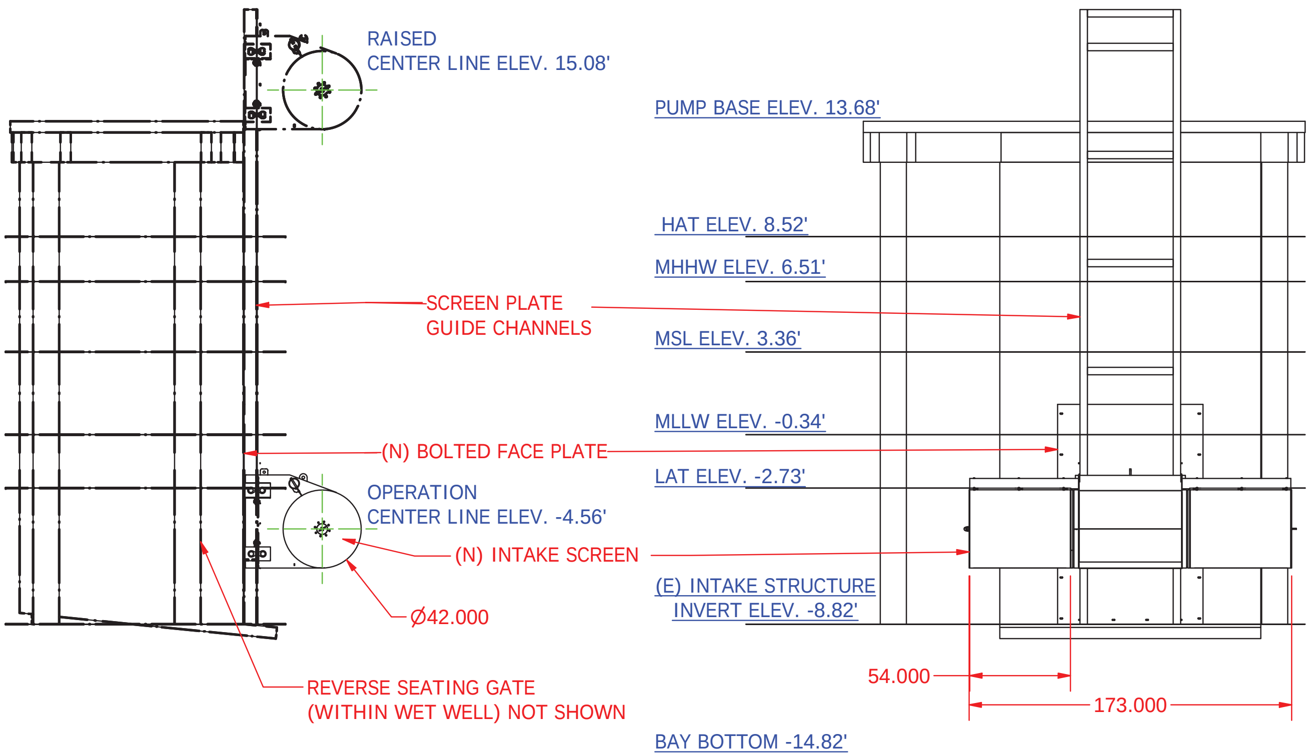
DEFINITIONS

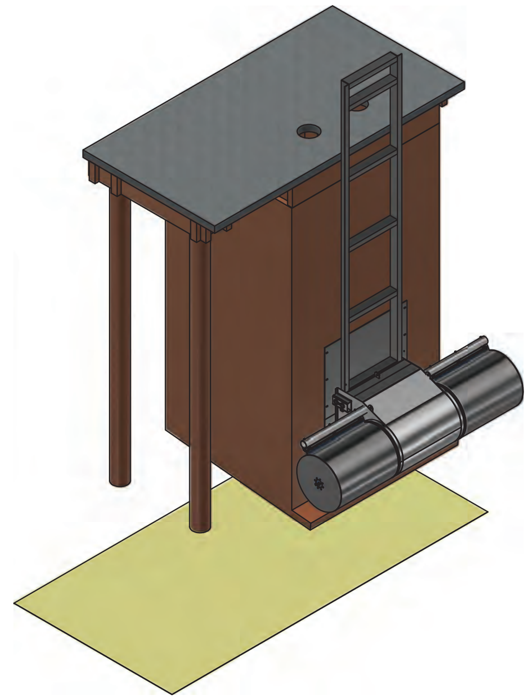
HAT: HIGHEST ASTRONOMICAL TIDE
MHHW: MEAN HIGHER HIGH WATER
MSL: MEAN SEA LEVEL
MLLW: MEAN LOWER LOW WATER
LAT: LOWEST ASTRONOMICAL TIDE

NOTES

ELEVATIONS IN REFERENCE TO NORTH AMERICAN VERTICAL DATUM OF 1988

PRESSURE DIFFERENTIAL MONITORING SYSTEM NOT SHOWN





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REV	DESCRIPTION	DATE	APPROVED
2			
1	INITIAL RELEASE	4/4/24	RJ

ALL DIMENSIONS IN INCHES UNLESS NOTED

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STANDARD TOLERANCES
Fractional Dimensions ± 1/32
Decimal Dimensions ± 0.005

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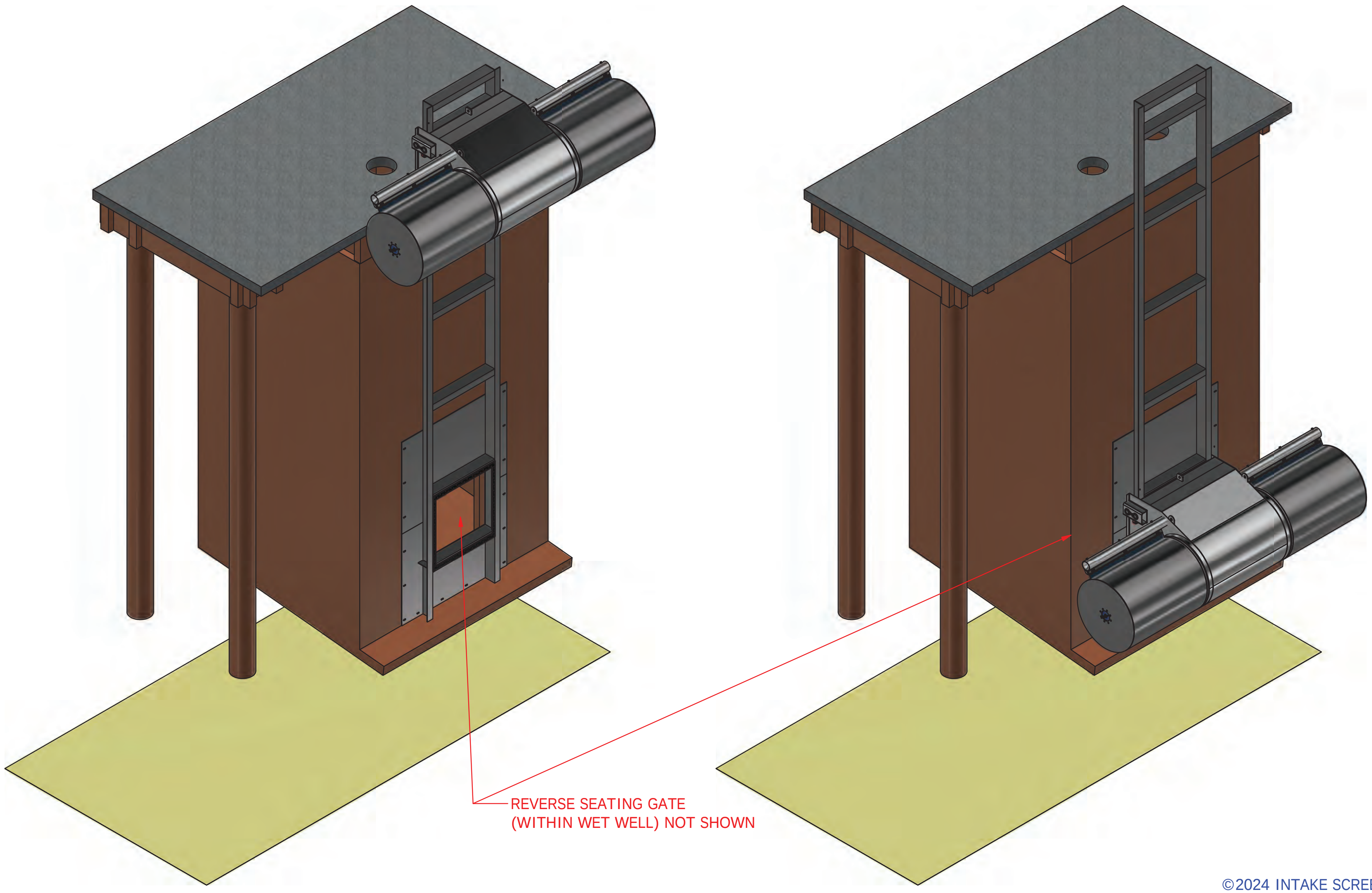
ISI Intake Screens, Inc.
8417 RIVER ROAD | SACRAMENTO, CA 95832 | 916-665-2727
www.isi-screens.com

DATE	4/4/2024
APP'D BY	RUSSELL BERRY IV
DRAWN BY	LESLIE TRAN
"B" SHEET SCALE	
PROJECT	RTM II
DESCRIPTION	RMT II DOCK T42-54EC-R
MATERIAL	N/A
DRAWING NUMBER	RMT II-LAYOUT
MASS	N/A
SHEET NUMBER	1 of 2



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ALL DIMENSIONS IN INCHES UNLESS NOTED	CONFIDENTIAL	Intake Screens, Inc.	DATE 4/4/2024	PROJECT RMT II	DESCRIPTION RMT II DOCK T42-54EC-R	DRAWING NUMBER RMT II-LAYOUT	SHEET NUMBER 2 of 2
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SELECTION & SPECIFICATION DATA

Generic Type
Solvent free epoxy lining

Description
PLASITE 4500 is a solvent free, flake-reinforced, high performance epoxy coating designed as an internal tank lining for chemical or other commodity storage. It is resistant to a broad range of chemicals such as fuels, salts, alkalis, many acids and some solvents.
Excellent versatility allows for potable water and water treatment immersion service.

Features
- High impact resistance
- Superior adhesion to steel
- Resistance to a broad range of chemicals
- Can be applied as low as 35°F/2°C
- Can be applied as a one-coat 20-60 mil system
- NSF/ANSI 61 compliant for use in potable water tanks, pipes, and valves.*
- Certified by UL to meet the drinking water criteria of NSF/ANSI/CAN 600
- Meets AWWA C210 requirements for use in water supply pipeline and valves
- Passes ASTM G210 - Severe Waste Water Analysis Tests (SWAT)

*Valid when manufactured at a certified location.

Color
Standard color: U80P (Off White)

Other colors may be available by special order.

Finish
Gloss

Primer
N/A, coating is applied direct to metal

Dry Film Thickness
20 - 30 mils (508 - 762 microns) DFT

Typically applied at this thickness per coat.
Applications for potable water or AWWA C210 service may be applied at a dry film thickness of 16 mils (406 microns) with a maximum of 60 mils (1,524 microns).

Coverage Rate
1604 mil sq ft/gal
80 sq ft at 20 mils

Allow for loss in mixing and application

VOC Values
As Supplied : 0 g/l

SUBSTRATES & SURFACE PREPARATION

General
Surfaces must be clean and dry. Employ adequate methods to remove dirt, dust, oil and all other contaminants that could interfere with adhesion of the coating

Steel
Cleanliness: Abrasive blast to SSPC-SP10 (minimum)
Profile: Minimum 3 mil (75 micron) dense, sharp anchor profile free of peening, as measured by ASTM D 4417. Defects exposed by blasting must be repaired.

SUBSTRATES & SURFACE PREPARATION

Concrete
Concrete shall be designed, placed, cured, and prepared per NACE No. 6/SSPC-SP 13, latest edition. Abrade to remove all laitance, loose concrete, etc. and to create surface profile in accordance with the appropriate ICRI CSP 4-7. Do not apply coating unless concrete has cured at least 28 days @ 70°F (21°C) or equivalent. Voids in concrete may require filling and/or surfacing. Consult Carboline Technical Service for recommended primer/sealer.

MIXING & THINNING

Mixing
Mix each component separately to a smooth uniform consistency. Any settling in the container must be thoroughly scrapped and re-dispersed. Use a Jiffy type mixer and avoid plunging it up and down in the bucket, which can fold air in to the resin causing bubbles to form in the coating after it has been applied.

Thinning
Thinning not recommended
Clean up thinner: Thinner #71

Ratio
4:1 Ratio (A to B)

Pot Life
35°F (2°C): 30-40 minutes
75°F (24°C): 15-25 minutes

APPLICATION EQUIPMENT GUIDELINES

Listed below are general equipment guidelines for the application of this product. Job site conditions may require modifications to these guidelines to achieve the desired results.

Airless Spray
Use a fixed ratio (4:1 by volume) plural component spray rig with heated hoppers, heated hoses to mixer manifold through a static mixer to a 50 ft/15.2 m whip hose followed by a silver gun utilizing self-cleaning reverse-a-tips from 0.017-0.035 inches.
NOTE: the Part A side should be at a minimum of 110-140°F and the part B side 90-131°F.
Use a 3/8" min I.D. material hose
Pump Ratio: 30:1 (min)
Volume Output: 2.5 g/m (9.5 l/m) (min)
Material Hose: 3/8" I.D. min (9.4 mm)
Tip Size: 0.017-0.021” (0.43-0.53 mm)
Output Pressure: 2000-2500 psi (13.8- 17.2 MPa)
*PTFE packings are recommended and available from pump manufacturer.

APPLICATION PROCEDURES

Film Build
Maximum film build (per coat) on vertical surfaces and overhead decreases with age:
Fresh: Over 60 mils
3-6 months: 50-30 mils
After 6 months: less than 30 mils.
Follow intercoat preparation requirements when applying multiple coats
The cure mechanism of this product is not affected for a minimum of 24 months.

Exhibit 8
CDP 1-21-0653
Page 40 of 42

APPLICATION CONDITIONS

Condition	Material	Surface	Ambient	Humidity
Minimum	110°F (43°C)	35°F (2°C)	35°F (2°C)	0%
Maximum	140°F (60°C)	125°F (52°C)	110°F (43°C)	85%

This product requires the substrate temperature to be 5°F (3°C) above the dew point. Contact Carboline Technical Service if conditions are not within recommended guidelines.

CURING SCHEDULE

Surface Temp.	Dry to Touch	Firm	Immersion Service, for crude oil, unblended gasoline, and fuel oils	Immersion Service; all other exposures
35°F (2°C)	8 Hours	16 Hours	36 Hours	5 Days
75°F (24°C)	6 Hours	8 Hours	24 Hours	4 Days
100°F (38°C)	2 Hours	3 Hours	12 Hours	3 Days

Based on 50% relative humidity. Plasite 4500 has the propensity to blush during its cure cycle. It is imperative that the blush be remove before top coating or placing this material into potable water service. Before any touch-up or recoat material can be applied, the first coat must be properly prepared for intercoat adhesion.

Recoat Procedure

• The first coat must be cured firm to the touch. Coating on floors must be able to support foot traffic.
• Scrub the coating with soap and water and thoroughly rinse/dry.
• If the coating has cured more than 24-hours, lightly sand or mechanically abrade (de-gloss) the surface and vacuum dust and debris.

CLEANUP & SAFETY

Cleanup | Plasite Thinner #71

Safety | Ventilation should be used during and after installation. Ventilation can be discontinued once the material has cured. The ventilation equipment should be capable of preventing the solvent concentration from reaching the lower explosion level for the solvents used. The applicator should monitor the exposure levels or use MSHA/NIOSH approved air respirators.

Ventilation | When used in enclosed areas, thorough air circulation must be used during and after application until the coating is cured. The ventilation system should be capable of preventing the solvent vapor concentration from reaching the lower explosion limit for the solvents used. User should test and monitor exposure levels to insure all personnel are below guidelines. If not able to monitor levels, use MSHA / NIOSH approved respirator.

Caution | Fire and explosion hazards: This product contains less than 1% volatile components, however, vapors are heavier than air and can travel long distances, ignite and flash back. Eliminate all Ignitions sources. Keep away from sparks and open flames. All electrical equipment and installations should be made and grounded in accordance with the National Electric Code. In areas where explosion hazards exist, workers should be required to use non-ferrous tools and wear conductive and non-sparking shoes.

TESTING / CERTIFICATION / LISTING

TESTING / CERTIFICATION / LISTING

Potable Water Certifications	**<u>NSF 61 Potable Water Use Approvals @ 75°F (24°C):</u>** *Meets drinking water criteria of NSF/ANSI/CAN 600* Max DFT: 50 mils (1270 microns) # of Coats: 1 Tank Rating: 5 gallons or larger (18.9271 Liters) Pipe Rating: 4" or larger (10.16 cm) Valve Rating: 4" or larger (10.16 cm) Approved Thinner: N/A 3 Day Cure Required before service Approved Colors: U80P (Off White) and V131 (Blue) Special Order Colors: U74P (Light Grey) and U51P (Tile Red) Consult the UL website for further approval parameters.

PACKAGING, HANDLING & STORAGE

Packaging	5 and 20 gallon units
Shelf Life	Part A: 24 months Part B: 24 months
Storage Temperature & Humidity	40-110°F (4-43°C) For the 24-48 hours just prior to use, narrow the storage temperature to 70- 85°F (21-29°C) to facilitate ease of mixing.
Storage	Keep product tightly sealed in original container until ready for use. Store out of direct sunlight.
Shipping Weight (Approximate)	9.3 lbs per gallon

WARRANTY

To the best of our knowledge the technical data contained herein is true and accurate on the date of publication and is subject to change without prior notice. User must contact Carboline Company to verify correctness before specifying or ordering. No guarantee of accuracy is given or implied. We guarantee our products to conform to Carboline quality control. We assume no responsibility for coverage, performance, injuries or damages resulting from use. Carbolines sole obligation, if any, is to replace or refund the purchase price of the Carboline product(s) proven to be defective, at Carbolines option. Carboline shall not be liable for any loss or damage. NO OTHER WARRANTY OR GUARANTEE OF ANY KIND IS MADE BY CARBOLINE, EXPRESS OR IMPLIED, STATUTORY, BY OPERATION OF LAW, OR OTHERWISE, INCLUDING MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. All of the trademarks referenced above are the property of Carboline International Corporation unless otherwise indicated.

Plasite® 4500
PRODUCT PERFORMANCE SUMMARY

HARDNESS

Method	ASTM D2240 (Shore Hardness)
System	One coat of Plasite 4500 @ 40 mils DFT
Surface Prep	SSPC-SP5 over 3.0 mil profile
Results	Shore D: 80

EIS (ELECTROCHEMICAL IMPEDANCE SPECTROSCOPY)

Method	ISO 16773 (draft)
System	One coat of Plasite 4500 @ 25 mils DFT
Surface Prep	SSPC-SP5 over 3.0 mil profile
Results	Log Z = 8.8 (Scale: 4 = Poor, 6 = Protection begins, 8 = Good, 10 = Excellent) Stable data over 28 day test indicating minimal continued water uptake representing no physical deterioration

ADHESION AFTER THERMAL CYCLING

Method	ASTM D4541
System	One coat of Plasite 4500 @ 20-40 mils DFT
Substrate	Steel plate (3”x4”x0.25”)
Surface Prep	SSPC-SP5 over 3-4 mil profile
Thermal Cycle	23ºC to -40ºC (73º to -40ºF) for 4 hours and back to 23 C (water bath)
Results	2333 psi (glue failure); No other effects

AUTOCLAVE TEST

Method	NACE Standard TM0185-93
Exposure	Temperature – 65ºC (149ºF) Pressure – 15 psig Gas Phase Composition – 5% H_2S, 5% CO_2, balance CH_4 Organic Phase: 1:1 – kerosene: toluene Aqueous Phase: 5% NaCl
Duration	28 days
Surface Prep	SSPC-SP5 with 3.0-3.5 mil profile
Results	Adhesion rating: B No blistering or undercreep No other visual defects EIS Impedance: Log Z = 10.2 (Excellent)

OIL AND GAS IMMERSION RESISTANCE

Method	Major oil company test protocol for evaluating tank linings for refined fuels, ethanol, crude oil and hot water		
Exposure	Petrochemical Immersion 50/50: Crude oil / 3% NaCl (60ºC/140ºF) 50/50: Gasoline/tap water (50ºC/122ºF) Atlas Cell Testing (30 days; Crude oil at 60ºC/140ºF)		
Duration	Immersion Tests: 6 months		
System	One coat of Plasite 4500 @ 25 mils DFT		
Surface Prep	SSPC-SP5 with 3.5-4.0 mils profile		
Results	<u>Exposure</u> 50/50: Crude oil / 3% NaCl (60ºC/140ºF) 50/50: Gasoline/tap water (50ºC/122ºF) Atlas Cell Testing (60ºC/140ºF)	<u>Results</u> No effect No effect No effect	<u>Adhesion After Immersion</u> Crude phase: 2777 psi; Water: 1851 psi Gas phase: 2000 psi; Water: 1500 psi

FLEXIBILITY

Method	NACE RP0394-2002, Procedure B (Four-Point) Method
System	One coat of Plasite 4500 @ 20 mils DFT
Results	Permanent Strain (º/pd): 2.78 average of 3 samples Permanent Elongation (%): 2.42 average of 3 samples

CATHODIC DISBONDMENT

Method	CSA Z245.20-06 Claus 12.8
Exposure	Duration: 30 days Voltage: -1.5V Temperature: 23ºC (73ºF) Solution: 3% NaCl
System	One coat of Plasite 4500 @ 25 mils DFT
Surface Prep	SSPC-SP5 with 3.0-4.0 mils profile
Results	5.2 mm average disbondment

ABRASION RESISTANCE

Method	ASTM D4060
Exposure	5000 cycles; 1000 gram weight; CS-17 wheel (measurements taken between 1000-5000 cycles)
System	One coat of Plasite 4500 @ 25 mils DFT
Results	944 cycles/mil; 11.3 cycles/mg (356 mg loss)
Discussion	The Tabor Abrasion test (referenced method) can produce results that do not correlate to the true abrasion resistance of a coating based on the test method. Coatings that contain film reinforcement (such as glass flake, mica, or MIO) can result in higher weight loss; even though the coatings perform quite well in actual service.

CHEMICAL IMMERSION RESISTANCE

Method	NACE TM01-74		
Exposure	See Chemical Resistance		
Duration	12 months immersion		
System	One coat Plasite 4500 @ 20-30 mils DFT		
Surface Profile	3.0-3.5 mil profile		
Chemical Resistance	Black liquor @ 130ºF (54ºC)	Hydrochloric acid (10%) @ 120ºF (66ºC)	Sodium hydroxide (50%) @ 130ºF (54ºC)
	Diesel fuel @ 100ºF (38ºC)	Jet fuel @ 120ºF (49ºC)	Sulfuric acid (10%) @ 120ºF (49ºC)
	Diethanolamine @ 130ºF (54ºC)	Naptha @ 100ºF (38ºC)	Sulfuric acid (50%) @ 120ºF (49ºC)
	Ethylene glycol @ 100ºF (38ºC)	Salt brine @ 130ºF (54ºC)	Urea (sat.) @ 120ºF (49ºC)
	Gasoline @ 100ºF (38ºC)	Sodium hydroxide (10%) @ 130ºF (54ºC)	Water – DI @ 130ºF (54ºC)

NOTE

The technical data presented in this document is accurate to the best of Carboline's knowledge based on laboratory testing of the product(s) or system(s) described. Actual results in the field may vary depending on field conditions and application methods. The performance characteristics stated do not constitute a guarantee or warranty that the products will meet the stated results under all circumstances. Contact Carboline technical staff with questions.

Intersleek 1100SR

Advanced Fluoropolymer Foul Release Coating

PRODUCT DESCRIPTION

Advanced fluoropolymer foul release coating for the control of slime.

INTENDED USES

For use at Newbuilding or Maintenance & Repair.

PRODUCT INFORMATION

Color	FXA991-Grey, FXA992-Blue, FXA997-Red, FXA999-Black and a limited range of colors
Finish/Sheen	Gloss
Part B (Curing Agent)	FXA993 (Part B), FXA994 (Part C)
Volume Solids	72% ±2% (ISO 3233:1998)
Mix Ratio	9 volume(s) Part A to 2 volume(s) Part B to 1 volume(s) Part C
Typical Film Thickness	Range: 6 - 8 mils dry (8.3 - 11.1 mils wet) may be specified depending upon end use.
Theoretical Coverage	Range: 196 - 147 ft²/US gal at 6 - 8 mils dft, allow appropriate loss factors
Method of Application	Airless Spray, Brush
Flash Point	Part A 115°F; Part B 72°F; Part C 97°F; Mixed 91°F
Induction Period	Not required

Drying Information	32°F	59°F	77°F	95°F
Touch Dry [ISO 9117/3:2010]	5 hrs	3 hrs	2 hrs	60 mins
Hard Dry [ISO 9117-1:2009]	15 hrs	6 hrs	4 hrs	2 hrs
Before Flooding	48 hrs	36 hrs	20 hrs	17 hrs
Pot Life	140 mins	90 mins	60 mins	30 mins

Note The interval prior to flooding may be reduced to 24 hours at temperatures between 41°F and 68°F provided that the ship remains at rest for a minimum period of 2-3 days after flooding. At temperatures between 32°F and 41°F, the absolute minimum time to flooding is 48 hours and the ship must remain at rest for a minimum of 4 days afterundocking. However, the coating may suffer intercoat detachment in any areas that are subject to mechanical abrasion due to, eg. fendering or impact damage.

Overcoating Data - see limitations

	Substrate Temperature							
	32°F		59°F		77°F		95°F	
Overcoated By	Min	Max	Min	Max	Min	Max	Min	Max

Note May be overcoated by self, either when fresh or after prolonged immersion provided surface is in good, clean condition. Consult International Paint.

REGULATORY DATA

VOC

240 g/lt (2.00 lb/US gal) as supplied (EPA Method 24)
238 g/kg of liquid paint as supplied. EU Solvent Emissions Directive (Council Directive 1999/13/EC)
2.10 g/lt Chinese National Standard GB23985

Note: VOC values are typical and are provided for guidance purposes only. These may be subject to variation depending on factors such as differences in color and normal manufacturing tolerances.

This product does not contain organotin compounds acting as biocides and as such is in compliance with the International Convention on the Control of Harmful Anti-fouling Systems on ships as adopted by IMO in October 2001 (IMO document AFS/CONF/26).

CERTIFICATION	When used as part of an approved scheme, this product has the following certification: Product recognised by the following classification societies as compliant with the International Convention on the Control of Harmful Anti-fouling Systems on Ships, 2001 (AFS 2001): • Bureau Veritas • DNV GL • Lloyds Register • Korean Register of Shipping Consult your International Paint representative for details.
SYSTEMS AND COMPATIBILITY	Consult your International Paint representative for the system best suited for the surfaces to be protected.
SURFACE PREPARATIONS	Use in accordance with the standard Worldwide Marine Specifications. All surfaces to be coated should be clean, dry and free from contamination. High pressure fresh water wash or fresh water wash, as appropriate, and remove all oil or grease, soluble contaminants and other foreign matter in accordance with SSPC-SP1 solvent cleaning. Intersleek 1100SR must always be applied over Intersleek 737 tie coat (Intersleek 731 tie coat in USA) within the required overcoating interval. Consult International Paint for detailed application advice and recommendations.

APPLICATION

Mixing	Material is supplied in 3 containers as a unit. Always mix a complete unit in the proportions supplied. (1) Agitate Part A with a power agitator (2) Combine entire contents of Part A and Part B and mix thoroughly with a power agitator. (3) Add entire contents of Part C and mix thoroughly with a power agitator. Carefully add Part C (under slow power-mixing) into the Part A / Part B mix. **These products are moisture sensitive and they should not be opened until just before they are needed.**
Thinner	Not recommended. Use International GTA007 only in exceptional circumstances. DO NOT thin more than allowed by local environmental legislation.
Airless Spray	Recommended Tip Range 15-21 thou (0.38-0.53 mm) Total output fluid pressure at spray tip not less than 3000 psi (211 kg/cm²)
Conventional Spray	Application by conventional spray is not recommended.
Brush	Application by brush is recommended for touch up areas only. Multiple coats may be required to achieve specified film thickness.
Roller	Application by roller is recommended for small areas only. Multiple coats may be required to achieve specified film thickness.
Cleaner	International GTA007/GTA822
Work Stoppages and Cleanup	Do not allow material to remain in hoses, gun or spray equipment. Thoroughly flush all equipment with International GTA007/GTA822. Once units of paint have been mixed they should not be resealed and it is advised that after prolonged stoppages work recommences with freshly mixed units. Clean all equipment immediately after use with International GTA007/GTA822. It is good working practice to periodically flush out spray equipment during the course of the working day. Frequency of cleaning will depend upon amount sprayed, temperature and elapsed time, including any delays. Do not exceed pot life limitations. All surplus materials and empty containers should be disposed of in accordance with appropriate regional regulations/legislation.
Welding	In the event welding or flame cutting is performed on metal coated with this product, dust and fumes will be emitted which will require the use of appropriate personal protective equipment and adequate local exhaust ventilation. In North America do so in accordance with instruction in ANSI/ASC Z49.1 "Safety in Welding and Cutting."

SAFETY

All work involving the application and use of this product should be performed in compliance with all relevant national Health, Safety & Environmental standards and regulations.

Prior to use, obtain, consult and follow the Material Safety Data Sheet for this product concerning health and safety information. Read and follow all precautionary notices on the Material Safety Data Sheet and container labels. If you do not fully understand these warnings and instructions or if you can not strictly comply with them, do not use this product. Proper ventilation and protective measures must be provided during application and drying to keep solvent vapor concentrations within safe limits and to protect against toxic or oxygen deficient hazards. Take precautions to avoid skin and eye contact (ie. gloves, goggles, face masks, barrier creams etc.) Actual safety measures are dependant on application methods and work environment.
EMERGENCY CONTACT NUMBERS:
USA/Canada - Medical Advisory Number 1-800-854-6813
Europe - Contact (44) 191 4696111. For advice to Doctors & Hospitals only contact (44) 207 6359191
China – Contact (86) 532 83889090
R.O.W. - Contact Regional Office

LIMITATIONS

Minimum acceptable substrate temperature at the time of application is 32°F. A minimum Relative Humidity of 30% is required to ensure satisfactory curing. Longer cure times will be required if the Relative Humidity falls below 30%.
Care should be taken to avoid overspray onto other coated areas.
Intersleek 1100SR must be applied over Intersleek 737 tie coat (Intersleek 731 tie coat in USA) within the required overcoating interval.
All equipment must be thoroughly clean prior to use, and before re-use with other materials, to prevent contamination. Liquid cleaners for Intersleek 1100SR must not be allowed to contaminate other paints.
Precautions should be taken to prevent silicone contamination of adjacent areas.

Overcoating information is given for guidance only and is subject to regional variation depending upon local climate and environmental conditions. Consult your local International Paint representative for specific recommendations. Apply in good weather. Temperature of the surface to be coated must be at least 5°F above the dew point. For optimum application properties bring the material to 70°F-81°F, unless specifically instructed otherwise, prior to mixing and application. Unmixed material (in closed containers) should be maintained in protected storage in accordance with information given in the STORAGE Section of this data sheet. Technical and application data herein is for the purpose of establishing a general guideline of the coating application procedures. Test performance results were obtained in a controlled laboratory environment and International Paint makes no claim that the exhibited published test results, or any other tests, accurately represent results found in all field environments. As application, environmental and design factors can vary significantly, due care should be exercised in the selection, verification of performance and use of the coating.

UNIT SIZE

Unit Size	Part A		Part B		Part C	
	Vol	Pack	Vol	Pack	Vol	Pack
10 lt	7.5 lt	10 lt	1.67 lt	2.5 lt	0.83 lt	1 lt
5 US gal	3.75 US gal	5 US gal	0.83 US gal	1 US gal	0.42 US gal	0.5 US gal

Part C is supplied in a polyethylene container
For availability of other unit sizes consult International Paint

UNIT SHIPPING WEIGHT

Unit Size	Unit Weight
10 lt	12.2 Kg
5 US gal	48.3 lb

STORAGE

Shelf Life: 12 months minimum at 77°F. Subject to re-inspection thereafter. Store in dry, shaded conditions away from sources of heat and ignition.

WORLDWIDE AVAILABILITY Consult International Paint.

IMPORTANT NOTE

The information in this data sheet is not intended to be exhaustive; any person using the product for any purpose other than that specifically recommended in this data sheet without first obtaining written confirmation from us as to the suitability of the product for the intended purpose does so at their own risk. All advice given or statements made about the product (whether in this data sheet or otherwise) is correct to the best of our knowledge but we have no control over the quality or the condition of the substrate or the many factors affecting the use and application of the product. Therefore, unless we specifically agree in writing to do so, we do not accept any liability at all for the performance of the product or for (subject to the maximum extent permitted by law) any loss or damage arising out of the use of the product. We hereby disclaim any warranties or representations, express or implied, by operation of law or otherwise, including, without limitation, any implied warranty of merchantability or fitness for a particular purpose. All products supplied and technical advice given are subject to our Conditions of Sale. You should request a copy of this document and review it carefully. The information contained in this data sheet is liable to modification from time to time in the light of experience and our policy of continuous development. It is the user's responsibility to check with their local representative that this data sheet is current prior to using the product.

This Technical Data Sheet is available on our website at www.international-marine.com or www.international-pc.com, and should be the same as this document. Should there be any discrepancies between this document and the version of the Technical Data Sheet that appears on the website, then the version on the website will take precedence.

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Attachment 2

Tenera Technical Memorandum – APF

March 2024

Head Capsule Analysis for Determining Probability of Entrainment at Intakes Using Wedgewire Screen

March 29, 2024

Document SLO2024-008.0

Prepared for:

Humboldt Bay Harbor District

Eureka, CA

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Introduction and Background

This report provides background and a description of the methods that were used to estimate the probability of entrainment for fish larvae at the 0.5 mm wedgewire screen (WWS) modules proposed for use at the two intakes analyzed in the Intake Assessment of the Potential Effects on Ichthyoplankton and other Meroplankton Due to Entrainment at Proposed Samoa Peninsula Water Intakes (Intake Assessment) dated May 1, 2023. The project is now planning to use intake modules with WWS slot openings of 0.5 mm instead of the 1.0 mm modules that were analyzed in the Intake Assessment. The intake modules will also have approach velocities of 0.12 ft/s. The decreased width of the slot openings and low approach velocities will significantly reduce potential impacts from entrainment. The recalculated entrainment values for the 0.5 mm WWS are presented below.

A technical memorandum dated March 11, 2024 provided estimates on the expected reduction in entrainment with the change to the 0.5 mm WWS (**Table 1**). The average reduction in entrainment with the 0.5 mm WWS was 74.8% which resulted in a decrease in the estimate of APF required to compensate for the impacts due to entrainment from 17.9 to 4.7 acres at the 50^{th} percentile and from 28.2 to 7.8 acres for the estimate at the 95^{th} percentile of a cumulative probability curve based on the APF estimates from the seven fishes.

All of the estimates of the reductions in entrainment for the seven fishes are based on the probabilities of entrainment for fish larvae at each mm of length which are calculated using the relationship between the length of the larvae and the width and depth of the head capsule for the larvae. This approach has been presented for use at several intake projects in California and has been largely based on work in a report completed by Tenera (2011) that looked at entrainment probabilities for a large number of species using data collected during entrainment studies over several years. This same report was later updated for use in assessing alternative intake technologies for the Diablo Canyon Power Plant by the State Water Resources Board (Tenera 2013).[1]

Table 1 (from March 11, 2024 Technical Memorandum). ETM estimates of proportional mortality (PM), unadjusted estimates of Area of Production Foregone (APF), estimated entrainment reductions due to 0.5 mm WWS intake screen modules, and APF estimates adjusted for reductions in entrainment for seven taxa analyzed Humboldt Bay May 2023 Intake Assessment. The unadjusted APF estimates are from Table 5-9 of the Intake Assessment. Entrainment probabilities at each mm length for the 0.5 mm WWS are provided in **Table 5** of this report.

Taxa	Combined PM Estimates for both intakes	Unadjusted APF Estimate (acres [hectares])	Estimated 0.5mm WWS Entrainment Reduction (%)	APF Adjusted for 0.5mm WWS Entrainment Reduction (acres [hectares])
Arrow Goby	0.3757	56.7 (22.9)	72.8	15.4 (6.2)
Bay Goby	0.1166	17.6 (7.1)	67.4	5.7 (2.3)
Whitebait Smelt	0.0464	7.0 (2.8)	73.8	1.8 (0.7)
Pacific Herring	0.0308	4.7 (1.9)	82.7	0.8 (0.3)
Pacific Tomcod	0.0842	12.7 (5.1)	74.7	3.2 (1.3)
Surf Smelt	0.0783	11.8 (4.8)	63.4	4.3 (1.7)
Pacific Staghorn Sculpin	0.0960	14.5 (5.9)	89.1	1.6 (0.6)
Averages	0.1183	17.9 (7.2)	74.8	4.7 (1.9)
APF values at 95% percentile		28.8 (11.7)		7.8 (3.2)

WWS or slot screened intakes have been studied extensively in freshwater environments and in laboratory studies. Background on the testing and development of WWS was presented in the Intake Assessment additional information is provided in the following paragraphs on the effectiveness off WWS.

Various types of screens have been developed to keep larger numbers of organisms out of cooling water systems and to return them safely to the environment. The Electric Power Research Institute (EPRI) has critically reviewed the efficacy and feasibility of most intake screen designs and other intake technologies (EPRI 1999). Out of the many screen technologies and intake systems reviewed, cylindrical WWS were not only one of the few promising technologies at the time, but were one of only three technologies that were pre-approved by the EPA Director for the new 316(b) Phase II Rule for detailed engineering and economic analysis.

The primary feature of a cylindrical WWS that produces its unique filtering performance is its "V" or wedge-shaped, cross-section wire. The wire when welded to a frame to form a slotted screen prevents impingement of juvenile and adult fishes and dramatically reduces entrainment. The slot size is designed so that it is sufficiently narrow to physically block passage of entrainable organisms, and the low through-slot velocity when combined with adequate ambient

[1] https://www.waterboards.ca.gov/water_issues/programs/ocean/cwa316/rcnfpp/docs/tenera_rev073113.pdf. Accessed March 28, 2024.

current (i.e., “sweeping” velocity) allows passive or weak swimming organisms to avoid impingement on the screen’s surface. Under these conditions WWS can be very effective at eliminating impingement of juvenile and adult fishes and reducing impingement and entrainment of larval fishes. Large reductions in entrainment and impingement are also expected even when aquatic organisms are physically able to pass through slots, if through-slot velocities are low and sweeping velocities are high. EPRI (2003) published results of laboratory tests that examined combinations of WWS design parameters and how they may have contributed to reductions in entrainment and impingement at WWS facilities, concluding that both entrainment and impingement increased with increased through-slot velocities and decreased with increased ambient velocities.

Through-slot velocity and ambient velocity (also referred to as channel or approach velocity) can greatly affect impingement and entrainment of fishes exposed to WWS. Impingement and entrainment have been positively correlated with slot velocity and inversely related to ambient velocity (Hanson et al. 1978, EPRI 2003). The interaction between these two velocity parameters is also important, with available data suggesting that the ratio of ambient velocity to slot velocity should be maximized for effective exclusion of aquatic organisms (Hanson et al. 1978). The ability to “sweep” fish past cylindrical WWS modules most likely contributes to lower entrainment and impingement rates of larvae and eggs that otherwise would become entrapped. The effects of sweeping currents will help reduce entrainment and impingement at the two intakes for the project which will be located in the Samoa Channel where they will be subject to strong tidal currents on incoming and outgoing tides.

Biological factors that have been shown to influence entrainment and impingement of fishes exposed to cylindrical WWS include fish size (length, width, body depth), life stage or age, and swimming ability. All of these factors are closely related (i.e., as fish mature they become larger and have greater swimming capabilities), and contribute to the susceptibility of fish larvae to entrainment and impingement. The size of a fish larva can lead to physical or behavioral exclusion if it is larger than a screen’s slot width and is capable of avoiding intake flows that can lead to impingement or entrainment. Weisburg et al. (1987) determined that exclusion of fish larvae from cylindrical WWS with varying slot widths was highly dependent on fish length.

During the study by Weisburg et al. (1987), larvae less than 5 mm were not excluded by any of the slot sizes evaluated (1, 2, and 3 mm), whereas larger fish (greater than 10 mm) were excluded at rates greater than 80% for all slot sizes. Other studies have also demonstrated that many fish larger than about 10 mm in length can be effectively excluded by screens with 1-mm slot widths (Hanson et al. 1978, 1981, Otto et al. 1981). In addition to length, body depth or width may also preclude fish from becoming entrained through WWS (Schneeberger and Jude 1981). The width and depth of the head capsule are the least compressible portions of the larvae and would be the dimensions that would most likely limit entrainment.

The relationship between WWS slot width and impingement and entrainment rates is mainly dependent on fish size. Most fishes that are physically too large to pass through a screen cannot become entrained. However, at higher slot velocities, some larger fish, as well as eggs, may be forced through screen slots. Also, fishes that cannot physically pass through a screen mesh may become impinged if they cannot swim or be swept away from intake flow. A direct relationship between slot size and entrainment has been demonstrated in some previous studies, but the strength or importance of this relationship may vary with fish size (Hanson et al. 1978, Weisburg et al. 1987).

The size of fish eggs within a species are generally fairly uniform. Therefore, the susceptibility to entrainment and impingement of this life stage generally depends on size, the screen design (e.g., slot size), and hydraulic conditions. The sizes of fish eggs for several species of fish in California with a planktonic egg stage show that most fish eggs would not be subject to entrainment thorough a 0.5 mm WWS especially a screen designed with a low approach velocity (**Table 2**). The strong tidal currents that occur in the Samoa Channel will also help sweep fish eggs and other planktonic organisms past the screen modules.

Table 2. Sizes of fish eggs for some common taxa of fishes from southern California. Egg diameters taken from Moser et al. (1996).

Family	Taxa	Common Name	Egg Diameter Range (mm)
Clupeidae	*Sardinops sagax*	Pacific sardine	1.3 - 2.1
Engraulidae	Engraulidae unid.	anchovies	0.7 - 0.8 x 1.2 - 1.5
Serranidae	*Paralabrax* spp.	sand and kelp basses	0.8 - 1.0
Haemulidae	*Xenistius californiensis*	salema	0.7 - 1.0
Sciaenidae	Sciaenidae unid.	croakers	0.7 - 1.3
Sciaenidae	*Atractoscion nobilis*	white seabass	1.2 - 1.3
Sciaenidae	*Cheilotrema saturnum*	black croaker	0.8 - 0.9
Sciaenidae	*Genyonemus lineatus*	white croaker	0.8 - 0.9
Sciaenidae	*Roncador stearnsi*	spotfin croaker	0.7 - 0.8
Sciaenidae	*Seriphus politus*	queenfish	0.7 - 0.8
Sciaenidae	*Umbrina roncador*	yellowfin croaker	0.7 - 0.8
Kyphosidae	*Girella nigricans*	opaleye	1.0 - 1.1
Labridae	*Oxyjulis californica*	senorita	0.7 - 0.8
Labridae	*Semicossyphus pulcher*	California sheephead	0.8
Sphyraenidae	*Sphyraena argentea*	Pacific barracuda	1.0 - 1.4
Scombridae	*Scomber japonicus*	Pacific mackerel	0.8 - 1.3
Pleuronectiformes	Pleuronectiformes unid.	flatfishes	0.6 - 3.1
Paralichthyidae	Paralichthyidae unid.	sand flounders	0.6 - 0.9; 1.2 - 1.4
Paralichthyidae	*Citharichthys* spp.	sanddabs	0.6 - 0.8
Paralichthyidae	*Paralichthys californicus*	California halibut	0.7 - 0.8
Pleuronectidae	*Microstomus pacificus*	Dover sole	2.1 - 2.7
Pleuronectidae	*Parophrys vetulus*	English sole	0.8 - 1.1
Pleuronectidae	*Pleuronichthys* spp.	turbots	0.8 - 2.1
Pleuronectidae	*Pleuronichthys guttulatus*	diamond turbot	0.8 - 0.9

Although fish length is an important biological factor with respect to physical exclusion, the entrainment and impingement of fishes through WWS is also dependent on active avoidance by larvae. Visual observations and estimated entrainment rates of fishes that are physically capable of passing through slots indicate that a portion of larvae exposed to screens will evade entrainment through avoidance behaviors (Hanson et al. 1978, Zeitoun et al. 1981, Otto et al. 1981).

Early studies of the effectiveness of WWS reported the potential for substantial ichthyoplankton impingement and entrainment reductions. Zeitoun et al. (1981) studied the use of WWS in Lake Michigan and found that ambient concentrations of ichthyoplankton, as determined by a towed net, were about 11 times greater than in a pipe screened with slot sizes of 2.0 mm and 9.5 mm. They found that larval avoidance, and to a lesser extent, screen exclusion was responsible for the low entrainment. Jude et al. (1978, 1979) conducted mathematical modeling of exclusion sizes for alewife. They postulated that there would be a seasonal change in exclusion rates that ranged from 7.2 to 100% as the alewife grew between July and October; results showed that the mathematical predictions of larval exclusion were not consistent with their laboratory results and tended to be unrealistically conservative. They concluded that the test larvae, which were reared under sub-optimal laboratory conditions and restrained in a continuous pumping test environment, would in a natural setting move out of the velocity field and avoid impingement and entrainment pumping effects.

Weisberg et al. (1987) investigated the efficiency of cylindrical wedge-wire screen to exclude larval bay anchovy and naked goby using slot sizes of 1.0, 2.0, and 3.0 mm compared to an unscreened intake. They found that fish smaller than 5 mm were not excluded by any of the screens, but screens with all three slot sizes excluded more than 80% of all the larger ichthyoplankton. The percentage excluded by the screens may have even been as high as 100%, although this could not be determined because some ichthyoplankton were lost during the experiment. The 2.0-mm and 3.0-mm slot screens were not as effective at excluding ichthyoplankton as the 1-mm screen, but the effect of slot size on exclusion efficiency was small relative to the effect of fish size. The authors concluded that the use of WWS in the range of 1.0–3.0-mm slot size would successfully reduce, if not eliminate, the entrainment of larval fishes larger than 5 mm. Bestgen et al (2004) also examined the exclusion and survival of fathead minnow larvae using slot mesh screen sizes of 0.5 mm and 1.0 mm. All (100%) of 22.5 mm and 45.0 mm minnows were excluded by both slot sizes. Survival was 100% for the 22.5-mm minnows and 88% for the 45.0-mm minnows.

Amaral (2003) considered cylindrical WWS to be an intake technology with significant potential to minimize entrainment and impingement of aquatic organisms at cooling water intakes. From a series of laboratory evaluations using the early life stages of eight different species of fish, he concluded that: 1) both entrainment and impingement decreased with decreased through-slot velocity, and 2) impingement increased at smaller slot sizes while entrainment was reduced. Interrelationships between the effects of through-slot velocities, channel hydraulic conditions, fish size, and swimming ability were not uniform at the slot sizes tested (0.5 mm, 1.0 mm, and 2.0 mm), but low entrainment rates were demonstrated for the 0.5 mm screen for fish less than 10 mm, particularly at a through-slot velocity of 0.15 m/s, which is roughly the slot velocity expected at the project intakes Mean impingement of fish larvae was typically less than 10% for all species and slot sizes tested, including 0% for all tests using striped bass larvae. The mean percent entrainment of striped bass larvae for 0.5mm slot size and slot velocity of 0.15 m/s was 3.4, 4.6, and 2.7% for channel velocities of 0.8, 0.15, and 0.30 m/s, respectively. Alewife eggs, which averaged 0.7 mm in diameter, did not impinge on the 0.5 mm screen, but were entrained at rates of 10% to 20% for the two channel velocities evaluated, giving insight into potential entrainment and impingement rates of fish eggs for California species (**Table 2**). Overall, the mean percent of fish larvae lost to impingement and entrainment decreased with slot size and the ratio of through-slot velocity to channel velocity. The results of his statistical analyses indicate that entrainment and impingement may be highly dependent on this low velocity ratio.

In summary, the results of the studies discussed in this section support the findings more recently presented by Coutant (2020) that intakes utilizing WWS have levels of entrainment much lower than estimated based solely on the size of the larvae and the width of the slot openings. Coutant (2020) concluded that the contribution of screen-size opening and through-screen velocity was a minor factor in the reduction in entrainment. The major factor was the cylindrical design of the intake and its orientation parallel to ambient current which creates a bow wave, and resulting flow dynamics help move larvae and other objects away from the screen surface where they may be subject to entrainment. The increased turbulence also probably decreases the likelihood that larvae would be oriented exactly parallel to the screen slots where they could be more easily entrained. Although not as large a factor as the cylindrical design of the screen, sweeping currents along the screen surface that far exceed through-screen velocities also made entrainment unlikely. Therefore, entrainment loss estimates solely on larval size are likely to be highly conservative especially due to the proposed placement of the intake screens in an area of Humboldt Bay where they will be subject to strong sweeping velocities on ebb and flood tides.

Methods

The methods used in estimating the proportional entrainment of a taxon of fish larvae at different mm length increments in the Intake Assessment is the same method used in the Tenera (2011) report. The larval fishes measured for the analyses presented in the Tenera (2011) report were collected with the same sampling gear and mesh size as the samples collected for the Intake Assessment.

Measurements were made from a randomly selected subset of larvae collected from the two intake stations and stations SW2 and SW3, which were closest to the intakes. Due to the small numbers of larvae collected at the intake stations for some of the taxa, all of the larvae from the four stations were measured and used for analyses. The body length (standard [notochord] length [NL]), head width, and head depth (**Figure 1**) were measured for each specimen to the nearest 0.004 in. (0.1 mm) using a digital camera mounted on a dissecting microscope interfaced with digital imaging analysis software. The number of larvae measured, and the average NL, head width, and head depth for each of the seven taxa are shown in **Table 3**.

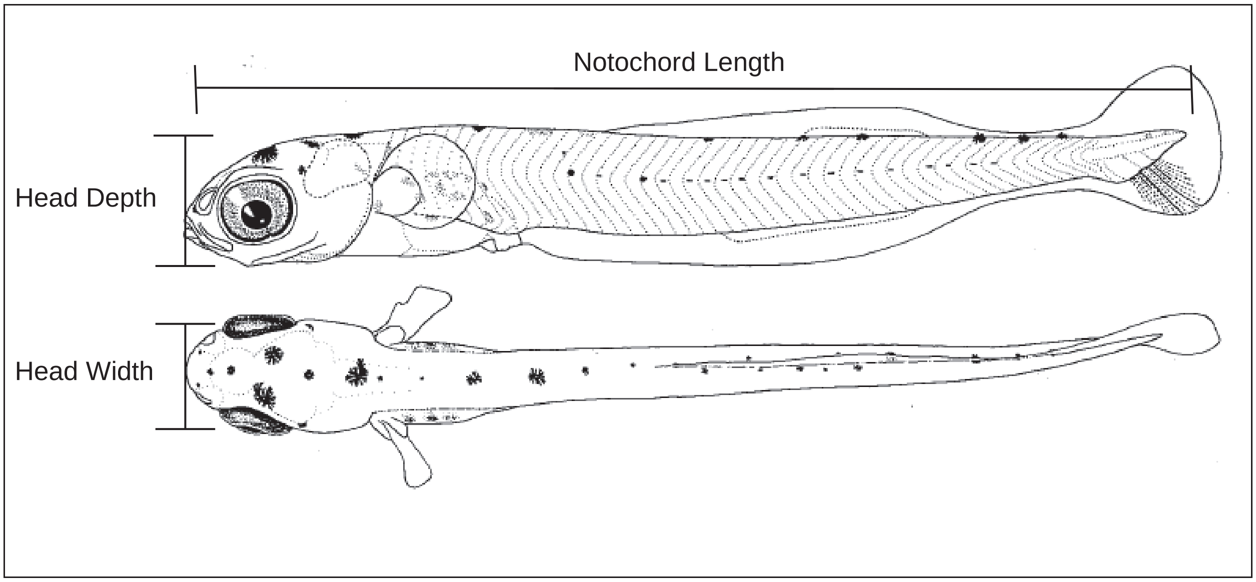

Figure 1. Illustration of the measurement locations for notochord length and head depth (height) and width of a preflexion stage larval fish. Larval fish is a jacksmelt from Moser (1996).

Table 3. Numbers of larvae measured for each of the seven taxa and average notochord length, head width and head depth from larvae collected during Humboldt Bay Impact Assessment.

		Average (mm)		
Taxa	Count	Length	Head Width	Head Depth
Arrow Goby	204	3.89	0.2533	0.4811
Bay Goby	175	3.06	0.3062	0.5183
Whitebait Smelt	240	6.41	0.4713	0.4164
Pacific Herring	126	8.45	0.5039	0.4783
Pacific Tomcod	112	3.17	0.3027	0.3954
Surf Smelt	36	16.65	0.9937	1.1845
Pacific Staghorn Sculpin	77	5.91	0.6106	0.8094

Detailed Analysis Methods

Step 1. Non-linear squares (NLS) regression

The analysis of notochord length and head capsule dimensions was done using the same allometric regression model used in Tenera (2011) where head capsule dimension was assumed to be a power function of notochord length. This type of regression model is used to describe changes in body shape with growth (e.g., Fuiman 1983, Gisbert et al. 2002, and Pena and Dumas 2009). The length data were used to calculate separate regression models with the corresponding data for head width and head depth. This was done using the R programming language using the nls (non-linear squares) function fitting the model $Head\ Capsule\ dimension = a * Length^b$ for both head capsule width and head capsule depth. The data were plotted and the non-linear least squares parameters (a and b) and their associated standard errors were written out to a file.

The parameters from the analysis are shown in **Table 4**. The plots showing the NLS regressions for each species from the analysis are included in the Impact Assessment.

Table 4. The parameters and standard errors (Std. Err.) for the non-linear squares function fitted to the head capsule width and depth data from larvae collected during Humboldt Bay Impact Assessment.

Taxon	Head Width				Head Depth			
	a	Std. Err. a	b	St. Err. b	a	Std. Err. a	b	St. Err. b
Arrow Goby	0.0826	0.0026	0.8315	0.0191	0.1246	0.0037	1.0000	0.0164
Bay Goby	0.1741	0.0210	0.5070	0.1055	0.2450	0.0250	0.6721	0.0888
Whitebait Smelt	0.1609	0.0162	0.5821	0.0524	0.1370	0.0152	0.6013	0.0575
Pacific Herring	0.0597	0.0066	1.0000	0.0490	0.0570	0.0063	1.0000	0.0485
Pacific Tomcod	0.1398	0.0203	0.6715	0.1241	0.2120	0.0365	0.5423	0.1477
Surf Smelt	0.0582	0.0239	1.0000	0.1345	0.0695	0.0250	1.0000	0.1177
Pacific Staghorn Sculpin	0.1043	0.0158	1.0000	0.0804	0.1382	0.0204	1.0000	0.0784

Step 2. Monte Carlo simulation to generate probabilities

Length-specific probabilities of entrainment at the intake screens were calculated using estimates of variability around the allometric regressions from the analyses of each of the seven taxa. To describe the effects of this variation on head capsule dimensions, a Monte Carlo simulation, which is a statistical model used to predict stochastic outcomes by repeated random sampling, was used to generate the proportion reduction in entrainment for each length class. The Monte Carlo simulation allowed for the incorporation of morphological variation seen due to the variation in the relationship between larval fish length and head capsule dimension. In order to relate each mm (0.04 in.) length increment to the potential for entrainment, it was necessary to incorporate this variation in body length (NL) to head capsule dimension in the model. The simulation generated 1,000 estimates of head width and head depth for 100 random increments within each millimeter size class of notochord length (from a minimum up to a maximum length determined for the taxon) using the estimated standard errors for each regression parameter. Errors for the regression parameters were assumed to be normally distributed.

Step 3. Summarize data from Monte Carlo simulation

The data from the 100,000 estimates at each mm length for each taxon were averaged to provide a single estimate of entrainment probability at each mm length increment. The results that are provided in the Impact Assessment report are for the 1.0 mm WWS analysis. The analysis was subsequently done for 0.5 mm WWS, which is now planned for use at the intakes for the project.

The entrainment probability results for the 0.5 mm WWS in **Table 5** show that the reduction in slot size for the WWS results in a large decrease in potential entrainment from the results for the 1.0 mm WWS presented in the Impact Assessment. The average mortality reduction in the table represents the reduction in mortality to the population of each taxon because each mm group of larvae will result in the same number of equivalent 26 mm larvae if constant growth and survival are assumed to occur over the length range in the table. This is demonstrated in **Table 6** using the results for Arrow and Bay goby. As shown in previous memos on this issue, the average reduction in probability of entrainment is equal to the theoretical loss of 25 mm larvae that would have occurred to the population.

Table 5. Estimated probabilities of entrainment for fish larvae analyzed for the Humboldt Bay entrainment study at mm NL intervals from estimated hatch NL through 25 mm for a wedgewire screen slot size of 0.02 in. (0.5 mm) using estimates of variability around the allometric regressions parameters in Table 4.

Length	Arrow Goby	Bay Goby	Whitebait Smelt	Pacific Herring	Pacific Tomcod	Surf Smelt	Pacific Staghorn Sculpin
3	1.0000	0.9983	1.0000	1.0000	0.9951	0.9993	0.9953
4	1.0000	0.9672	0.9997	1.0000	0.9410	0.9829	0.8256
5	1.0000	0.8796	0.9901	1.0000	0.7905	0.9164	0.4317
6	1.0000	0.7580	0.9324	0.9964	0.6140	0.8132	0.1623
7	0.9992	0.6225	0.7941	0.9403	0.4643	0.6896	0.0569
8	0.8983	0.5086	0.6099	0.7304	0.3545	0.5770	0.0198
9	0.3371	0.4179	0.4440	0.4381	0.2709	0.4845	0.0074
10	0.0300	0.3475	0.3108	0.2092	0.2089	0.4107	0.0026
11	0.0005	0.2931	0.2119	0.0903	0.1669	0.3482	0.0014
12	0.0000	0.2502	0.1454	0.0369	0.1306	0.3020	0.0005
13	0.0000	0.2115	0.0970	0.0123	0.1103	0.2584	0.0003
14	0.0000	0.1790	0.0678	0.0047	0.0976	0.2271	0.0001
15	0.0000	0.1598	0.0470	0.0016	0.0889	0.1996	0.0000
16	0.0000	0.1387	0.0317	0.0007	0.0802	0.1779	0.0000
17	0.0000	0.1219	0.0232	0.0002	0.0723	0.1630	0.0000
18	0.0000	0.1100	0.0158	0.0000	0.0671	0.1456	0.0000
19	0.0000	0.0995	0.0115	0.0001	0.0627	0.1289	0.0000
20	0.0000	0.0898	0.0079	0.0000	0.0585	0.1195	0.0000
21	0.0000	0.0804	0.0063	0.0000	0.0544	0.1085	0.0000
22	0.0000	0.0748	0.0048	0.0000	0.0524	0.1014	0.0000
23	0.0000	0.0671	0.0039	0.0000	0.0483	0.0919	0.0000
24	0.0000	0.0617	0.0027	0.0000	0.0459	0.0860	0.0000
25	0.0000	0.0583	0.0021	0.0000	0.0429	0.0810	0.0000
Average	0.2724	0.3259	0.2939	0.2809	0.2530	0.3658	0.1089
Mortality Reduction	0.7276	0.6741	0.7061	0.7191	0.7470	0.6342	0.8911

Table 6. Estimated probabilities of entrainment for Arrow and Bay goby and resulting adult equivalents at each mm length increment assuming constant survival of 0.9 per day and growth of 0.25 mm per day. The number of larvae surviving through each mm length increment in the absence of entrainment is also shown.

	Entrainment Probability			25 mm Equivalents		
Length	Arrow Goby	Bay Goby	Number of Larvae without Entrainment	Constant Growth and Mortality	Arrow Goby	Bay Goby
3	1.0000	0.9983	100,000.00	9.40	0.00	0.02
4	1.0000	0.9672	65,610.00	9.40	0.00	0.31
5	1.0000	0.8796	43,046.72	9.40	0.00	1.13
6	1.0000	0.7580	28,242.95	9.40	0.00	2.28
7	0.9992	0.6225	18,530.20	9.40	0.01	3.55
8	0.8983	0.5086	12,157.67	9.40	0.96	4.62
9	0.3371	0.4179	7,976.64	9.40	6.23	5.47
10	0.0300	0.3475	5,233.48	9.40	9.12	6.14
11	0.0005	0.2931	3,433.68	9.40	9.40	6.65
12	0.0000	0.2502	2,252.84	9.40	9.40	7.05
13	0.0000	0.2115	1,478.09	9.40	9.40	7.42
14	0.0000	0.1790	969.77	9.40	9.40	7.72
15	0.0000	0.1598	636.27	9.40	9.40	7.90
16	0.0000	0.1387	417.46	9.40	9.40	8.10
17	0.0000	0.1219	273.89	9.40	9.40	8.26
18	0.0000	0.1100	179.70	9.40	9.40	8.37
19	0.0000	0.0995	117.90	9.40	9.40	8.47
20	0.0000	0.0898	77.36	9.40	9.40	8.56
21	0.0000	0.0804	50.75	9.40	9.40	8.65
22	0.0000	0.0748	33.30	9.40	9.40	8.70
23	0.0000	0.0671	21.85	9.40	9.40	8.77
24	0.0000	0.0617	14.33	9.40	9.40	8.82
25	0.0000	0.0583	9.40	9.40	9.40	8.86
Average	0.2724	0.3259	Totals	216.31	157.39	145.81
Mortality Reduction	0.7276	0.6741			0.7276	0.6741

Summary

The background on testing and studies of WWS show that the estimates of theoretical levels of mortality presented here and in the Impact Assessment likely represent very conservative estimates of entrainment impacts. The use of small slot WWS intakes by the project benefit larval fishes and likely most other planktonic organisms.

As shown in Table 2, there is unlikely to be significant effects due to entrainment of fish eggs, both due to the small 0.5 mm WWS openings and the strong sweeping velocities that will occur in the vicinity of the intakes. To estimate the effects of the reduction in WWS slot opening for other forms of plankton, data on the dimensions of the larvae for several species of crabs that occur in the Humboldt Bay area were collected from a taxonomic reference on larval marine invertebrates (Shanks 2001). The information on the sizes of several species of crustacean in Shanks (2001) indicates that entrainment of the larvae for these species of crustacean would be limited to the earliest zoeal stages for a few of the species (**Table 7**). The data indicate very limited potential for impacts to species of crabs and shrimp that are targeted by commercial and recreational fisheries (i.e., Dungeness, red, and brown crabs, pink ocean shrimp, and spot prawn).

Although most of the species listed in the table are important species for commercial and recreational fisheries, data are also presented for lined shore crab, decorator crab, and Pacific sand crab (**Table 7**). Although the lengths of the early zoeal stages for Pacific sand crab were smaller than other crabs, data presented on the widths of the larval stages for this species were all larger than 0.5 mm indicating that the larvae for this species would not be entrained. Shanks (2001) does not provide width measurements for any of these other species, but the spines, appendages and setae present for these larvae would likely limit entrainment through the openings for the 0.5 mm WWS modules.

Table 7. Information on the lengths (mm) of the larval stages for several species of crustaceans that occur in the Humboldt Bay area (Shanks 2001) (ND indicates no information provided).

Common Names	Species	Stages	Zoea I	Zoea II	Zoea III	Zoea IV	Zoea V	Megalops	Notes
Crabs			measurements in mm						
Dungeness crab	*Metacarcinus magister*	5 zoeal and megalops	2.5	ND	4.0	ND	9.0	5.3 - 6.6	1
slender crab	*Metacarcinus gracilis*	5 zoeal and megalops	1.1	1.5	1.9	2.5	3.3	2.3 - 3.3	2
red crab	*Cancer productus*	5 zoeal and megalops	2.5	3.0	3.5	4.0	5.5	3.4 - 3.6	1
brown crab	*Romaleon antennarius*	5 zoeal and megalops	1.8	2.0	2.3	3.1	4.4	2.3 - 3.3	1
lined shore crab	*Pachygrapsus crassipes*	5 - 7 zoeal stages and megalops	1.0	1.2	1.5	1.8	2.5	4.1	3
graceful decorator crab	*Oregonia gracilis*	2 zoeal and megalops	3.5	5.0				3.3	1
Pacific sand crab	*Emerita analoga*	5 zoeal and megalops	0.7	1.0	1.6	2.4	3.5		4
Shrimp									
pink ocean shrimp	*Pandulus jordani*	11-13 stages, 11 zoeal stages	5.0						1
spot prawn	*Pandulus platyceros*	4 zoeal and megalops	8.1						1

1 – size of zoeal stage I indicates that none of the larvae for this species would be subject to entrainment.

2 – size of zoeal stage I indicates that some of the larvae for this stage may be subject to entrainment but spines and setae would limit entrainment.

3 – size of zoeal stage I and II indicates that some of the larvae for this stage may be subject to entrainment but spines and setae would limit entrainment.

4 – widths of the larval stages provided by Shanks (2001) indicate that none of the larvae for this species are likely to be entrained.

Although the analyses and information provided in this report does not cover the large number of other taxonomic categories of plankton, the APF estimated for larval fishes of 7.8 acres (Table 1) seems appropriate due to the limited impacts to the limited impacts on the taxonomic categories examined and the other physical characteristics of the WWS intake modules which should result in reduced impact to marine organisms.

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Attachment 3

H.T. Harvey Technical Memorandum – Longfin Smelt Larvae

H. T. HARVEY & ASSOCIATES
Ecological Consultants
50 years of field notes, exploration, and excellence

Memorandum

Project No. 4444-10.15.2
2081-2023-053-07

April 3, 2024

To: **Nordic Aquafarms**

From: **Sharon Kramer, Senior Marine Ecologist; Carolyn Belak, Marine Ecologist**

Subject: **Estimated Entrainment of Larval Longfin Smelt for a 0.5 mm Wedgewire Screen at the Humboldt Bay Master Seawater Intakes**

This memo presents the estimated impact of the Humboldt Bay Master Seawater Intake Project (the Project) on longfin smelt (LFS) larvae. A reduction of slot size from 1 mm to a new size of 0.5 mm will result in a significant reduction in the entrainment of LFS. These calculations and adjustments are based on previous studies and models, with special consideration of the Tenera Environmental (2023a) memo initially used to calculate LFS entrainment reductions. It is estimated that a total of 1,961 LFS larvae will be entrained using a 0.5 mm wedgewire screen (WWS).

Project Overview

The seawater intakes are in the Main Channel of Humboldt Bay, between Entrance and Arcata Bays. There is potential for larval organisms to be entrained in the intakes, including larval LFS. While larval LFS may be subject to incidental take, the Project site is not within suitable rearing habitat for those larvae. Previous studies have found higher densities of LFS larvae further upstream in Eureka Slough, in close proximity to low-salinity and brackish LFS rearing habitat (Brennan et al. 2022, Figure 1). The larvae obtained in both years of Brennan's tows were yolk-sac and early post-yolk absorption with an average length of 6.9 mm (range 6.5-8.5 mm; Figure 2), lengths consistent with those found by Tenera Environmental (2023b) near the intakes. Larvae at this size likely have far lower survival in the full-strength seawater based on field and laboratory studies (Yanagitsuru et al. 2022, Tenera Environmental 2023b), thus it is probable that LFS larvae near the intakes have been pushed out from optimal habitat in the upper bay areas as a result of flows, tidal activity, and lack of habitat with larval retention capability.

Tenera Environmental (2023b)'s initial assessment determined that approximately 28,013 LFS larvae per year could be entrained by Project intakes while pumping at their maximum capacity. This number is the result of sampling conducted in 2022 where monthly surveys were performed at 8 locations through Humboldt Bay including locations at both intakes for the project. Seven (7) LFS larvae approximately 14 days post hatch were

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captured from surveys at the intake locations during the months of January and February. The entrainment number has been estimated after extrapolating the seven captured larvae by the maximum daily intake volume and the number of consecutive days until the next sampling event. The estimated annual entrainment of 28,013 LFS larvae is highly conservative as it does not account for entrainment reductions due to the 1 mm (0.04 in) slot openings on the WWS. An initial 43% reduction to the entrainment number was thus calculated based on The Project intakes' 1 mm WWS design. Analysis of the screen design resulted in an estimated take of 15,881 larvae per year (Tenera Environmental 2023a). A further reduction in screen slot size to 0.5 mm will significantly reduce entrainment of larval fish to 1,961 LFS larvae. The present memo uses methods from Tenera Environmental (2023a) to calculate the number of fish entrained with use of 0.5 mm WWS, incorporating reductions due to the physical size of the larvae and information from previous literature on WWS design features.

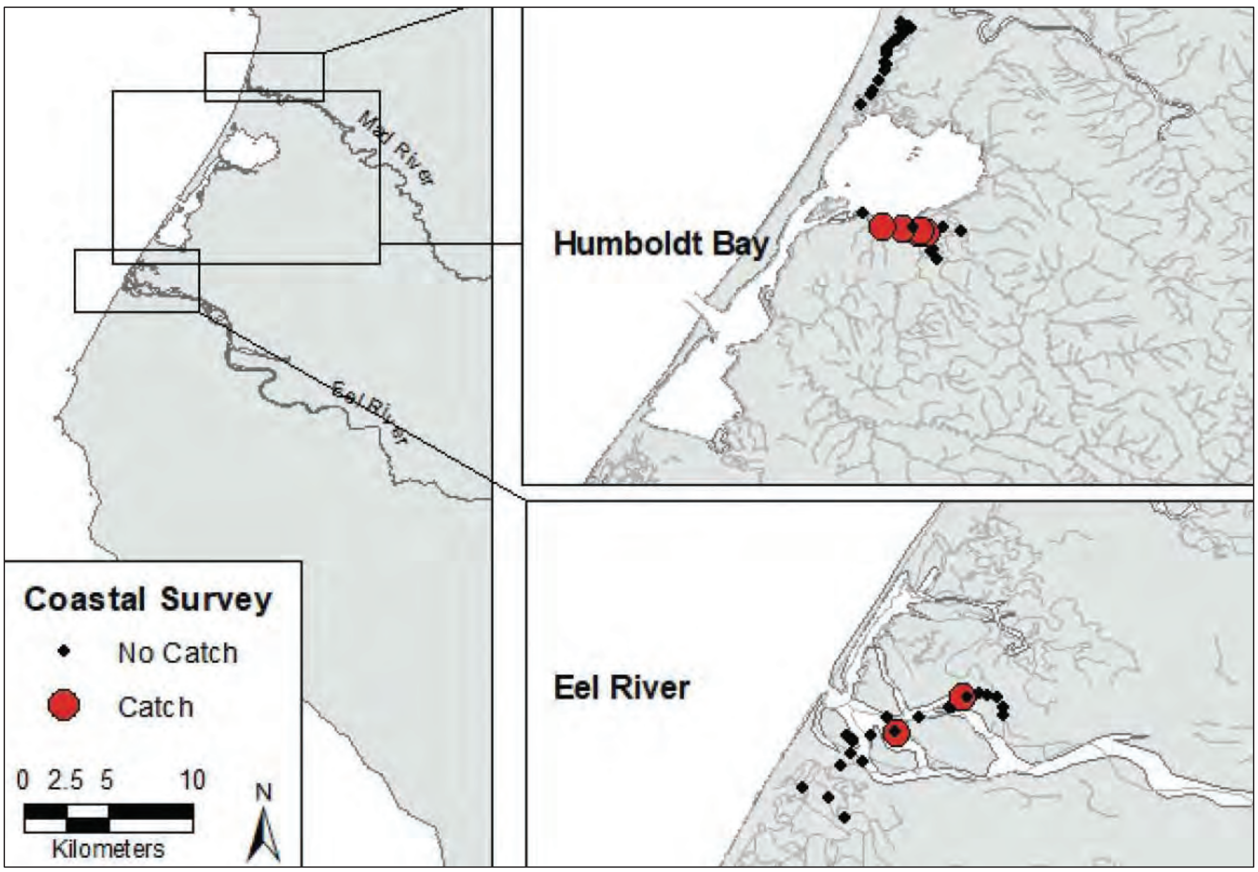

Figure 1. Survey Locations
Notes: Locations are from Brennan et al. (2022). Sampling sites with one or more positive detections are denoted by large red circles, while small black circles denote sampling site with no detections.

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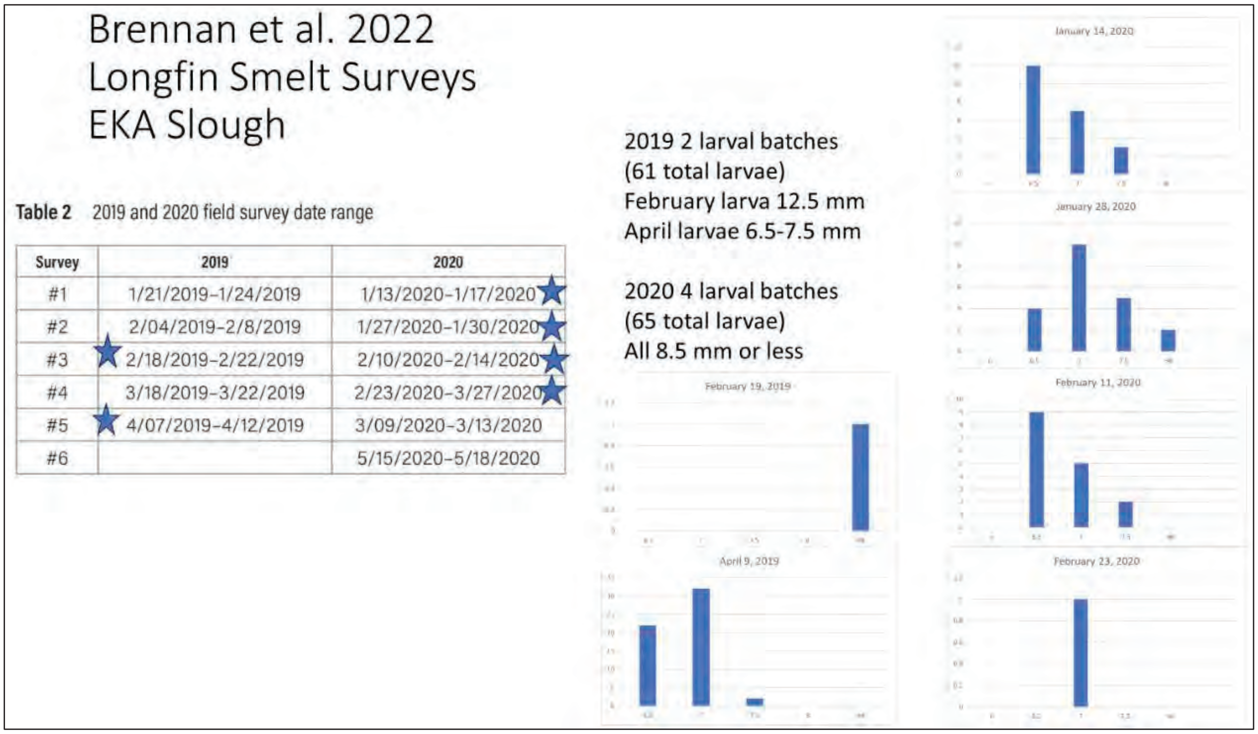

Survey	2019	2020
#1	1/21/2019–1/24/2019	1/13/2020–1/17/2020
#2	2/04/2019–2/8/2019	1/27/2020–1/30/2020
#3	2/18/2019–2/22/2019	2/10/2020–2/14/2020
#4	3/18/2019–3/22/2019	2/23/2020–3/27/2020
#5	4/07/2019–4/12/2019	3/09/2020–3/13/2020
#6		5/15/2020–5/18/2020

Figure 2. Survey Data and Larval Lengths of Longfin Smelt
Notes: Longfin smelt captured by Brennan et al. (2022) from Eureka Slough, 2019 – 2020.

Entrainment Reduction Due to Physical Size of Larvae

Tenera Environmental (2023b) used allometric regression models of the relationships between the notochord length (NL) and head capsule dimensions of seven taxa of larvae to calculate probabilities of entrainment in 1 mm NL bins. Although the sample size of LFS was too small to perform this probability analysis, analyses included data from two closely related species of smelt, whitebait smelt and surf smelt (family Osmeridae). Due to their similar larval morphology, this probability data was then used as proxy to estimate potential entrainment reductions due to 1 mm WWS for LFS. Applying these proxies resulted in a 0.2331 reduction in LFS entrainment (76.69% entrainment) due to larval size alone.

Probability assessments were subsequently conducted for 0.5 mm WWS modules (provided by John Steinbeck, Tenera Environmental; Table 1). The entrainment probabilities for whitebait smelt and surf smelt are based on measurements for 240 and 31 larvae, respectively. Due to the similarity of the larvae for both these species to LFS the final estimate of entrainment mortality reductions was averaged. Following the methodology of Tenera Environmental (2023a), a weighted average was used to account for the differences in sample size for the two species. The estimated average entrainment reduction for LFS larvae due to the use of the 0.5 mm WWS module is thus 0.7263 (27.37% entrainment). Applying this reduction to the annual estimated entrainment of LFS results in a value of 7,667 larvae (i.e. 20,346 fewer LFS larvae entrained from the original estimate of 28,013 outlined in Tenera Environmental 2023b).

Table 1. Data from John Steinbeck, Tenera Environmental

NL Length (mm)	Arrow Goby	Bay Goby	Whitebait Smelt	Pacific Herring	Pacific Tomcod	Surf Smelt	Pacific Staghorn Sculpin
3	1.0000	0.9983			0.9951	0.9993	0.9953
4	1.000	0.9672	0.9997		0.9410	0.9829	0.8256
5	1.000	0.8796	0.9901		0.7905	0.9164	0.4317
6	1.000	0.7580	0.9324	0.9964	0.6140	0.8132	0.1623
7	0.9992	0.6225	0.7941	0.9403	0.4643	0.6896	0.0569
8	0.8983	0.5086	0.6099	0.7304	0.3545	0.5770	0.0198
9	0.3371	0.4179	0.4440	0.4381	0.2709	0.4845	0.0074
10	0.0300	0.3475	0.3108	0.2092	0.2089	0.4107	0.0026
11	0.0005	0.2931	0.2119	0.0903	0.1669	0.3484	0.0014
12	0.0000	0.2502	0.1454	0.0369	0.1306	0.3020	0.0005
13	0.0000	0.2115	0.0970	0.0123	0.1103	0.2584	0.0003
14	0.0000	0.1790	0.0678	0.0047	0.0976	0.2271	0.0001
15	0.0000	0.1598	0.0470	0.0016	0.0889	0.1996	0.0000
16	0.0000	0.1387	0.0317	0.0007	0.0802	0.1779	0.0000
17	0.0000	0.1219	0.0232	0.0002	0.0723	0.1630	0.0000
18	0.0000	0.1100	0.0158	0.0000	0.0671	0.1456	0.0000
19	0.0000	0.0995	0.0115	0.0001	0.0627	0.1289	0.0000
20	0.0000	0.0898	0.0079	0.0000	0.0508	0.1195	0.0000
21	0.0000	0.0804	0.0063	0.0000	0.0544	0.1085	0.0000
22	0.0000	0.0748	0.0048	0.0000	0.0524	0.1014	0.0000
23	0.0000	0.0671	0.0039	0.0000	0.0483	0.0919	0.0000
24	0.0000	0.0617	0.0027	0.0000	0.0459	0.0860	0.0000
25	0.0000	0.0583	0.0021	0.0000	0.0429	0.0810	0.0000
Average	0.2727	0.3259	0.2618	0.1731	0.2530	0.3658	0.1089
Mortality reduction	0.7276	0.6741	**0.7382**	0.8269	0.7470	**0.6342**	0.8911

Notes: Estimated probabilities of entrainment for fish larvae analyzed for the Humboldt Bay entrainment study at mm notochord length (NL) intervals from estimated hatch NL through 25 mm for a wedgewire slot size of 0.5 mm (0.2 in) using estimates of variability around the allometric regressions shown in Tenera Environmental (2023b) Figure 5-1, Figure 6-1, and Figure 6-2. Average proportion entrained of fishes from hatch length to 25 mm, and subsequent mortality reduction (the inverse of average proportion entrained) are also shown. Values for Whitebait Smelt and Surf Smelt, used to calculate LFS entrainment, are in bold.

Head capsule dimensions for LFS captured during the Tenera Environmental (2023b) study were comparable to those modeled for Whitebait Smelt and Surf Smelt, validating the use of these species as proxy for LFS potential entrainment in 0.5 mm WWS slot openings due to larval size (Figures 3-5). Head width for LFS captured near the intake locations varied between 250 – 950 μm (average 530 μm) and head depth ranged from 491 – 812 μm (average 667 μm; Figure 3).

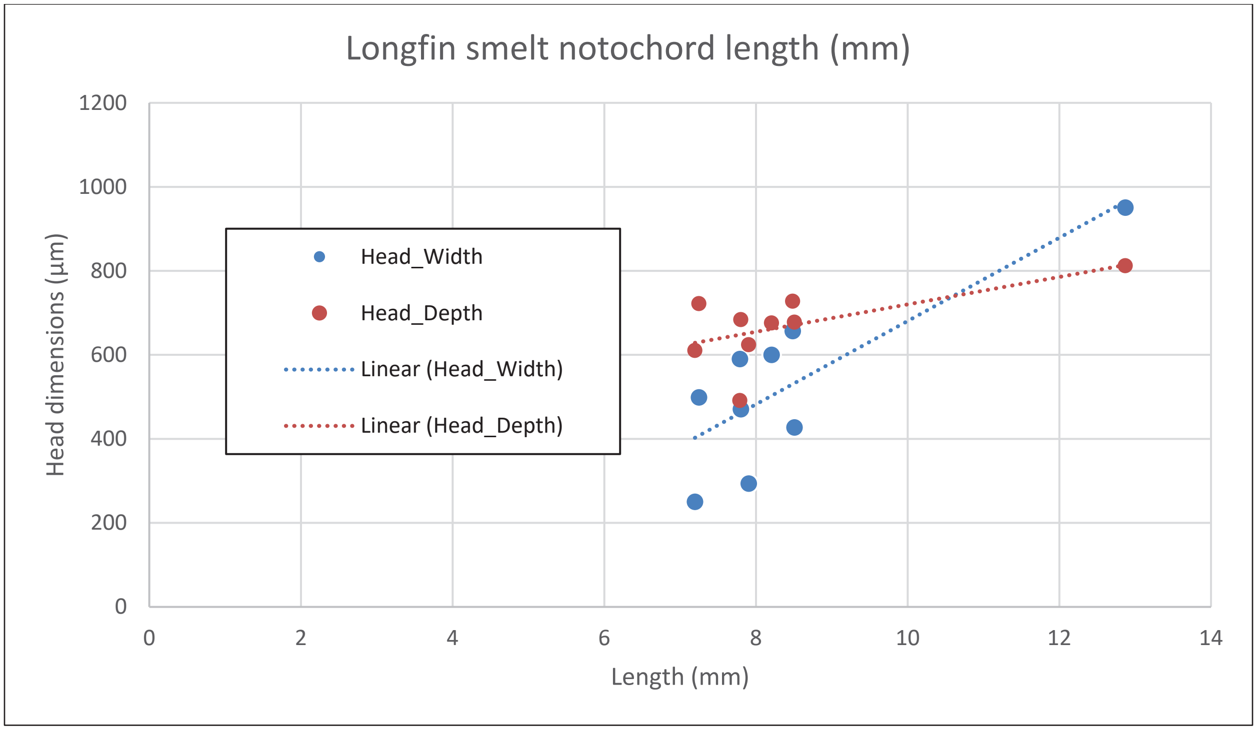

Figure 3. Head Capsule Width and Depth Against Notochord Length for Longfin Smelt Captured Near Proposed Project Intake Locations
Source: Tenera Environmental 2023a.

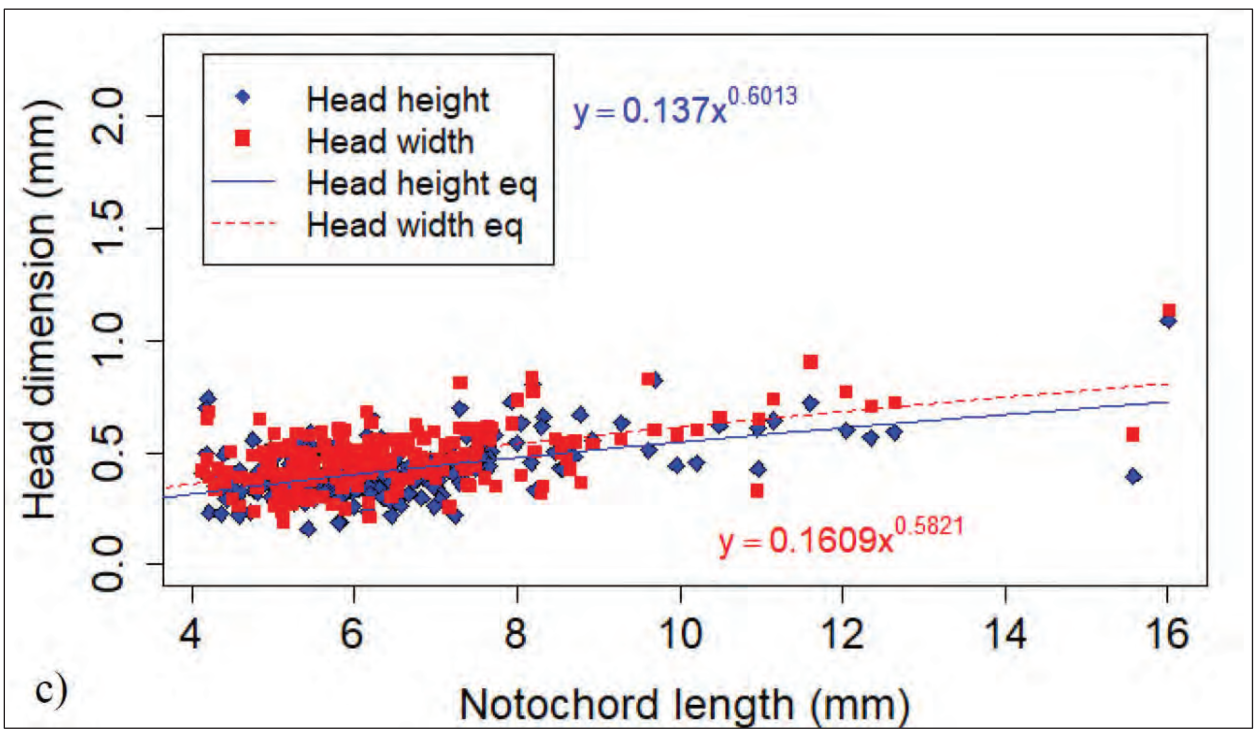

Figure 4. Head Capsule Width and Depth Against Notochord Length for Whitebait Smelt Calculated using Allometric Regression Modeling
Source: Tenera Environmental 2023b.

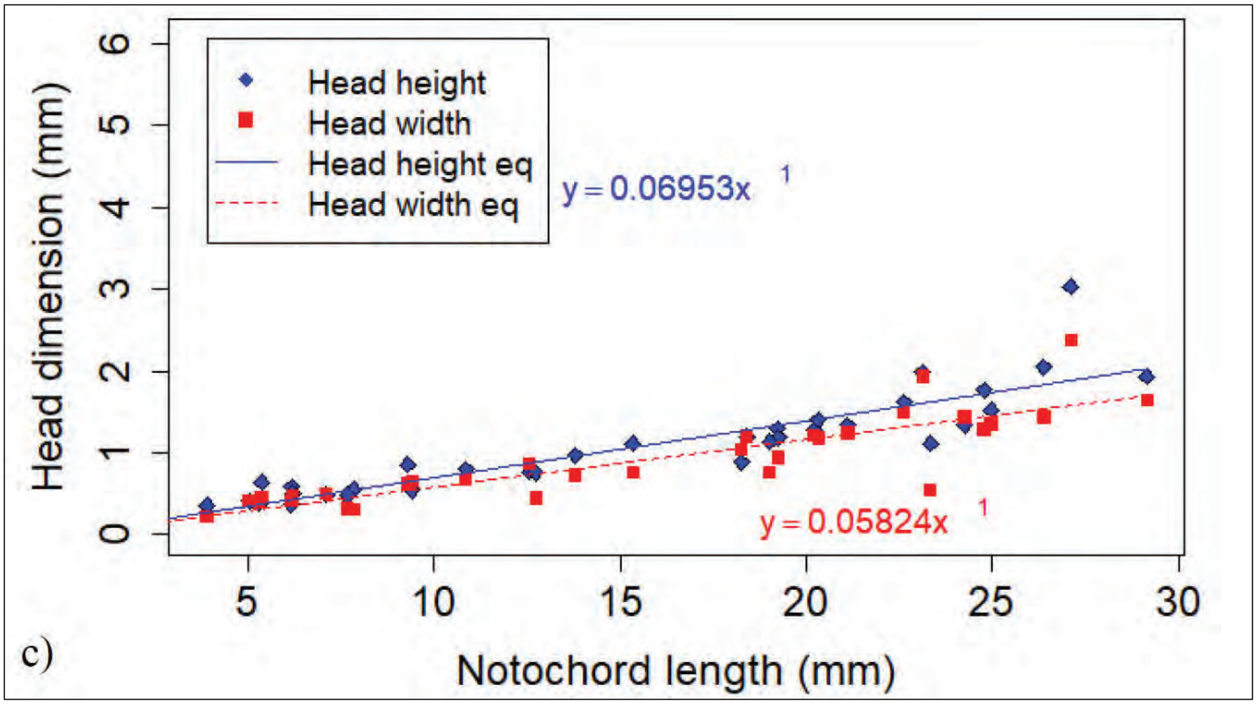

Figure 5. Head Capsule Width and Depth Against Notochord Length for Surf Smelt Calculated using Allometric Regression Modeling
Source: Tenera Environmental 2023b.

Entrainment Reduction Due to WWS Design Properties

Studies on the effectiveness of WWS modules have also shown that apart from small slot openings, modules often exceed the expected levels of entrainment reduction based on other WWS design features. Analyzing the design of cylindrical intake screen systems, Coutant (2021) reviews features such as the cylindrical shape of the intakes, their alignment relative to existing tidal streams, and their low through-screen velocities. Based on his laboratory studies, Coutant (2021) concludes that the contributions of slot opening size and through-screen velocity were minor in the reduction of entrainment. Rather, the cylindrical shape of the intakes and their alignment relative to existing tidal currents have a greater influence of entrainment reduction due to the creation of deflecting bow-wave-like hydraulics and upstream pressure and velocity changes (Coutant 2021). These flow dynamics move larvae and other objects away from the screen surface where they may be subject to entrainment and decrease the likelihood that larvae would be oriented exactly parallel to the screen slots where they could be more easily entrained. Due to the presence of strong tidal currents at the intake locations in Humboldt Bay, entrainment loss estimates solely based on larval size are likely to be highly conservative and these hydrodynamic benefits of the WWS module should be considered.

Electric Power Research Institute (EPRI) (2003) tested the effectiveness of WWS design in a laboratory setting and provides a quantitative metric for incorporating WWS hydrodynamic benefits. EPRI (2003) tested larval fish entrainment and impingement rates under varying WWS slot size, through-slot velocity, and adjacent channel velocity regimes. The test results from the WWS slot opening of 1.0 mm and through-slot velocity of

15 cm/s (0.5 fps) are presented below to provide comparison with the WWS modules being considered for the Humboldt intakes (Table 2). These reduction numbers were previously presented in Tenera Environmental (2023a) to apply entrainment reduction to due WWS design, providing a reduction value (20%) previously agreed upon by California Department of Fish and Wildlife.

Table 2. Percentage Entrainment of Fish Larvae

Fish Species	Average Length and Range (mm)	Channel Velocity 0.08 m/s	Channel Velocity 0.15 m/s	Channel Velocity 0.30 m/s	Average Entrainment (%)
Striped bass	not available	41.40	27.00	16.70	28.37
Winter flounder	mean = 6.1; 2.4 – 11.0	84.60	72.40	61.30	72.77
White sucker	mean = 13.9; 12.5 – 15.5	12.40	8.30	5.80	8.83
Common carp	mean = 6.4; 5.6 – 7.5	94.00	81.90	64.50	80.13
Average		58.10	47.40	37.01	47.53

Notes: Sourced from Electric Power Research Institute (2003). Presented for tests conducted using 1.0 mm wedgewire screens (WWS) and a slot velocity of 15 cm/s (0.5 fps). Percentage entrainment was calculated using the number of larvae injected upstream from the WWS module during each test run and the number collected downstream from the WWS module.

The EPRI (2003) study results can help to estimate the entrainment efficiencies of WWS modules resulting from hydrodynamic design features. Entrainment rates, however, varied across and within fish taxa due to the variation in average larval length and range of lengths seen amongst species (Table 2). Tenera Environmental (2023a) justified using common carp results to estimate LFS entrainment due to their comparable larval size – common carp had a narrow range of lengths that were all less than 8 mm, consistent with the larval LFS lengths found near the intakes (Figure 3). An entrainment reduction of 20% (Table 2) can thus be applied to further reduce LFS larval entrainment due to the hydrodynamic features of the WWS design. The results from EPRI (2003) also supplement the conclusions from Coutant (2021), demonstrating the effects of increased channel or tidal velocities on the effectiveness of the WWS screen modules at reducing entrainment - entrainment decreases with increased ratios of channel velocity to through-slot velocity. This is especially relevant to the Humboldt intakes where strong tidal currents often exceed tested channel velocities and intake through-slot velocity is designed for a maximum of 6 cm/s (0.2 fps), less than half of EPRI's studied values (EPRI 2003). Using this 20% entrainment reduction value thus likely gives a conservative estimate of LFS entrainment.

Adding the estimated effects of the hydrodynamic exclusion features of WWS modules to the estimated average entrainment reduction for the physical size of LFS larvae due to the use of 0.5 mm WWS slot of 0.7263 results in a total reduction of approximately 0.9263, or 93% entrainment reduction. Applying these reductions due to LFS morphology and WWS hydrodynamic efficiency to the annual estimated entrainment of LFS larvae results in an estimate of 1,961 larval LFS potentially entrained at the screens.

On March 27, 2024, the California Department of Fish and Wildlife (CDFW) issued a response to the Humboldt Bay Harbor, Recreation and Conservation District regarding the Determination of Mitigation Area – Incidental Take Permit Application for Humboldt Bay Master Seawater Intakes Project Memorandum. By applying credits based on intake screen design, habitat quality, and productivity, CDFW has agreed to a mitigation equation to calculate the Project's mitigation acreage. Applying the reduction of estimated LFS entrainment due to the 0.5 mm WWS to this accepted equation results in 1,961 larvae (annual entrainment) / 245 larvae per acre (maximum observed density of longfin smelt larvae in Humboldt Bay) = 8.00 acres * 11:1 credit (to account for higher productivity of prey at mitigation site) = 0.73 acres.

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National Marine Fisheries Service: Summary of Endangered Species Act Acoustic Thresholds (Marine Mammals, Fishes, and Sea Turtles)

This document summarizes NMFS acoustic thresholds for marine mammals, protected fishes, and sea turtles. These acoustic thresholds use the best available science at the time which they were developed (see references following each section or threshold table).

Note: NMFS expects to re-evaluate these thresholds in the near future.

SOUND SOURCE CHARACTERIZATION (NMFS 2018)

To determine which threshold is appropriate, NMFS characterizes sound sources as impulsive/non-impulsive (permanent and temporary threshold shifts) and intermittent/continuous (behavioral disturbance):

- Impulsive sound sources: produce sounds that are typically transient, brief (less than one second), broadband, and consist of high peak sound pressure with rapid rise time and rapid decay. Impulsive sounds can occur in repetition (e.g., seismic airguns, impact pile driving) or as a single event (e.g., explosives).

- Non-impulsive sound sources: can be continuous or intermittent, and produce sounds that can be broadband, narrowband or tonal, and brief or prolonged. Non-impulsive sources do not have the high peak sound pressure with rapid rise time typical of impulsive sounds. Examples of non-impulsive sources include drilling, vibratory pile driving, and certain active sonars.

- Continuous sound sources: emit sound with a sound pressure level that remains above ambient sound during the entire observation period. Examples of continuous sound sources include drilling and vibratory pile driving.

- Intermittent sound sources: have interrupted levels of low or no sound or bursts of sound separated by silent periods. Typically, intermittent sounds have a more regular (predictable) pattern of bursts of sounds and silent periods (i.e., duty cycle). Examples of intermittent sound sources include scientific sonar, high-resolution geophysical survey equipment (*i.e.*, sub-bottom profilers), and impact pile driving.

MARINE MAMMALS

Marine Mammal Hearing Groups (NMFS 2018)

The application of marine mammal hearing groups (based on h
First, thresholds are designated by hearing group to acknowlec

EXHIBIT NO. 9
NMFS SUMMARY OF ACOUSTIC THRESHOLDS
CDP APPLICATION NO. 1-21-0653
(Humboldt Bay Harbor District)

have identical hearing or susceptibility to noise-induced hearing loss. Second, marine mammal hearing groups are used to establish marine mammal auditory weighting functions.

Marine Mammal Hearing Groups (NMFS 2018)

Hearing Group	Generalized Hearing Range*
Low-frequency (LF) cetaceans (baleen whales)	7 Hz to 35 kHz
Mid-frequency (MF) cetaceans (dolphins, toothed whales, beaked whales, bottlenose whales)	150 Hz to 160 kHz
High-frequency (HF) cetaceans (true porpoises, *Kogia*, river dolphins, Cephalorhynchid, *Lagenorhynchus cruciger* & *L. australis*)	275 Hz to 160 kHz
Phocid pinnipeds (PW) (underwater) (true seals)	50 Hz to 86 kHz
Otariid pinnipeds (OW) (underwater) (sea lions and fur seals)	60 Hz to 39 kHz

***** Represents the generalized hearing range for the entire group as a composite (i.e., all species within the group), where individual species' hearing ranges are typically not as broad. Generalized hearing range chosen based on ~65 dB threshold from normalized composite audiogram, with the exception for lower limits for LF cetaceans (Southall et al. 2007) and PW pinniped (approximation).

Onset of Permanent Threshold Shift (PTS) (NMFS 2018)

PTS Onset for Impulsive and Non-impulsive Sources (NMFS 2018)

Hearing Group	PTS Onset Acoustic Threshold (Received Level) for Impulsive Sources*	PTS Onset Acoustic Threshold (Received Level) for Non-impulsive Sources*
Low-Frequency (LF) Cetaceans	*Cell 1* $L_{pk,flat}$: 219 dB $L_{E,LF,24h}$: 183 dB	*Cell 2* $L_{E,LF,24h}$: 199 dB
Mid-Frequency (MF) Cetaceans	*Cell 3* $L_{pk,flat}$: 230 dB $L_{E,MF,24h}$: 185 dB	*Cell 4* $L_{E,MF,24h}$: 198 dB
High-Frequency (HF) Cetaceans	*Cell 5* $L_{pk,flat}$: 202 dB $L_{E,HF,24h}$: 155 dB	*Cell 6* $L_{E,HF,24h}$: 173 dB
Phocid Pinnipeds (PW) (Underwater)	*Cell 7* $L_{pk,flat}$: 218 dB $L_{E,PW,24h}$: 185 dB	*Cell 8* $L_{E,PW,24h}$: 201 dB
Otariid Pinnipeds (OW) (Underwater)	*Cell 9* $L_{pk,flat}$: 232 dB $L_{E,OW,24h}$: 203 dB	*Cell 10* $L_{E,OW,24h}$: 219 dB

* Dual metric acoustic thresholds for impulsive sounds: Use whichever results in the largest isopleth for calculating PTS onset. If a non-impulsive sound has the potential of exceeding the peak sound pressure level thresholds associated with impulsive sounds, these thresholds should also be considered.

Note: Peak sound pressure (L_{pk}) has a reference value of 1 μPa, and cumulative sound exposure level (L_E) has a reference value of $1\mu Pa^2s$. In this Table, thresholds are abbreviated to reflect American National Standards Institute standards (ANSI 2013). However, peak sound pressure is defined by ANSI as incorporating frequency weighting, which is not the intent for this Technical Guidance. Hence, the subscript "flat" is being included to indicate peak sound pressure should be flat weighted or unweighted within the generalized hearing range. The subscript associated with cumulative sound exposure level thresholds indicates the designated marine mammal auditory weighting function (LF, MF, and HF cetaceans, and PW and OW pinnipeds) and that the recommended accumulation period is 24 hours. The cumulative sound exposure level thresholds could be exceeded in a multitude of ways (i.e., varying exposure levels and durations, duty cycle). When possible, it is valuable for action proponents to indicate the conditions under which these acoustic thresholds will be exceeded.

Onset of Temporary Threshold Shift (TTS) (NMFS 2018)

TTS Onset for Impulsive and Non-impulsive Sources (NMFS 2018)

Hearing Group	TTS Onset Acoustic Thresholds (Received Level) for Impulsive Sources*	TTS Onset Acoustic Thresholds (Received Level) for Non-impulsive Sources*
Low-Frequency (LF) Cetaceans	*Cell 1* $L_{pk,flat}$: 213 dB $L_{E,LF,24h}$: 168 dB	*Cell 2* $L_{E,LF,24h}$: 179 dB
Mid-Frequency (MF) Cetaceans	*Cell 3* $L_{pk,flat}$: 224 dB $L_{E,MF,24h}$: 170 dB	*Cell 4* $L_{E,MF,24h}$: 178 dB
High-Frequency (HF) Cetaceans	*Cell 5* $L_{pk,flat}$: 196 dB $L_{E,HF,24h}$: 140 dB	*Cell 6* $L_{E,HF,24h}$: 153 dB
Phocid Pinnipeds (PW) (Underwater)	*Cell 7* $L_{pk,flat}$: 212 dB $L_{E,PW,24h}$: 170 dB	*Cell 8* $L_{E,PW,24h}$: 181 dB
Otariid Pinnipeds (OW) (Underwater)	*Cell 9* $L_{pk,flat}$: 226 dB $L_{E,OW,24h}$: 188 dB	*Cell 10* $L_{E,OW,24h}$: 199 dB

* Dual metric acoustic thresholds for impulsive sounds: Use whichever results in the largest isopleth for calculating TTS onset. If a non-impulsive sound has the potential of exceeding the peak sound pressure level thresholds associated with impulsive sounds, these thresholds should also be considered.

Note: Peak sound pressure (L_{pk}) has a reference value of 1 μPa, and cumulative sound exposure level (L_E) has a reference value of $1\mu Pa^2s$. In this Table, thresholds are abbreviated to reflect American National Standards Institute standards (ANSI 2013). However, peak sound pressure is defined by ANSI as incorporating frequency weighting, which is not the intent for this Technical Guidance. Hence, the subscript "flat" is being included to indicate peak sound pressure should be flat weighted or unweighted within the generalized hearing range. The subscript associated with cumulative sound exposure level thresholds indicates the designated marine mammal auditory weighting function (LF, MF, and HF cetaceans, and PW and OW pinnipeds) and that the recommended accumulation period is 24 hours. The cumulative sound exposure level thresholds could be exceeded in a multitude of ways (i.e., varying exposure levels and durations, duty cycle). When possible, it is valuable for action proponents to indicate the conditions under which these acoustic thresholds will be exceeded.

Onset of Behavioral Disturbance

NMFS acoustic thresholds for the onset of behavioral disturbance (underwater and in-air) are determined by the root-mean-square (RMS) received levels.

Underwater Onset of Behavioral Disturbance Acoustic Thresholds (NMFS 2005)

Source type	Threshold (RMS)
Continuous	120 dB re 1 μPa
Non-explosive impulsive or intermittent	160 dB re 1 μPa

In-Air Onset of Behavioral Disturbance Acoustic Thresholds (Southall et al. 2007; NOAA 2009)

Species/Group	Threshold (RMS)*
Harbor seal	90 dB re 20 μPa
All other pinnipeds	100 dB re 20 μPa

*Recent Navy activities involving airborne sources have relied upon a cumulative sound exposure level threshold of 100 dB re 20 μPa (DoN 2017). NMFS is currently in the process of re-evaluating the Navy's threshold.

Note: Sound levels underwater (re: 1 μPa) have a different reference pressure compared to in-air sounds (re: 20 μPa). Thus, it is not appropriate to compare sound levels in-air to those underwater.

Underwater Explosives

NMFS uses the acoustic and pressure thresholds below to predict the onset of PTS, TTS, behavioral disturbance, tissue damage (i.e., lung and g.i. tract), and mortality from the use of underwater explosives.

Note: For a single detonation (within a 24-h period), NMFS relies on the TTS onset threshold. For multiple detonations (within a 24-h period), NMFS relies on a behavioral thresholds that is -5 dB from TTS onset (see Table below).

PTS Onset, TTS Onset, and Behavioral Disturbance Onset (Multiple Detonations) for Underwater Explosives (NMFS 2018)

Hearing Group	PTS Impulsive Thresholds	TTS Impulsive Thresholds	Behavioral Threshold (multiple detonations)
Low-Frequency (LF) Cetaceans	*Cell 1* $L_{pk,flat}$: 219 dB $L_{E,LF,24h}$: 183 dB	*Cell 2* $L_{pk,flat}$: 213 dB $L_{E,LF,24h}$: 168 dB	*Cell 3* $L_{E,LF,24h}$: 163 dB
Mid-Frequency (MF) Cetaceans	*Cell 4* $L_{pk,flat}$: 230 dB $L_{E,MF,24h}$: 185 dB	*Cell 5* $L_{pk,flat}$: 224 dB $L_{E,MF,24h}$: 170 dB	*Cell 6* $L_{E,MF,24h}$: 165 dB
High-Frequency (HF) Cetaceans	*Cell 7* $L_{pk,flat}$: 202 dB $L_{E,HF,24h}$: 155 dB	*Cell 8* $L_{pk,flat}$: 196 dB $L_{E,HF,24h}$: 140 dB	*Cell 9* $L_{E,HF,24h}$: 135 dB
Phocid Pinnipeds (PW) (Underwater)	*Cell 10* $L_{pk,flat}$: 218 dB $L_{E,PW,24h}$: 185 dB	*Cell 11* $L_{pk,flat}$: 212 dB $L_{E,PW,24h}$: 170 dB	*Cell 12* $L_{E,PW,24h}$: 165 dB
Otariid Pinnipeds (OW) (Underwater)	*Cell 13* $L_{pk,flat}$: 232 dB $L_{E,OW,24h}$: 203 dB	*Cell 14* $L_{pk,flat}$: 226 dB $L_{E,OW,24h}$: 188 dB	*Cell 15* $L_{E,OW,24h}$: 183 dB

* Dual metric acoustic thresholds for impulsive sounds: Use whichever results in the largest isopleth for calculating PTS/TTS onset.

Note: Peak sound pressure (L_{pk}) has a reference value of 1 μPa, and cumulative sound exposure level (L_E) has a reference value of 1μPa²s. In this Table, thresholds are abbreviated to reflect American National Standards Institute standards (ANSI 2013). However, peak sound pressure is defined by ANSI as incorporating frequency weighting, which is not the intent for this Technical Guidance. Hence, the subscript "flat" is being included to indicate peak sound pressure should be flat weighted or unweighted within the generalized hearing range. The subscript associated with cumulative sound exposure level thresholds indicates the designated marine mammal auditory weighting function (LF, MF, and HF cetaceans, and PW and OW pinnipeds) and that the recommended accumulation period is 24 hours. The cumulative sound exposure level thresholds could be exceeded in a multitude of ways (i.e., varying exposure levels and durations, duty cycle). When possible, it is valuable for action proponents to indicate the conditions under which these acoustic thresholds will be exceeded.

Lung and G.I. Tract Injury Thresholds (DoN 2017)

Hearing Group	Mortality (Severe lung injury)*	Slight Lung Injury*	G.I. Tract Injury
All Marine Mammals	*Cell 1* Modified Goertner model; Equation 1	*Cell 2* Modified Goertner model; Equation 2	*Cell 3* $L_{pk,0\text{-}pk,flat}$: 237 dB

Modified Goertner Equations for severe and slight lung injury (pascal-second)

Equation 1: $103M^{1/3}(1 + D/10.1)^{1/6}$ **Pa-s**

Equation 2: $47.5M^{1/3}(1 + D/10.1)^{1/6}$ **Pa-s**

M **= animal (adult and/or juvenile) mass (kg) (Table C.9 in DoN 2017)**

D **= animal depth (meters)**

* Lung injury (severe and slight) thresholds are dependent on animal mass (Recommendation: Table C.9 from DoN 2017 based on calf/pup mass by species).

Note: Peak sound pressure (L_{pk}) has a reference value of 1 μPa. In this Table, thresholds are abbreviated to reflect American National Standards Institute standards (ANSI 2013). However, ANSI defines peak sound pressure as incorporating frequency weighting, which is not the intent for this Technical Guidance. Hence, the subscript "flat" is being included to indicate peak sound pressure should be flat weighted or unweighted within the overall marine mammal generalized hearing range.

FISHES

Below are the protected fish acoustic thresholds. Note that NMFS' acoustic thresholds for fishes are for all species of fish and do not distinguish between fishes of different groups (e.g., elasmobranchs or teleosts).

Onset of Physical Injury

Because of limited data, the FHWG relied on data from a variety of surrogate impulsive sources (i.e., explosives: Govoni et al. 2003; Govoni et al. 2007; Hastings et al. 2007; Yelverton et al. 1975; seismic airguns: Popper et al. 2005; Song et al. 2008; See Stadler and Woodbury 2009 for more information) to derive dual interim thresholds for impact pile driving that account for vulnerability depending on fish size. These thresholds are appropriate for other non-explosive impulsive sources.

Onset of Physical Injury[1] for Impulsive Sources for Fishes (FHWG 2008)

	Onset of Physical Injury (Received Level)
Fish Size	**Impulsive**
Fishes ≥ 2 g	*Cell 1* $L_{p,0\text{-pk,flat}}$: 206 dB $L_{E,p,,12h}$: 187 dB
Fishes < 2 g	*Cell 2* $L_{p,0\text{-pk,flat}}$: 206 dB $L_{E,p,12h}$: 183 dB

Onset of Mortality and Physical Injury for Underwater Explosives for Fishes (FHWG 2008; Popper et al. 2014)

Onset of Mortality (Received Level)	Onset of Physical Injury (Received Level)
Cell 1 $L_{p,0\text{-pk,flat}}$: 229 dB	*Cell 2* $L_{p,0\text{-pk,flat}}$: 206 dB $L_{E,p,,12h}$: 187 dB (≥ 2 g) $L_{E,p,,12h}$: 183 dB (< 2 g)

Onset of Behavioral Disturbance

While this is not a “formal” threshold, it allows us to have a level where one can begin to look at potential responses.

[1] For fishes, generally, the accumulation period can be reset to zero after a 12-h period of no pile driving, especially in a river or tidally-influenced waterway when the fish should be moving. Note: The accumulation period for marine mammals and sea turtles is 24-h. Furthermore, NMFS does not have physical injury thresholds for non-impulsive sources, except tactical sonar.

For fishes, the SELcum metric also incorporated effective quiet, which means if the received SEL from an individual pile strike is below a certain level (150 dB SELss), then the accumulated energy from multiple strikes would not contribute to injury, regardless of how many pile strikes occur. Effective quiet establishes a limit on the maximum distance from the pile where injury is expected. Beyond this distance no physical injury is expected, regardless of the number of pile strikes. There is currently not enough data to support an effective quiet level for other taxa.

Behavioral Disturbance Acoustic Thresholds for Fishes[2]

Source Type	Threshold
All Sources	L_{RMS} 150 dB

SEA TURTLES

Onset of Permanent Threshold Shift (PTS)

Onset of Permanent Threshold Shift (PTS) for Sea Turtles (DoN 2017)

Hearing Group	PTS Onset Thresholds (Received Level) for Impulsive Sources*	PTS Onset Thresholds (Received Level) for Non-impulsive Sources*
Sea Turtles	*Cell 1* $L_{p,0\text{-pk,flat}}$: 232 dB $L_{E,p,\text{ TU,24h}}$: 204 dB	*Cell 2* $L_{E,p,\text{ TU,24h}}$: 220 dB

* Dual metric thresholds for impulsive sounds: Use whichever results in the largest isopleth for calculating PTS onset. If a non-impulsive sound has the potential of exceeding the peak sound pressure level thresholds associated with impulsive sounds, these thresholds are recommended for consideration.

Note: Peak sound pressure level ($L_{p,0\text{-pk}}$) has a reference value of 1 µPa, and weighted cumulative sound exposure level ($L_{E,p}$) has a reference value of 1µPa²s. In this Table, thresholds are abbreviated to be more reflective of International Organization for Standardization standards (ISO 2017). The subscript "flat" is being included to indicate peak sound pressure are flat weighted or unweighted within the generalized hearing range of sea turtles (i.e., below 2 kHz). The subscript associated with cumulative sound exposure level thresholds indicates the designated sea turtle weighting function and that the recommended accumulation period is 24 hours. The weighted cumulative sound exposure level thresholds could be exceeded in a multitude of ways (i.e., varying exposure levels and durations, duty cycle). When possible, it is valuable for action proponents to indicate the conditions under which these thresholds will be exceeded.

Onset of Temporary Threshold Shift (TTS)

Onset of Temporary Threshold Shift (TTS) for Sea Turtles (DoN 2017)

Hearing Group	TTS Onset Thresholds (Received Level) for Impulsive Sources*	TTS Onset Thresholds (Received Level) for Non-impulsive Sources*
Sea Turtles	*Cell 1* $L_{p,0\text{-pk,flat}}$: 226 dB $L_{E,p,\text{ TU,24h}}$: 189 dB	*Cell 2* $L_{E,p,\text{ TU,24h}}$: 200 dB

[2] Note: The derivation and origin of the informal 150 dB threshold is not as well-defined as other thresholds. However, various recent publications do not refute that behavioral disturbance can occur around this level. As one example study, Hawkins et al. 2014 present their data in peak-to-peak sound pressure level and single strike SEL. However, in general, RMS levels for impact pile driving are approximately 10 dB higher than single strike SEL levels. Based on this conversion, the 50% RMS response level, from this study, for sprat and mackerel, range from 145 to 152 dB.

Note: Popper et al. 2019 advocate that the peak-to-peak metric is more appropriate for impulsive sounds compared to the RMS metric. However, pile driving data are not typically reported in this metric.

* Dual metric thresholds for impulsive sounds: Use whichever results in the largest isopleth for calculating PTS onset. If a non-impulsive sound has the potential of exceeding the peak sound pressure level thresholds associated with impulsive sounds, these thresholds are recommended for consideration.

Note: Peak sound pressure level ($L_{p,0\text{-pk}}$) has a reference value of 1 μPa, and weighted cumulative sound exposure level ($L_{E,p}$) has a reference value of 1μPa²s. In this Table, thresholds are abbreviated to be more reflective of International Organization for Standardization standards (ISO 2017). The subscript "flat" is being included to indicate peak sound pressure are flat weighted or unweighted within the generalized hearing range of sea turtles (i.e., below 2 kHz). The subscript associated with cumulative sound exposure level thresholds indicates the designated sea turtle weighting function and that the recommended accumulation period is 24 hours. The weighted cumulative sound exposure level thresholds could be exceeded in a multitude of ways (i.e., varying exposure levels and durations, duty cycle). When possible, it is valuable for action proponents to indicate the conditions under which these thresholds will be exceeded.

Onset of Behavioral Disturbance

Data on behavioral reactions of sea turtles to sound sources is limited. However, in general, behavioral disturbance occurs around RMS 175 dB (O'Hara and Wilcox 1990; Moein et al. 1994; Lenhardt 2002; McCauley et al. 2002).

Onset of Behavioral Disturbance Acoustic Thresholds for Sea Turtles (DoN 2017)

Source Type	Threshold
All Sources*	L_{RMS} 175 dB

* Currently, there are not enough data to derive separate thresholds for different source types.

Note: This threshold is also used for multiple detonations.

Underwater Explosives

For a single detonation (within a 24-h period), NMFS relies on the TTS onset threshold. For multiple detonations (within a 24-h period), NMFS relies on a behavioral thresholds that is -5 dB from TTS onset (see Table below).

Lung and G.I. Tract Injury Thresholds for Sea Turtles (DoN 2017)

Hearing Group	Mortality (Severe lung injury)*	Slight Lung Injury*	G.I. Tract Injury
All Sea Turtles	*Cell 1* Modified Goertner model; Equation 1	*Cell 2* Modified Goertner model; Equation 2	*Cell 3* $L_{pk,flat}$: 237 dB

Modified Goertner Equations for severe and slight lung injury (pascal-second)

Equation 1: $103M^{1/3}(1 + D/10.1)^{1/6}$ **Pa-s**

Equation 2: $47.5M^{1/3}(1 + D/10.1)^{1/6}$ **Pa-s**

M **= animal (adult and/or juvenile) mass (kg) (Table C.9 in DoN 2017)**

D **= animal depth (meters)**

* Lung injury (severe and slight) thresholds are dependent on animal mass (Recommendation: Table C.9 from DON 2017 based on adult and/or calf/pup mass by species).

Note: Peak sound pressure (L_{pk}) has a reference value of 1 μPa. In this Table, thresholds are abbreviated to reflect American National Standards Institute standards (ANSI 2013). However, ANSI defines peak sound pressure as incorporating frequency weighting, which is not the intent for this Technical Guidance. Hence, the subscript "flat" is being included to indicate peak sound pressure should be flat weighted or unweighted within the overall marine mammal generalized hearing range.

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TENERA Environmental

TECHNICAL MEMORANDUM

December 8, 2023

To: Rob Holmlund, Humboldt Bay Harbor, Recreation, and Conservation District

From: John Steinbeck, Tenera Environmental

Subject: APF Estimates for Humboldt Bay Intake Assessment Adjusted for Entrainment Reductions from 1mm Wedgewire Screen Intake

Attachments: Technical Memorandum dated October 2, 2023 to CDFW on adjustments to Longfin Smelt entrainment estimates

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This technical memorandum provides adjustments to the APF estimates provided in a technical memorandum dated December 7, 2023. The December 7, 2023 technical memorandum provided corrected estimates of APF that were provided in an earlier technical memorandum. All of the documents were issued as addendums to the final draft of the Intake Assessment of the Potential Effects on Ichthyoplankton and other Meroplankton Due to Entrainment at Proposed Samoa Peninsula Water Intakes (Intake Assessment) dated May 1, 2023.

This technical memorandum provides adjustments to the APF estimates provided in the December 7, 2023 based on the estimated reductions in entrainment resulting from the use of wedgewire screen (WWS) modules at the intakes with slot openings widths of 1 mm (0.04 in.). A separate technical memorandum, dated October 2, 2023, was submitted to staff at the California Department of Fish and Wildlife (CDFW) that provided estimates of the entrainment reduction to Longfin Smelt (LFS) larvae due to the WWS intakes (attached). The information in the technical memorandum estimated that the use of the 1 mm (0.04 in.) WWS modules would result in a total reduction in entrainment of LFS larvae of approximately 43%. This estimate is likely to be conservative since the estimate does not include any of the hydrodynamic exclusion mechanisms of the WWS modules. CDFW agreed to use to adjusted entrainment estimate in calculating the annual level of allowable entrainment in the Incidental Take Permit for LFS for the project.

The estimated entrainment reductions provided in this document are based directly on the larval measurements of notochord lengths and head capsule dimensions provided in the Intake Assessment. These estimates were provided in **Table 6-1** in the report which is copied below. The proportional mortality or entrainment reduction for each taxa of larvae varied and ranged from 0.2128 (21.3%) to 0.7217 (72.2%) due to differences in head capsule dimensions and lengths of the larvae collected for each taxon. While the average of the entrainment reductions for the seven taxa was 36.4%, the actual reduction in the average APF was 32.6% since the reductions were applied to each taxa individually.

The entrainment reductions were applied to the APF estimate[...] resulting APF values were used to calculate new total estimat[...] and 95th percentiles of a cumulative probability curve based c[...]

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ENTRAINMENT STUDY & RELATED MEMOS
CDP APPLICATION NO. 1-21-0653
(Humboldt Bay Harbor District)

APF estimates are normally distributed (**Table 1**). The average APF is equal to the value at the 50th percentile and is interpreted as having a 50% chance of providing adequate acreage to fully compensate for the estimated losses due to entrainment. The Desalination Amendment requires that the APF be calculated using the 95th percentile to help ensure that the mitigation fully compensates for entrainment losses. The adjusted values in Table 1 show that the APF estimate at the 95th percentile was 20.5 acres (8.3 hectares) and is the value that should be used in calculating appropriate mitigation for the effects due to entrainment from the project.

May 2023 Intake Assessment Report Table Error! No text of specified style in document.**-1**. Estimated probabilities of entrainment for fish larvae analyzed for the Humboldt Bay entrainment study at mm NL intervals from estimated hatch NL through 25 mm for a wedgewire slot size of 0.04 in. (1 mm) using estimates of variability around the allometric regressions shown in Figures 5-1, 6-1, and 6-2 in the May 2023 Intake Assessment. Average proportion entrained of fishes from hatch length to 25 mm, and subsequent mortality reduction (the inverse of average proportion entrained) are also shown.

NL Length (mm)	Arrow Goby	Bay Goby	Whitebait Smelt	Pacific Herring	Pacific Tomcod	Surf Smelt	Pacific Staghorn Sculpin
3	1.0000	1.0000			1.0000		
4	1.0000	1.0000			1.0000	1.0000	1.0000
5	1.0000	1.0000	1.0000		0.9999	0.9997	0.9996
6	1.0000	0.9999	1.0000	1.0000	0.9985	0.9967	0.9888
7	1.0000	0.9994	1.0000	1.0000	0.9918	0.9866	0.9320
8	1.0000	0.9975	1.0000	1.0000	0.9757	0.9658	0.8017
9	1.0000	0.9933	1.0000	1.0000	0.9492	0.9320	0.6334
10	1.0000	0.9854	0.9998	1.0000	0.9095	0.8823	0.4387
11	1.0000	0.9718	0.9995	0.9988	0.8666	0.8333	0.3002
12	1.0000	0.9576	0.9976	0.9916	0.8186	0.7769	0.2025
13	1.0000	0.9364	0.9936	0.9662	0.7672	0.7217	0.1316
14	1.0000	0.9160	0.9861	0.9149	0.7176	0.6757	0.0848
15	0.9999	0.8891	0.9730	0.8257	0.6676	0.6239	0.0571
16	0.9984	0.8662	0.9540	0.7107	0.6213	0.5757	0.0363
17	0.9837	0.8365	0.9299	0.5843	0.5803	0.5321	0.0241
18	0.9109	0.8110	0.8990	0.4575	0.5376	0.4952	0.0154
19	0.7588	0.7854	0.8644	0.3432	0.5007	0.4602	0.0112
20	0.5140	0.7574	0.8282	0.2439	0.4655	0.4247	0.0072
21	0.2911	0.7298	0.7835	0.1732	0.4325	0.3985	0.0048
22	0.1313	0.7051	0.7393	0.1236	0.4080	0.3731	0.0034
23	0.0486	0.6773	0.6949	0.0804	0.3955	0.3443	0.0025
24	0.0164	0.6559	0.6494	0.0548	0.3755	0.3236	0.0019
25	0.0047	0.6337	0.6006	0.0363	0.3610	0.3030	0.0012
Average	0.7357	0.8377	0.7872	0.5210	0.6808	0.6094	0.2783
Mortality Reduction	0.2643	0.1623	0.2128	0.4790	0.3192	0.3906	0.7217

Table 1. ETM estimates of proportional mortality (P_M), unadjusted estimates of Area of Production Foregone (APF), estimated entrainment reductions due to 1mm WWS intake screen modules, and APF estimates adjusted for reductions in entrainment for seven taxa analyzed Humboldt Bay May 2023 Intake Assessment. Entrainment reductions were calculated from data presented in Table 6-1 of the Intake Assessment (shown above).

Taxa	Combined P_M Estimates for both	Unadjusted APF Estimate (acres [hectares])	Estimated 1mm Screen Entrainment Reduction (%)	APF Adjusted for 1mm Screen Entrainment Reduction (acres [hectares])
Arrow Goby	0.3757	56.7 (22.9)	26.4	41.7 (16.9)
Bay Goby	0.1166	17.6 (7.1)	16.2	14.7 (6.0)
Whitebait Smelt	0.0464	7.0 (2.8)	21.3	5.5 (2.2)
Pacific Herring	0.0308	4.7 (1.9)	47.9	2.4 (1.0)
Pacific Tomcod	0.0842	12.7 (5.1)	31.9	8.6 (3.5)
Surf Smelt	0.0783	11.8 (4.8)	39.1	7.2 (2.9)
Pacific Staghorn Sculpin	0.0960	14.5 (5.9)	72.2	4.0 (1.6)
Averages	0.1183	17.9 (7.2)	**36.4**	12.0 (4.9)
APF values at 50% percentile		17.9 (7.2)		12.0 (4.9)
APF values at 95% percentile		28.8 (11.7)		20.5 (8.3)

TECHNICAL MEMORANDUM

October 2, 2023

To: Rob Holmlund, Humboldt Bay Harbor, Recreation, and Conservation District

From: John Steinbeck, Tenera Environmental

Subject: Addendum with Proposed Adjustments to Longfin Smelt Entrainment Estimates for the 2023 Humboldt Bay Intake Assessment

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This technical memorandum is an addendum to the Intake Assessment of the Potential Effects on Ichthyoplankton and other Meroplankton due to entrainment at Proposed Samoa Peninsula Water Intakes (Intake Assessment) dated May 1, 2023. This memo proposes adjustments to the final estimates of entrainment for Longfin Smelt (LFS). The adjustments will be based on the physical sizes of the larvae relative to the 1 mm (0.04 in.) slot opening and on information from the technical and scientific literature that is used to estimate the entrainment reduction due to the cylindrical shape of the intakes, their alignment relative to existing tidal or river currents, and their low through-screen velocities. Applying reductions due to LFS morphology and WWS slot size and hydrodynamic efficiency to the annual estimated entrainment of LFS larvae results in a value of 15,881 larvae.

Introduction

Seven LFS larvae were collected at the two intake stations, and two larvae from stations SW2 and SW3. The average notochord length (NL) of the seven larvae from the intake stations was 8.5 mm (0.33 in.). It is unlikely that under normal conditions larvae close to the estimated hatch NL of 5.6 mm (0.22 in.) would occur in close proximity of the intakes where they would be subject to entrainment. LFS spawning occurs in low salinity areas upstream from Humboldt Bay. The estimated age of 17.7 d for the larvae collected at the intake locations (Intake Assessment Section 5.2), is indicative of larvae that have been transported out of spawning areas that flow into the bay.

The estimated annual entrainment of 28,013 LFS larvae and ETM estimates for other taxa in the Intake Assessment are highly conservative as they do not account for entrainment reductions due to the 1 mm (0.04 in.) slot openings on the wedgewire screen (WWS). Also the entrainment and ETM estimates do not consider the other benefits of the WWS modules that will be used at the intakes such as the cylindrical shape of the intakes, their alignment relative to existing tidal or river currents, and their low through-screen velocities. The benefits discussed in the Intake Assessment (Section 6.2) are largely based on a recent paper by Coutant (2020). Coutant provides detailed discussions of how entrainment is reduced by using WWS, but he does not provide data that could be used to estimate the percent reductions due to these design features.

This technical memorandum provides information that will be used to develop proposed adjustments to the entrainment estimates for LFS larvae provided in the Intake Assessment. The adjustments will be based on 1) the physical sizes of the larvae relative to the 1 mm (0.04 in.) slot opening and 2) information from technical and scientific literature that is used to estimate the entrainment reduction due to other design aspects of the WWS modules, including fluid dynamics surrounding the screens.

Entrainment Reduction Due to WWS 1 mm Slot Opening

The probability that larvae at each 1 mm (0.04 in.) NL increment would be entrained were calculated for the seven larval fishes that were most abundant in the samples from the two intake stations. These calculations were based on allometric regression models of the relationships of the NL and head capsule dimensions (width and depth) of the larvae (Intake Assessment Section and Table 6.1). The probability analysis was not conducted for LFS larvae due to the small number of larvae collected during the study. The analysis does include data from two other species of smelt (Whitebait Smelt and Surf Smelt) that are related to LFS (family Osmeridae). Molecular and morphological analyses show that Whitebait Smelt and LFS are sister taxa (McAllister 1963, Wilson and Williams 1991, Ilves and Taylor 2009). Morphologically, the larvae for these three species, and especially Whitebait Smelt and LFS, are very similar. Therefore, the entrainment probabilities calculated for these two species will be used to estimate the potential entrainment reductions due to 1 mm (0.04 in.) WWS for LFS based on larval morphology.

The entrainment probabilities for Whitebait Smelt and Surf Smelt are based on measurements for 240 and 31 larvae, respectively. Due to the similarity of the larvae for both these species to LFS the final estimate of entrainment mortality reductions was averaged (Table 6-1). A weighted average was used to account for the differences in sample size for the two species. The estimated average entrainment reduction for LFS larvae due to the use of the 1 mm (0.04 in.) WWS module is 0.2331. Applying this reduction to the annual estimated entrainment of LFS larvae results in a value of 21,483 larvae (e.g., 6,530 fewer LFS larvae lost from the original estimate outlined in the Intake Assessment).

Entrainment Reduction Due to Other WWS Design Properties

There have been numerous studies on the effectiveness of WWS modules at reducing the effects of entrainment. Although some of the entrainment reductions are due to the small slot openings used on WWS, studies have also shown that the modules generally exceed the expected levels of entrainment reduction based solely on screen size and larval dimensions. Some of these studies have been conducted by Tenera (Ehrler and Raifsnider 2000, Tenera 2010, and Tenera 2014).

A recent review on the effectiveness of cylindrical screening systems at reducing entrainment of fishes by Coutant (2020) discusses how the design of cylindrical intake screen systems help reduce entrainment. These features include the cylindrical shape of the intakes, their alignment relative to existing tidal or river currents, and their low through-screen velocities. In his summary of lab studies on entrainment by cylindrical WWS Coutant (2020) concludes that the contribution of screen-size opening, and through-screen velocity was a minor factor in the reduction in entrainment.

One of the studies cited by Coutant (2020), which recognized that entrainment of fish eggs and larvae by WWS screens appeared to be less than could be explained by physical exclusion by slot size alone, was from Weisberg et al. (1987). The results of the study by Weisberg et al (1987) indicate that the rates of exclusion for the smaller size classes could be used to estimate the effects of the hydrodynamic exclusion mechanism of WWS modules. Even though this study predates many of the studies conducted by EPRI, Tenera, and other groups, it was one of the only studies that evaluated entrainment reduction using the lengths of the larvae. This is important because the level of entrainment reduction is proportional to the size of the larvae relative to the WWS slot opening.

Weisberg et al. (1987) collected data at the Chalk Point Steam Electric Station in Aquasco, Maryland. Samples were collected from two intake ports, one fitted with a WWS screen module and the other open to the environment, and also from the environment using a 505 micron plankton net. Unlike the WWS modules planned for the Humboldt intakes, which will be positioned parallel to the tidal current flow, the modules in this study were positioned perpendicular to the current flow which likely reduced the effectiveness of the screens.

To provide a direct comparison with the WWS modules planned for the Humboldt intakes, only the results from the tests done by Weisberg et al. (1987) using a 1 mm (0.04 in.) WWS module are reported here. The tests used a through-slot velocity of 13 cm/s (0.43 ft/s) for the tests in 1982 and a velocity of 20 cm/s (0.66 ft/s) in 1983 (**Table 1**). As expected, the results show large reductions in entrainment due to the WWS module in larvae with lengths greater than 8 mm (0.3 in.). The authors point out that only one Bay Anchovy larger than 8 mm (0.3 in.) in length was collected through the 1 mm (0.04 in.) screen in either year of the study. Although fish larvae from both species smaller than approximately 8 mm (0.3 in.) could have physically been entrained through the 1 mm (0.04 in.) screen module, there were still large reductions in entrainment in those size classes in both years for both species.

The authors provide evidence for both the physical and hydrodynamic exclusion mechanisms provided by WWS (Weisberg et al. 1987). The physical exclusion of larger larvae by the 1 mm (0.04 in.) screen was apparent from the results and the results also showed that exclusion was greater when compared with results from the 2 (0.08 in.) and 3 mm (0.12 in.) screen modules that are not presented here. The hydrodynamic properties of the screen that reduce entrainment were apparent in comparing the reductions in entrainment for larvae in the 5–6 (0.20–0.24 in.) and 5–7 mm (0.20–0.28 in.) ranges for both species, which would be subject to entrainment based solely on their length and body dimensions. Also, the authors point out that some larvae in the 5 mm (0.20 in.) size ranges for both species were even excluded by the 3 mm (0.12 in.) WWS module even though fish larvae as large as 20 mm (0.79 in.) were narrow enough to pass through the 3 mm (0.12 in.) screens. They point out that both the physical and hydrodynamic exclusion mechanisms are related to size.

Unlike the studies by Weisberg et al. (1987), which were conducted in the field, studies on the effectiveness of WWS by EPRI (2003) were conducted in a laboratory facility. The EPRI studies were conducted at a facility with a flume that was able to circulate water past a WWS module at different velocities and inject controlled numbers of fish eggs and larvae into the flow upstream from the WWS module. Intake flow through the WWS module could also be controlled and a net downstream captured all of the eggs and larvae that bypassed the module. This allowed for the control of channel velocity and precise measurement of entrainment effectiveness that could not be achieved in the field studies conducted by Weisberg et al. (1987).

Several species of fish larvae were tested along with WWS modules with slot openings of 0.5, 1.0, and 2.0 mm (0.02, 0.04,0.08 in.). Three to five tests at different combinations of fish species, slot opening width, through-slot velocity, and channel velocity were conducted. Only the results from the tests using a WWS slot opening of 1.0 mm (0.02 in.) and through-slot velocity of 15 cm/s (0.5 ft/s) are presented here to provide comparison with the WWS modules planned for the Humboldt intakes (**Table 2**).

Table 1. Data from Weisberg et al. (1987) on concentrations of fish larvae (# per 1,000 m^3) for Bay Anchovy and Naked Goby from samples collected from a 1 mm (0.04 in.) slot size WWS module, open intake port, and plankton tows at Chalk Point Steam Electric Station in Aquasco, Maryland in 1982 and 1983. Reductions calculated as 100*[open port (or canal) density - screen density] / open port (or canal) density. Negative reduction values indicate increase in entrainment density.

Fish Size Class	Concentrations of larvae (# per m^3)			Reduction Relative to	
1982 tests using through slot velocity of 13 cm/sec					
Bay Anchovy	Net	Open	1 mm WWS	Canal Water	Open Port
Eggs	0.00	0.00	0.00	--	--
<=4mm	2.00	0.00	0.00	100.00%	--
5-7mm	4.50	4.10	0.00	100.00%	100.00%
8-10mm	6.20	1.60	0.00	100.00%	100.00%
11-14mm	152.90	31.10	0.00	100.00%	100.00%
>=15	2,469.40	57.30	1.50	99.94%	97.38%
Naked Goby					
<=4mm	95.30	17.20	1.50	98.43%	91.28%
5-6mm	117.60	22.90	6.00	94.90%	73.80%
7-8mm	95.50	38.50	5.80	93.93%	84.94%
>=9mm	342.30	201.50	35.80	89.54%	82.23%
1983 tests using through slot velocity of 20 cm/sec					
Bay Anchovy					
Eggs	19,610.00	2,341.00	10,966.00	44.08%	-368.43%
<=4mm	60.00	9.60	9.20	84.67%	4.17%
5-7mm	37.60	20.10	10.80	71.28%	46.27%
8-10mm	11.20	7.70	1.00	91.07%	87.01%
11-14mm	3.50	1.30	0.00	100.00%	100.00%
>=15	9.30	3.30	0.00	100.00%	100.00%
Naked Goby					
<=4mm	223.50	535.70	562.50	-151.68%	-5.00%
5-6mm	514.80	148.70	66.50	87.08%	55.28%
7-8mm	370.50	49.70	3.90	98.95%	92.15%
>=9mm	243.70	49.10	1.90	99.22%	96.13%

The results of the EPRI (2003) studies provide useful information that supplements the findings from the Weisberg et al. (1987) study. The results demonstrate the effects of increased channel or ambient velocities on the effectiveness of the WWS screen modules at reducing entrainment (**Table 2**). Entrainment decreases with increased channel velocity, which is likely due to the shorter time that fish larvae are in close proximity to the WWS module. This is especially relevant to the Humboldt intakes where tidal currents vary daily depending on tidal condition and the range of tide heights and the screens will be parallel to the current flow. The effectiveness of ambient currents to move organisms along and past the screen will be dependent on the size and swimming ability of the organisms and the through-slot velocities. The complete results for the EPRI (2003) studies using the full range of slot openings and slot velocities showed that the effectiveness of flow along the screen to move fish eggs and larvae away from the screen decreased with higher slot velocities and larger slot widths and increased for larger fish larvae.

Table 2. Data from EPRI (2003) on percentage entrainment of fish larvae for four species of fish tested in flume using a WWS screen module with 1 mm (0.04 in.) slot openings and a through slot velocity of 15 cm/s. Percentage entrainment was calculated using the number of larvae injected upstream from the module during each test run (N = 3 or 5) and the number collected downstream from the WWS module.

			Channel Velocity			
Fish Species	Average Length and Range (mm)	N	0.08 m/s	0.15 m/s	0.30 m/s	Average Entrainment
Striped Bass	not available	3	41.00	27.00	17.00	28.33
Winter Flounder	mean = 6.1; 2.4 to 11.0	5	86.00	75.00	61.00	74.00
White Sucker	mean = 13.9; 12.5 to 15.5	5	12.00	8.00	5.80	8.60
Common Carp	mean = 6.4; 5.6 to 7.5	5	94.00	82.00	65.00	80.33
Averages			58.25	48.00	37.20	47.82

The results from the EPRI (2003) study support the results from the Weiberg et al. (1987) study and can help estimate the entrainment efficiencies of WWS modules resulting from primarily hydrodynamic features of the modules. A large factor in the variable results for the four species is due to the variation in the lengths of the larvae used in the testing. Although there were no data in the report on the lengths of the Striped Bass larvae used in the testing, it is stated that the length ranges for Striped Bass and Winter Flounder had the largest variation of the species used in the testing. This is reflected in the results for the four species (**Table 2**). White Sucker larvae, which had a narrow range of lengths that were all greater than 10 mm, had the lowest average levels of entrainment, while Common Carp which had a narrow range of lengths that were all less than 8 mm, had the highest average levels of entrainment. Striped Bass and Winter Flounder, the two species with more variable lengths during the testing had intermediate results.

The results for Common Carp in **Table 2** can be used to estimate an entrainment reduction of approximately 20% due to the hydrodynamic features of the WWS module (**Table 2**). As the results show, entrainment increases when current velocity is decreased which would likely occur when tidal conditions result in low flow. During periods when large changes in tidal elevation occur it is likely that the current velocities exceed the highest current velocity in the testing of 0.3 cm/s (~1.0 ft/s). Therefore, using the average estimate of entrainment reduction of approximately 20% due to the hydrodynamic features of the WWS module would seem to be a conservative approach.

The results of computational fluid dynamic (CFD) modeling for a WWS module used in testing for a project in southern California (Tenera 2014) shows the effects of the screen module design at inducing increased flow along the screen surface (**Figure 1**). The diversion of flow lines by the blunt end of the screen results in increased velocities along the screen face which helps decrease the time that marine organisms are exposed to the screen openings. The turbulence apparent at the two ends of the WWS module due to the flat, blunt ends of the module would be expected to be dramatically decreased or eliminated if conical sections were added to the ends of the WWS modules that would help divert the water over the screen face.

Adding the estimated effects of the hydrodynamic exclusion mechanism of WWS modules to the estimated average entrainment reduction for the lengths and body dimensions of LFS larvae due to the use of the 1 mm (0.04 in.) WWS module of 0.2331 results in a total reduction of approximately 43% (e.g., a reduction of 12,132). Applying these reductions due to LFS morphology and WWS hydrodynamic efficiency to the annual estimated entrainment of LFS larvae results in a value of 15,881 larvae.

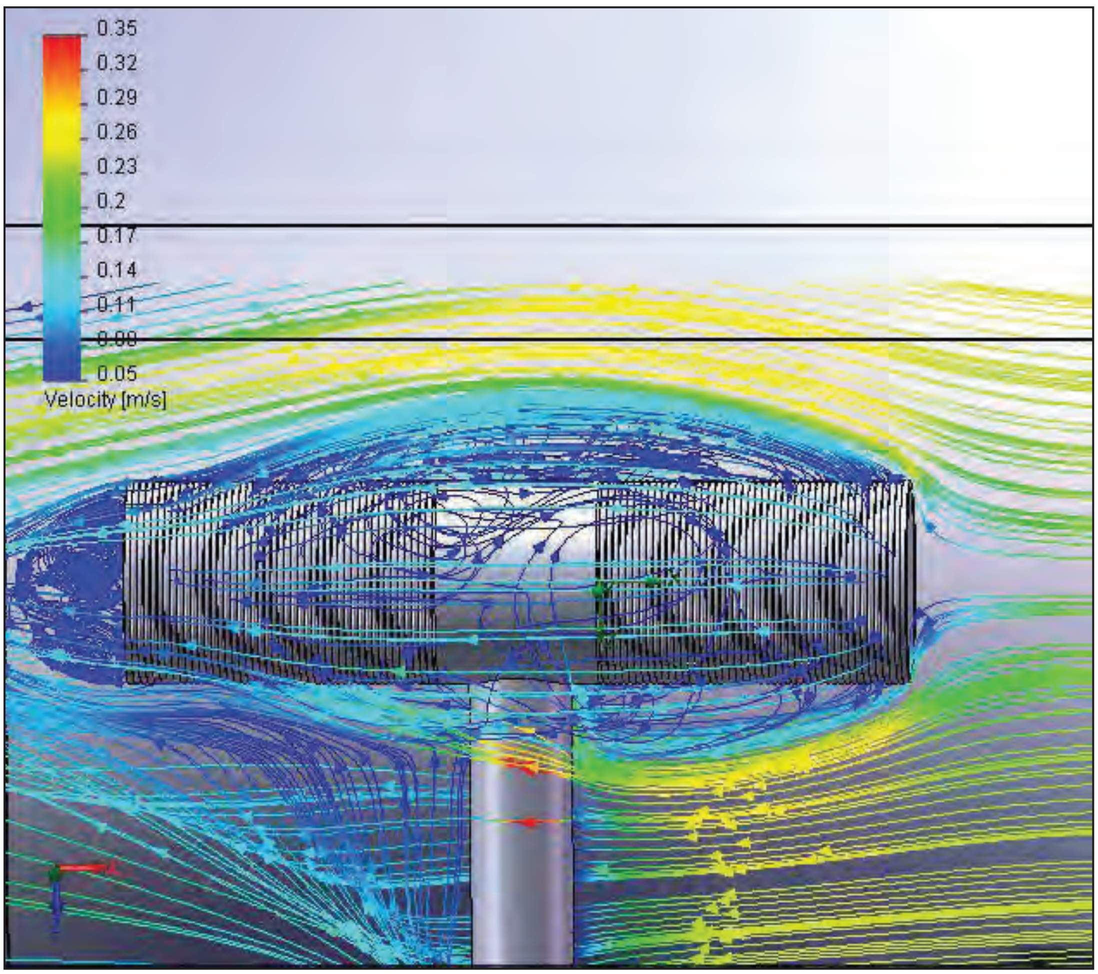

Figure 1. Graphical results of computational fluid dynamic (CFD) modeling for a WWS module used in testing for a project in southern California (Tenera 2014).

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December 7, 2023

To: Rob Holmlund, Humboldt Bay Harbor, Recreation, and Conservation District

From: John Steinbeck, Tenera Environmental

Subject: Correction to August 18, 2023 Addendum on APF Estimates for Humboldt Bay Intake Assessment

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This technical memorandum provides a correction to a technical memorandum dated August 18, 2023. The correction is to the estimate of the standard error used in calculating the value at the 95th percentile of the cumulative probability curve for the final estimates of Area of Production Foregone (APF). The correct APF estimate at the 95th percentile for the seven fishes from the study for the effects of entrainment from the two intakes is 28.8 acres (12 hectares) (**Table 5-9**), not the value of 34.6 (14 hectares) presented in the August 18, 2023 technical memorandum.

Technical Background

The technical memorandum, dated August 18, 2023, was issued as an addendum to the final draft of the Intake Assessment of the Potential Effects on Ichthyoplankton and other Meroplankton Due to Entrainment at Proposed Samoa Peninsula Water Intakes (Intake Assessment) dated May 1, 2023 and provides final estimates of Area of Production Foregone (APF) using the approach specified in the Desalination Amendment to the Statewide Water Quality Control Plan for the Ocean Waters of California (Desalination Amendment).[1] The APF estimates for the 95% percentile of the cumulative probability curve for the APF estimates in the original memorandum were calculated using an incorrect estimate of the standard error. The values in the corrected version of **Table 5-9** from the Intake Assessment are presented below for each of the seven fishes that were analyzed using the Empirical Transport Model (ETM) as specified in the Desalination Amendment.

The average APF for the seven fishes (17.9) in **Table 5-9** below is equal to the value at the 50th percentile of a cumulative probability curve for the APF estimate based on the assumption that the seven APF estimates are normally distributed. The average APF at the 50th percentile is interpreted as having a 50% chance of providing adequate acreage to fully compensate for the estimated losses due to entrainment. The Desalination Amendment requires that the APF be calculated using the 95th percentile of the cumulative probability curve to help ensure that the mitigation fully compensates for entrainment losses.

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[1] Final Staff Report Including the Final Substitute Environmental Documentation for California State Water Resources Control Board Resolution 2015-0033: Amendment to the Statewide Water Quality Control Plan for the Ocean Waters of California Addressing Desalination Facility Intakes, Brine Discharges, and to Incorporate other Nonsubstantive Changes. Adopted May 6, 2015.

The correct APF estimate at the 95th percentile for the seven fishes from the study for the effects of entrainment from the two intakes is 28.8 acres (12 hectares) (**Table 5-9**), not the value of 34.6 (14 hectares) presented in the August 18, 2023 technical memorandum.

Table 5-9 from May 2023 Intake Assessment. Summary of ETM results for taxa analyzed from sampling in Humboldt Bay from January–December 2022 with ETM estimates of P_M for the RMT II (Station E1) and RTD (Station E2) intakes. Area Production Foregone (APF) estimates were calculated based on an estimate of the surface area of Humboldt Bay at MSL of 15,098 acres (6,110 hectares). Note: In addition to the average APF estimates (50th percentile estimate) in the original table, the 95th percentile estimates were added to the table.

	P_M Estimates (%)			APF Estimates (acres [hectares])		
Taxa	RMT II Intake (Station E1)	RTD Intake (Station E2)	Total	RMT II Intake	RTD Intake	Total
Arrow Goby	0.3010	0.0747	0.3757	45.4 (18.4)	11.3 (4.6)	56.7 (23.0)
Bay Goby	0.0762	0.0404	0.1166	11.5 (4.7)	6.1 (2.5)	17.6 (7.1)
Whitebait Smelt	0.0323	0.0142	0.0464	4.9 (2.0)	2.1 (0.9)	7.0 (2.8)
Pacific Herring	0.0210	0.0098	0.0308	3.2 (1.3)	1.5 (0.6)	4.7 (1.9)
Pacific Tomcod	0.0754	0.0088	0.0842	11.4 (4.6)	1.3 (0.5)	12.7 (5.1)
Surf Smelt	0.0535	0.0248	0.0783	8.1 (3.3)	3.7 (1.5)	11.8 (4.8)
Pacific Staghorn Sculpin	0.0636	0.0324	0.0960	9.6 (3.9)	4.9 (2.0)	14.5 (5.9)
Average (50th percentile APFs)	0.0890	0.0293	0.1183	13.4 (5.4)	4.4 (1.8)	17.9 (7.2)
95th percentile APF estimates				22.4 (9.1)	6.6 (2.7)	28.8 (11.7)

The proposed mitigation ratio used in calculating the projects to meet the calculated APF is based on the following:

The May 1, 2023 Tenera Report Intake Assessment of the Potential Effects on Ichthyoplankton and other Meroplankton Due to Entrainment at Proposed Samoa Peninsula Water Intakes on page 6-12 states:

> *An initial estimate of APF was provided for the District in Appendix N of the Draft EIR for the project that was based on the results of the Initial ETM Assessment prepared by Tenera (2021) (Appendix P of the Draft EIR). The APF estimate of 10.4 acres (4.2 hectares) in Appendix N was based on a source water area of 10,000 acres (4,047 hectares) and was intended to be used as an example of how APF was calculated. The source water area based on the data in Swanson (2015) that was used in the APF calculations in the Initial ETM Assessment and in this report was 15,104 acres (6,112 hectares). Therefore, the corrected APF from the Initial ETM Assessment would be 15.7 acres (6.3 hectares), which, as expected, is very close to the APF estimate of 17.9 acres (7.2 hectares) in this report. Using the same 4:1 ratio proposed in Appendix N, an area of piling removal equivalent to 4.5 acres (1.8 hectares) would fully compensate for the losses to marine resources resulting from entrainment at the two intakes.*

Also note that an MOU between regulatory agencies regarding desalination projects cites California Water Code (Water Code) section 13142.5(b) and Water Board Ocean Plan Section M. Those citations state that for out-of-kind mitigation:

- An owner or operator shall evaluate the biological productivity of the impacted open water or softbottom habitat calculated in the Marine Life Mortality Report and the proposed mitigation habitat.
- If the mitigation habitat is a more biologically productive habitat (e.g. wetlands, estuaries, rocky reefs, kelp beds, eelgrass beds, surfgrass beds), then the regional water board may apply a mitigation ratio based on the relative biological productivity of the impacted open water or softbottom habitat and the mitigation habitat.
- The mitigation ratio shall not be less than one acre of mitigation habitat for every ten acres of impacted open water or soft-bottom habitat.

The proposed intake project is impacting open water and mitigating by creating a higher quality habitat (out-of-kind mitigation). For the Kramer Dock pile removal, the mitigation ratio is 1:4. As described in the Final Environmental Impact Report for the project,[2] the planned restoration of 2.7 acres of bay habitat by the removal of pilings from the old Kramer Dock will be used to account for 10.8 acres of the total required APF mitigation. This approach assumes using the 1:4 mitigation ratio for the Kramer Dock site[3] that was presented in Appendix N of the draft EIR. This is the mitigation ratio used for the Poseidon desalination plant project in Carlsbad, California that is provided in the Final Staff Report for the May 6, 2015 Desalination Amendment to the Water Quality Control Plan for Ocean Waters of California.[4] The remaining acres of mitigation required from the APF (and the associated mitigation ratio) will be determined based on discussions between the resource agencies, and the Humboldt Bay Harbor, Recreation, and Conservation District.

A different mitigation ratio for any additional mitigation at any alternate site may be justifiable.

[2] Final Environmental Impact Report Samoa Peninsula Land-based Aquaculture Project. County of Humboldt, Planning and Building Department, June 30, 2022. SCH#: 2021040532. Prepared by GHD, Eureka, CA. Accessed August 18, 2023 at https://humboldtgov.org/DocumentCenter/View/108020/Nordic-Aquafarms-Final-EIR.

[3] A different form of mitigation at a different site may require a different mitigation ratio. For instance, a higher ratio may be appropriate for a mitigation project that consists of restoring filled estuarine channels.

[4] Final Staff Report Including the Final Substitute Environmental Documentation. Adopted May 6, 2015 Amendment to the Water Quality Control Plan for Ocean Waters of California addressing Desalination Facility Intakes, Brine Discharges, and the Incorporation of Other Non-Substantive Changes. Accessed August 18, 2023 at https://www.waterboards.ca.gov/board_decisions/adopted_orders/resolutions/2015/rs2015_0033_sr_apx.pdf.

Intake Assessment of the Potential Effects on Ichthyoplankton and other Meroplankton Due to Entrainment at Proposed Samoa Peninsula Water Intakes

May 1, 2023

ESLO2023-001.2

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List of Abbreviations and Acronyms

APF	Area of Production Foregone – modeling approach used to estimate the area required to compensate for the production of a biological population due to entrainment or some other impact source
CalCOFI	California Cooperative Oceanic Fisheries Investigations
cm	centimeters
cm/s	centimeters per second
CDFG	California Department of Fish and Game (now CDFW)
CDFW	California Department of Fish and Wildlife
CO1	Cytochrome c oxidase subunit 1
CWA	Clean Water Act
CWIS	cooling water intake systems
DNA	deoxyribonucleic acid
E	entrainment
ETM	Empirical Transport Model – modeling approach used to estimate the losses to a biological population due to entrainment or some other impact source
f	Parameter representing the proportion of total source water population subject to entrainment during each survey period in ETM equation
ft	feet
ft/s	feet per second
ft^3	cubic feet
Mft^3	million cubic feet
g	grams
gal	gallons
gpm	gallons per minute
in.	inches
km	kilometers
km^2	square kilometers
lb	pounds
LFS	Longfin Smelt
µm	microns
m	meters
mgd	million gallons per day
m^3	cubic meter
mi	miles
mi^2	square miles
mm	millimeters
MHHW	mean higher high water
MHW	mean high water
MLLW	mean lower low water
MLW	mean low water
MOU	Memorandum of Understanding
MSL	mean sea level
N	number - used in PE calculations as the number of estimated larvae in entrained (N_E) or source water (N_S)

NL	notochord length
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
OTC	once-through-cooling
ppt	parts per thousand
PCR	Polymerase Chain Reaction- laboratory technique for amplifying copies of DNA segments
PE	Proportional Entrainment – calculated as the ratio of estimated number of organisms of a taxon impacted to the estimate of the number in the source water
PLD	planktonic larval duration
psu	practical salinity unit
P_M	Proportional Mortality – the estimate of population mortality provided from the ETM
P_S	Parameter representing the proportion of the total estimated source water for a taxon represented by the area sampled for the study (sampled source water)
ρ	Greek symbol rho – used as an abbreviation for concentrations used in calculating *PE* estimates of estimated larvae in entrained (N_E) or source water (N_S)
q	Parameter representing the planktonic larval duration in the ETM calculations. Represents the estimate of the number of days that the larvae for a taxon are subject to shear stresses due to entrainment
QA	quality assurance
QC	quality control
RMT II	Redwood Marine Terminal II
RTD	Red Tank Dock
RWQCB	Regional Water Quality Control Board
SL	standard length
SW	source water
SWB	source water body
SWRCB	State Water Resources Control Board
taxon	refers to an individual taxonomic category of biological organisms. Taxa refers to multiple categories.
USFWS	United States Fish and Wildlife Services
V	volume - used in calculating *PE* estimates of estimated larvae in entrained (N_E) or source water (N_S)
WWS	wedgewire screen

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Executive Summary

This report presents the results of a sampling and modeling study to assess the potential for impacts to marine organisms that could occur due to the operation of two seawater intakes that will support aquaculture and a variety of other uses in Humboldt Bay, California. The design and operation of intakes in ocean and estuarine waters in California are required to minimize effects on marine life due to impingement and entrainment. Impingement occurs when larger organisms are trapped against screening systems commonly used at intake openings and entrainment occurs when small planktonic organisms, including the eggs and larvae of fishes (ichthyoplankton) and invertebrates, pass through the screens into the system. The intake proposed for this project is designed with screens and intake velocities that reduce any potential for impacts due to impingement. Therefore, the impact assessment for this project focuses solely on the effects of entrainment. The potential impacts due to entrainment at the proposed intake locations are evaluated using the Empirical Transport Model (ETM), a modeling approach that has been used on larger intake systems throughout California and is the standard approach in California for assessing impacts due to power plant and desalination plant ocean intakes. The results from the ETM are required to calculate appropriate mitigation for the impacts using the Area of Production Foregone (APF), which is required under state policy. The results of the study will additionally be used to estimate any required mitigation for estimated entrainment effects on Longfin Smelt (*Spirinchus thaleichthys*) larvae, a species listed as threatened under the California Endangered Species Act.

The two intakes are located at the Redwood Marine Terminal II Dock (RMT II) and the Red Tank Dock (RTD) on the eastern shore of the Samoa Peninsula approximately 3.8 mi (6 km) from the entrance to Humboldt Bay. The proposed intake design pump capacities are 5,500 gallons per minute (gpm) (20.8 m^3 per minute) for the RMT II intake and 2,750 gpm (10.4 m^3 per minute) for the RTD intake, for a total design capacity of 8,250 gpm (31.2 m^3 per minute) or 11.88 million gallons per day (mgd) (44,970 m^3 per day). The existing screens at the two locations will be replaced with T-shaped stainless steel wedgewire screen (WWS) modules that feature wedge-shaped wire wrapped around the screen frame with a slot opening designed to provide a flat surface that helps eliminate debris buildup on the screen surface. The design specifications for the RMT II and RTD intake screen modules meet or exceed requirements established by the National Marine Fisheries Service (NMFS) for screening water intakes to prevent impingement or entrainment of juvenile salmonids. The slot opening for the two screens is designed to be 0.04 in. (1.0 mm), which is smaller than the NMFS criteria of 1/16 in. (1.6 mm).

The design of ETM studies requires sampling at entrainment locations that provide data used to estimate the concentrations of fish larvae potentially subject to entrainment and sampling at locations throughout the source waters that is used to estimate the numbers of larvae potentially subject to entrainment. In Humboldt Bay, source water stations were located in each of the four regions of the bay: Arcata Bay, Main Channel Entrance Bay, and South Bay. The entrainment and source water stations were all sampled twice a survey (day and night) on a roughly monthly interval. The average taxa concentrations at the entrainment and source water stations during

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each survey were multiplied by the volumes of the intakes and source water bodies to calculate an estimate of proportional entrainment (*PE*) for each species and survey. The *PE* is the ratio of the estimated number entrained each day to the number in the source water. For each species analyzed, the estimates of *PE* for each survey are used to calculate the ETM estimate of proportional mortality (P_M), which is an estimate of the loss to the source water population of that species over the year due to entrainment.

A total of 189 samples was collected during the study which resulted in the collection of 60 different taxa of fish larvae from 28 different taxonomic families. The two most abundant taxa over the course of the study were the Arrow Goby and the Bay Goby, respectively. In addition to the two species of gobies, five other species were selected for analysis using the ETM based on their abundance and frequency of occurrence in the samples. Combined, the seven species comprised almost 95% of the total abundance of the samples collected at the two entrainment stations. The total estimated annual entrainment of larval fishes at the two intakes when operated at full capacity was approximately 17.81 million. In addition, approximately 20.44 million fish eggs were estimated to be entrained. Crab megalops larvae were also processed from the samples, but no entrainment estimates were calculated because the larvae are larger in size than the slot openings on the WWS intake modules.

A total of eleven Longfin Smelt larvae were collected during the sampling, seven of which were collected at the two entrainment stations. These eleven larvae were used to calculate that an estimated total of 28,013 larvae would be entrained annually at the intakes when operated at full capacity (see Section 3.1.6 for methods). Life history information on Longfin Smelt presented in the report were used to estimate that these 28,013 larval stage fish were equivalent to the production of 73 reproductive age, female adult smelt. Similar to the APF which provides estimates of habitat that is used by regulatory agencies in determining the amount of habitat required to compensate for entrainment losses from the ETM, the estimate of 73 average size females from the entrainment estimate can be used to determine appropriate compensation for the take of Longfin Smelt larvae. Based on the conservative estimate of the required spawning area for a female Longfin Smelt of 43 ft^2 (4 m^2) used in the Project FEIR, a mitigation area of 3,139 ft^2 (292 m^2) of spawning, rearing, and nursery habitat would compensate for the annual entrainment losses from the intake when operated at full capacity.

The ETM estimates of P_M for the seven taxa presented in the previous sections are shown in **Table ES-1**. The highest ETM estimate of P_M from this study was 0.376% for Arrow Goby. Compared to other taxa, Arrow Goby larvae were in especially high abundance at the entrainment stations at the intakes. Therefore, the intakes would be predicted to entrain a higher proportion of the population of Arrow Goby in the bay than the other taxa analyzed. Arrow Goby live on mudflats, which are one of the predominant habitat types in Arcata Bay. The prevalence of mudflat habitat near the location of the intakes, especially in Arcata Bay, explains the high P_M for Arrow Goby compared to the other species.

Although ETM estimates of P_M are typically used on projects in California to provide a basis for calculating mitigation using the APF (Raimondi 2011), the P_M also provides important information that should be used in the initial determination of whether the losses might be significant to the population, and whether mitigation should be required for a project. ETM estimates of P_M that are sufficiently small compared to natural mortality or natural variation in larval population size provide evidence that the effects of entrainment are negligible and therefore compensation for entrainment losses is not necessary. The ETM estimates of P_M for all seven taxa represent percentage losses to larval populations due to entrainment of less than 0.4%, with an average loss of only 0.118%. Average annual larval fish abundances off the coast of California have been shown to vary by as much as four orders of magnitude among years. This large variation is likely due to differences in larval production and mortality among years due to changes in ocean conditions. Therefore, an additional source of mortality that averages only 0.118% is unlikely to have any significant effect on biological populations in the bay.

Table ES-1. Summary of ETM results for taxa analyzed from sampling in Humboldt Bay from January–December 2022 with ETM estimates of P_M for the RMT II (Station E1) and RTD (Station E2) intakes. Area Production Foregone (APF) estimates were calculated based on an estimate of the surface area of Humboldt Bay at MSL of 15,098 acres (6,110 hectares).

	P_M Estimates (%)			APF Estimates (acres [hectares])		
Taxa	RMT II Intake (Station E1)	RTD Intake (Station E2)	Total	RMT II Intake	RTD Intake	Total
Arrow Goby	0.3010	0.0747	0.3757	45.4 (18.4)	11.3 (4.6)	56.7 (23.0)
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Average	0.0890	0.0293	0.1183	13.4 (5.4)	4.4 (1.8)	17.9 (7.2)

It is important to remember that the estimated levels of mortality from the ETM for this study are extremely conservative because they do not consider the design of the intake systems. The geometry of the slot openings on the WWS modules exclude larger fish larvae and invertebrate larvae such as crab megalops. The WWS modules are also designed to maintain a through-slot velocity at the intake surface of 0.2 fps (6 cm/s), which is one of the NMFS criteria for protection of salmonids. Tenera has conducted studies that show that many larger fish larvae are able to swim against such currents. Also, other research has shown that the design features of cylindrical intake screen systems such as the cylindrical WWS modules used for this study also help reduce entrainment beyond the features of the small slot openings and low approach velocities. These features include the cylindrical shape of the intakes and their alignment relative to existing tidal or river currents that creates a bow wave and resulting flow dynamics that help move larvae and other objects away from the screen surface where they may be subject to entrainment. The increased turbulence decreases the likelihood that larvae would be oriented exactly parallel to the screen slots where they could be more easily entrained. The design of the intake, under normal operations, also eliminates any effects of impingement, and effects on fishes (e.g., sharks and surfperches) and other organisms that do not have life stages subject to entrainment.

Estimates of APF for each of the taxa analyzed are shown in **Table ES-1**. The ETM estimates were based on the approximate surface area of Humboldt Bay at mean sea level which is consistent with the estimates of the volumes at MSL for the different areas of the bay used in the ETM analyses. The average estimate of APF from the seven taxa was 17.9 acres (7.2 hectares) (**Table ES-1** and **Table 5-9** in **Section 5.1.8**). On previous projects where APF has been used, the amount of habitat area required as compensation for the effects of entrainment has been based on the average APF from the taxa analyzed for a study. The APF is a conservative estimate of the area required to compensate for entrainment losses because the actual spawning habitat for the species being analyzed is much more limited than the entire bay. This is evident in the sampling results for Arrow Goby, but in fact none of the seven taxa analyzed using the ETM occur throughout the bay in all habitats. The APF is based on the entire source water because it is meant to compensate for entrainment losses to a much broader range of planktonic organisms than just the ichthyoplankton sampled in the study. These organisms, such as some of the invertebrate zooplankton and phytoplankton, occur throughout the entire bay. Therefore, effects on these organisms would be compensated using the average APF.

Based on the same 4:1 mitigation ratio proposed in Appendix N of the Draft EIR[1] for the project that was based on the results of the Initial ETM Assessment prepared by Tenera (2021), an area of piling removal equivalent to 4.5 acres (1.8 hectares) would fully compensate for the APF estimate of 17.9 acres (7.2 hectares) losses to marine resources resulting from entrainment at the two intakes. The APF is calculated from the ETM estimates and therefore incorporates all of the conservative assumptions in the ETM, as well as the multiple factors that indicate that the estimates of impact to populations in the bay are also conservative due to the design of the intake modules. As a result, the average estimate of APF should fully compensate for the small estimated losses to the source water populations in Humboldt Bay. The average ETM and APF estimates can also be used to estimate not only the effects of entrainment on the taxa analyzed, but also all of the planktonic organisms in the source water subject to entrainment including any effects on salmonids and other species of concern due to reductions in prey.

[1] Appendix N of Draft EIR Prepared by GHD for the County of Humboldt Planning Department. Humboldt Bay Piling Removal Restoration for Longfin Smelt and other Marine Resources. December 13, 2021. Prepared by Tenera Environmental Inc., San Luis Obispo, CA Tenera Document SLO2021-019.

1.0 Introduction

This report presents the results of a sampling and modeling study to assess the potential for impacts to marine organisms that could occur due to the operation of two seawater intakes that will support aquaculture and a variety of other uses in Humboldt Bay, California. The two intakes are owned and operated by the Humboldt Bay Harbor, Recreation, and Conservation District (referred to as the District in this report). The design and operation of intakes in ocean and estuarine waters in California are required to minimize effects on marine life due to impingement and entrainment. Impingement occurs when larger organisms are trapped against screening systems commonly used at intake openings and entrainment occurs when small planktonic organisms, including the eggs and larvae of fishes (ichthyoplankton) and invertebrates, pass through the screens into the system. The intake proposed for this project is designed with screens and intake velocities that reduce any potential for impacts due to impingement. Therefore, the impact assessment for this project focuses solely on the effects of entrainment. The potential impacts due to entrainment at the proposed intake locations are evaluated using the Empirical Transport Model (ETM) (Steinbeck et al. 2007), a modeling approach that has been used on larger intake systems throughout California and is the standard approach in California for assessing impacts due to power plant and desalination plant ocean intakes. The results from the ETM are also required to calculate appropriate mitigation for the impacts using the Area of Production Foregone (APF), which is also required under state policy.[2] The results of the study will also be used to estimate any required mitigation for estimated entrainment effects on Longfin Smelt (*Spirinchus thaleichthys*) (LFS) larvae, a species listed as threatened under the California Endangered Species Act.

1.1 Project Description

The two intakes are located at the Redwood Marine Terminal II Dock (RMT II) and the Red Tank Dock (RTD) on the eastern shore of the Samoa Peninsula approximately 3.8 mi (6 km) from the entrance to the bay (**Figure 1-1**). The Samoa Peninsula is west of the City of Eureka in Humboldt County, California and east of the Pacific Ocean. The two intakes are located at the north end of the Main Channel where it starts to bifurcate around Tuluwat Island before merging into Arcata Bay (**Figure 1-2**). The distance between the two intake locations on the peninsula is approximately 0.6 mi (0.9 km). The proposed intake design pump capacities are 5,500 gallons per minute (gpm) (20.8 m^3 per minute) for the RMT II intake and 2,750 gpm (10.4 m^3 per minute) for the RTD intake for a total maximum capacity of 8,250 gpm (31.2 m^3 per minute) or 11.88 million gallons per day (mgd) (44,970 m^3 per day). The total daily capacities for the RMT II and RTD intakes are 7.92 and 3.96 mgd (29,980 and 14,990 m^3), respectively. These maximum daily intake volumes were used in the modeling, although the average daily intake

[2] Final Staff Report Including the Final Substitute Environmental Documentation for California State Water Resources Control Board Resolution 2015-0033: Amendment to the Statewide Water Quality Control Plan for the Ocean Waters of California Addressing Desalination Facility Intakes, Brine Discharges, and to Incorporate other Nonsubstantive Changes. Adopted May 6, 2015.

volumes may be less during operation. The Harbor District is proposing to modernize the existing intake structures located in Humboldt Bay through the installation of new screen modules and pumps .. The capacity of the existing intakes will be expanded to support a variety of tenants at the two locations. For example, there are proposed finfish, shellfish and seaweed culture operations that would utilize bay water from the intakes.

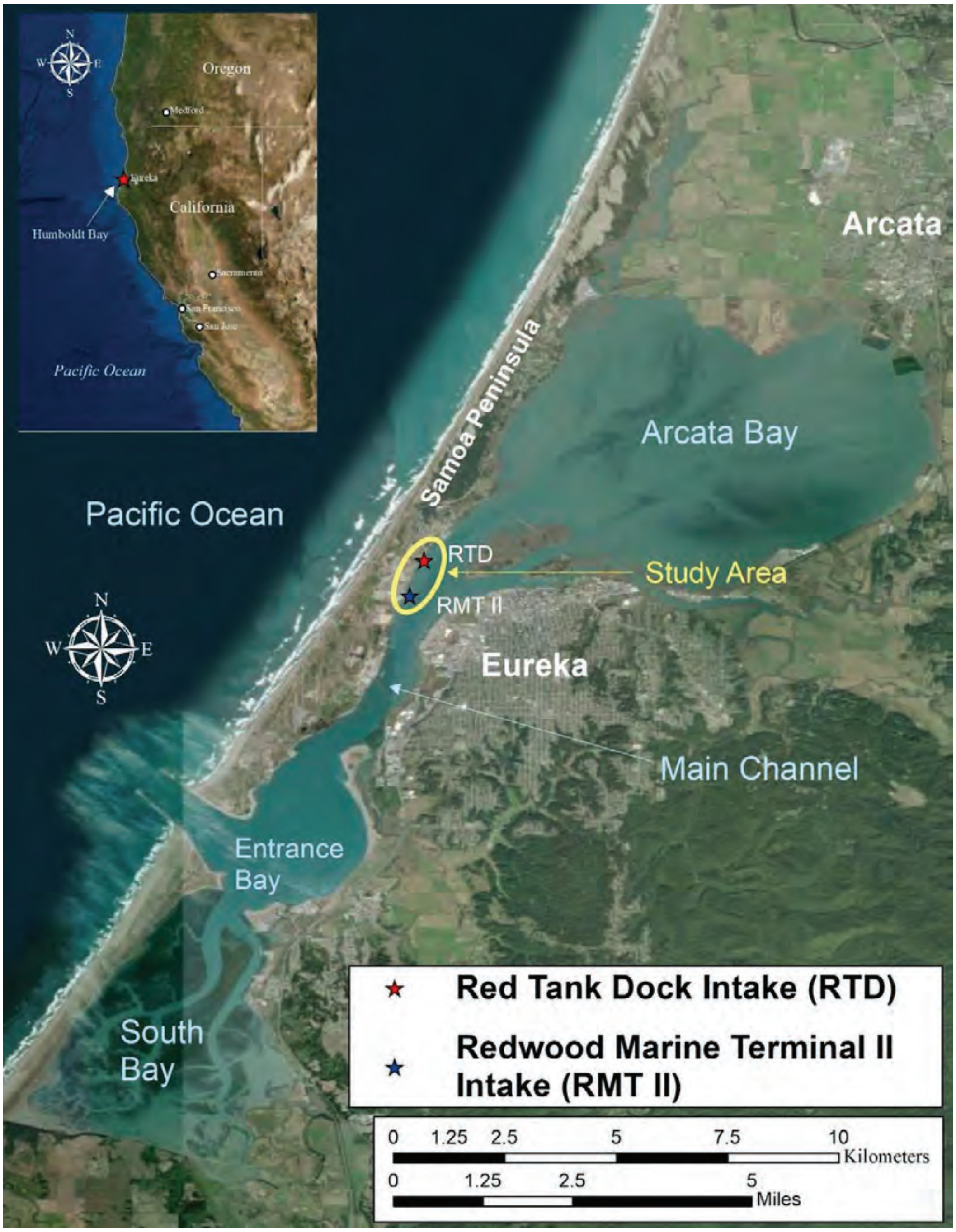

Figure 1-1. Map showing the locations of the two intakes on the eastern shore of the Samoa Peninsula along Humboldt Bay.

The proposed designs of the intakes at the two locations are similar. Although the current intakes have vertical guides on either side of the opening to allow screens to be inserted in front of the intake openings, there are no screens currently in use at the intakes. The current intake system will be replaced with T-shaped stainless steel wedgewire screen (WWS) modules that can also be raised and lowered into place for cleaning (**Figure 1-3a**). The WWS modules utilize wedge shaped wire that is wrapped around a screen frame with a designed slot opening to provide a flat surface that helps eliminate debris buildup on the screen surface (**Figure 1-3b**). The modules will be placed so they are parallel to the tidal flow at both locations, which will help eliminate debris buildup on the screen surface and sediment at the bases of the intakes.

The proposed design specifications for the RMT II and RTD intake screen modules were provided in a letter report from SHN Consulting Engineers and Geologists dated May 29, 2020 to Mr. Adam Wagschal at the District. The design specifications exceed the requirements established by the National Marine Fisheries Service (NMFS) for screening water intakes to prevent impingement or entrainment of juvenile salmonids (NMFS 1997). The specifications in the 1997 NMFS document are also consistent with updated criteria provided by NMFS for the design of anadromous salmonid passage facilities (NMFS 2011). The slot size for the two screens is designed to be 0.04 in. (1.0 mm), which is smaller than the NMFS criteria of 1/16 in. (1.75 mm) (NMFS 2011). The system will utilize manifolds inside the screen modules that equalize pressure across the entire screen surface. These design features result in an approach velocity of 0.2 fps (6 cm/s), which is below the NMFS criteria for lakes, reservoirs, and tidal basins of 0.33 fps (10 cm/s) for salmonid fry less than 2.36 in. (60 mm) in length (NMFS 1997), and meets the requirement 0.2 fps (6 cm/s) in the 2011 guidelines (NMFS (2011). Other details on the locations and specifications for the intakes are provided in **Table 1-1**.

While this project and the associated intake system do not include the use of bay water as cooling water, standards established for cooling water are relevant to this project. Cooling water intake structures for power plants and other industrial facilities that use water for cooling with through-screen velocities of less than 0.5 fps (15 cm per sec) are one of the “Best Technology Available” (BTA) options for meeting the compliance standards for minimizing impacts due to impingement under the CWA Section 316(b).[3] This same velocity standard is used in policies adopted by California for the regulation of power plant cooling water intake systems (CWIS) (California Once Through Cooling [OTC] Policy),[4] and intakes for desalination plants (Ocean Plan Desalination Amendment).[5] The screen designs for the RMT II and RTD intakes result in very low approach velocities that reduce any potential for impacts due to impingement and will utilize airburst cleaning systems to reduce any buildup of debris or fouling on the screens to help

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[3] Environmental Protection Agency. 40 CFR Parts 122 and 125. National Pollutant Discharge Elimination System—Final Regulations to Establish Requirements for Cooling Water Intake Structures at Existing Facilities and Amend Requirements at Phase I Facilities, Final Rule. Federal Register / Vol. 79, No. 158 / Friday, August 15, 2014.

[4] Statewide Water Quality Control Policy on the Use of Coastal and Estuarine Waters for Power Plant Cooling. Adopted by the California State Water Resources Control Board on May 4, 2010. Effective October 1, 2010.

[5] Amendment to the Water Quality Control Plan for the Ocean Waters of California (Ocean Plan) to address effects associated with the construction and operation of seawater desalination facilities. Adopted May 6, 2015 by the State Water Resources Control Board.

maintain the low approach velocities. Therefore, the study presented in this report focuses solely on the potential effects of entrainment resulting from the operation of the two intakes.

Figure 1-2. Detailed map showing locations of Redwood Marine Terminal II (RMT II) and the Red Tank Dock (RTD) intakes on the eastern shore of the Samoa Peninsula.

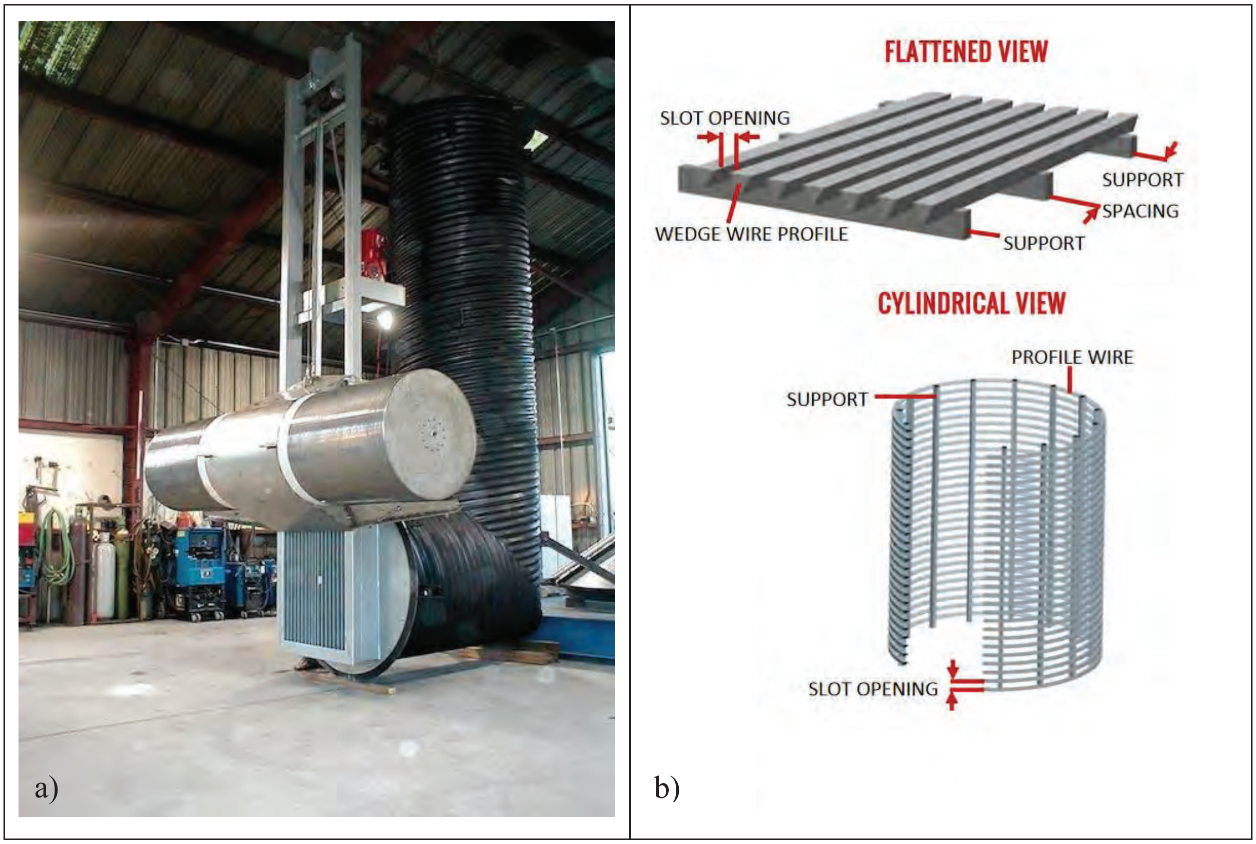

Figure 1-3. Wedgewire screen module and design showing **a)** wedgewire T-shaped module designed to be raised and lowered into place (Source: Intake Screens, Inc.), and **b)** design of wedgewire screen module (Source: Hendrick Manufacturing).

1.2 Policy and Regulatory Background

The Empirical Transport Model approach is the primary method used in California by regulatory authorities to assess entrainment of marine organisms by ocean intakes. Power plant intakes have been subject to regulation nationwide under the Federal Clean Water Act (CWA) Section 316(b)[6] since its passage in 1976. The Act is regulated in California by the California State Water Resources Control Board (Waterboard) under the Statewide Policy on the Use of Coastal and Estuarine Waters for Power Plant Cooling (Once-Through Cooling or OTC Policy). The ETM is the required approach for assessment of entrainment by power plant intakes under the OTC Policy.

Other than power plants, the intake of seawater and discharges into ocean waters[7] in California are regulated under the provisions of the Water Quality Control Plan for Ocean Waters of

[6] Section 316(b) applies to existing power generating and manufacturing and industrial facilities that are designed to withdraw more than 2 mgd and use at least 25% of the water for cooling purposes.

[7] Ocean water includes coastal estuaries and coastal lagoons.

California (Ocean Plan), which was most recently updated in 2019.[8] The Desalination Amendment to the Ocean Plan (Desalination Amendment), which was passed in 2015, also requires that an ETM approach be used to quantify entrainment. Prior to adopting the Desalination Amendment, seawater intakes for desalination plants were required to conduct studies similar to those required for power plant intakes under Section 316(b) based on State Water Code Section 13142.5(b). State Water Code Section 13142.5(b) requires that industrial installations using seawater for cooling, heating, or industrial processing use the best available site, design, technology, and mitigation measures feasible to minimize the intake and mortality of all forms of marine life. This section of the State Water Code was incorporated directly into the Ocean Plan and the subsequent Desalination Amendment.

Table 1-1. Tidal data[1] and intake structure elevations for RMT II dock and Red Tank dock, Samoa, California. Reprinted from information provided in letter report from SHN Consulting Engineers and Geologists dated May 29, 2020 to Mr. Adam Wagschal, Humboldt Bay Harbor, Recreation, and Conservation District.

Description	Abbreviation	RMT II Dock	Red Tank Dock
Project Elevations		Elevation (feet, NAVD88) (2)	Elevation (feet, NAVD88)
Existing Pump Base Elevation	N/A (3)	13.68	11.20 +/-
Existing Pump Discharge Pipe Center Line Elevation	N/A	9.93	N/A
Highest Astronomical Tide, December 31, 1986	HAT	8.52	8.52
Mean Higher High Water	MHHW	6.51	6.51
Mean High Water	MHW	5.80	5.80
Mean Sea Level	MSL	3.36	3.36
Mean Low Water	MLW	0.91	0.91
North American Vertical Datum of 1988	NAVD88	0.00	0.00
Mean Lower Low Water	MLLW	-0.34	-0.34
Lowest Astronomical Tide, May 25, 1990	LAT	-2.73	-2.73
National Geodetic Vertical Datum of 1929	NGVD29	-3.32(4)	-3.32
Existing Intake Structure Invert Elevation	N/A	-8.82	-4.38
Bay Bottom Adjacent to Intake Structure	N/A	-14.82	-5.90
Screen Module Specifications	Units	RMT II Intake	RTD Intake
Screen Module Diameter	in.	36	24
Maximum Flow Rate	gpm	5,500	2,750

1. National Oceanic and Atmospheric Administration (NOAA) Station 9418767 North Spit, CA
2. NAVD88: North American Vertical Datum of 1988
3. N/A: not applicable
4. NGVD29 is 1.013 meters (3.32 feet) lower than NAVD88 according to the NOAA VERTCON orthometric height conversion tool (https://www.ngs.noaa.gov/cgi-bin/VERTCON/vert_con.prl) for 40.804624 North Latitude, 124.193127 West Longitude.

[8] California Ocean Plan. Water Quality Control Plan. Ocean Waters of California. California State Water Resources Control Board. Revised 2019.

Therefore, although the RMT II and RTD intakes are not intended for use at a power or desalination facility, California State Water Resources Control Board (SWRCB) and Regional Water Quality Control Board (RWQCB) members and staff have generally required 316(b)-type studies be conducted for seawater intakes. The ETM modeling was developed to satisfy these regulatory frameworks and is the approach taken to assess entrainment in this study.

The results from the ETM assessment are used to calculate estimates of APF, which is required in the Desalination Amendment. Estimates of APF provide ETM results in an acreage value that represents the amount of habitat required to replace marine life lost due to entrainment. A separate assessment is done on the estimated entrainment of LFS that includes the calculation of an estimate of the area of mitigation required to compensate for the entrainment losses.

1.3 Approach

The assessment in this report uses the ETM modeling approach to estimate the potential for impacts to fish and invertebrate larvae due to entrainment by RMT II and RTD intakes. The sampling plan was based on a survey of available background literature and results of intake system studies at other facilities in California using the ETM that have been conducted over the past several years (e.g., MBC and Tenera 2005, Tenera 2005, Tenera 2008, Tenera 2014a, Tenera 2014b).

The output of the ETM is an estimate of the proportion (or percentage) of a source water population that is entrained and assumed lost to the population each year. This value is referred to as Proportional Mortality (P_M). The methods and assumptions required to calculate P_M using the ETM and how the APF is calculated using the ETM estimate of P_M are provided in Section 3.0.

The design of the study was also based on information presented in an Initial ETM Assessment prepared for the District by Tenera (2021). Both the previous study and this study use an ETM approach, which is a robust method for assessing entrainment impacts and provides the same type of information used by resource scientists in managing fisheries. The estimates of P_M are similar to estimates of the effects of fishing mortality on an adult population and, in this context, can be interpreted relative to other sources of mortality. An estimate of P_M that is very low when compared to other natural sources of mortality or levels of natural population variation provides evidence that entrainment effects on the population are not likely to be significant. McClatchie et al. (2018) in an analysis of long-term data from CalCOFI on changes in average annual larval fish abundances reported variation as high as four orders of magnitude among years. This large variation is likely due to differences in larval production and mortality among years due to changes in ocean conditions. Given these high natural levels of variation, an additional source of mortality that increases larval mortality by a very small amount (e.g., less than 1.0 %) should not cause any effects on a fish population. Conversely, a P_M that is large compared to natural mortality or natural population variation would suggest that entrainment effects could be significant. The P_M mortality estimate represents the potential losses to the population of larvae in the source water body. The source water body is defined in the ETM approach as the population of organisms that are subject to entrainment. In fisheries applications analogous to an

ETM, the population is typically referred to as a stock. While the definition of a fishery stock varies by application, it is generally accepted to be a reproductively isolated population of fish with rates of growth, reproduction, and mortality that are independent of other populations of the same species (e.g., Secor 2014, Begg et al. 1999).

While the modified ETM approach used in the Initial ETM Assessment did utilize data on the intake and source water volumes, it did not use biological data collected directly from the marine environment around the proposed intakes that are usually incorporated into a full ETM model. Instead, the Initial ETM relied on assumptions based on generic biological parameters of fish and invertebrate larvae. Also, the proportional entrainment (*PE*) estimates that are the fundamental input parameters in the ETM are typically calculated as the ratio of the estimated numbers of larvae entrained to the population at risk in the sampled source water (Steinbeck et al. 2007). The approach used in the Initial ETM Assessment used a simplifying assumption that the concentrations of larvae at the intake and in the source water areas were approximately equal. This allowed the *PE* to be estimated as the ratio of the volume of water entrained to the volume of the sampled source water. This assumption was used in the original formulation of the ETM to estimate impacts due to an intake located on a river (Boreman et al. 1978, 1981). The potential for using this volumetric modeling approach for intake assessment was shown to be applicable at certain locations by Steinbeck et al. (2016). The limited biological data in the Initial ETM study were based on data used in an entrainment assessment study conducted in San Francisco Bay (Tenera 2005). This approach was useful for providing estimates of entrainment effects that were used in the initial planning and permitting for the project.

The ETM study described in this report had two main objectives:

- Establish a baseline on the species composition, abundance, and temporal variability of fish larvae in the source waters of the intakes; and
- Model the potential impacts on local fish populations caused by the loss of entrained organisms and evaluate their ecological and economic significance.

The overall approach was to collect data on the concentrations of fish larvae and selected invertebrate larvae at the intake locations in the Samoa Channel and also at locations in the surrounding source water within Humboldt Bay using towed plankton nets, the standard sampling method for these organisms.

The study plan included sampling at both the RMT II and RTD intakes (**Figure 1-1**). This allowed for ETM estimates of P_M to be calculated for each intake to account for periods of time when one of the intakes will not be in operation. Due to the short distance between the two intakes (0.6 mi [0.9 km]), the only difference in the parameters used in the calculations of P_M for the two intakes was the estimated daily entrainment. Therefore, the estimates of P_M for each intake can be added together to provide an estimate of the combined entrainment effects during operations due to both intakes. Detailed assessments were only completed for the most abundant organisms collected from the samples to ensure that adequate data exist to provide reasonable levels of confidence in the abundance estimates, which is a standard method for any ETM application. Estimates of APF are also calculated for both intakes and for the combined operations of the intakes from the ETM estimates of P_M.

1.4 Report Organization

The information provided in the other sections of this report is described below.

Section 2.0 includes brief descriptions of the physical and biological characteristics of Humboldt Bay. Section 3.0 provides descriptions of the field sampling, sample processing, and data analysis including an overview of the ETM and the ETM model that is used in the impact assessment for the two intakes, and the calculation of APF. Section 4.0 provides the results of the analyses of the biological sampling data and the methods used to verify the source water model used in the ETM. Finally, the results of the impact assessment are presented in Section 5.0. A discussion of the impact assessment, an evaluation of the effectiveness of the intake technology, and conclusion from the study are provided in Section 6.0. All of the references used in the report are listed in Section 7.0.

Appendices include the following:

- Appendix A provides the data from each sample collected during the study;
- Appendix B provides details on conditions during the collection of each sample including date, time, sample volume, sample depth, tide conditions, and temperature and salinity data; and
- Appendix C provides plots of temperature and salinity through the water column at each station during sampling.

2.0 Environmental Setting

This section provides background on the physical features and an overview of the biological resources of Humboldt Bay, especially the area of the bay around the proposed RMT II and RTD intakes on the eastern shore of the Samoa Peninsula (**Figure 1-1**).

2.1 Physical Setting of Humboldt Bay

Humboldt Bay is the second largest natural bay in California and is the largest estuary in the state north of San Francisco. Two cities border the bay: Arcata to the north with a population of approximately 18,000, and Eureka to the east with a population of approximately 27,000 (US Census Bureau 2019) (**Figure 1-1**). Humboldt Bay is best defined as a coastal lagoon because it primarily contains ocean water which is exchanged regularly through the bay entrance due to tidal fluctuations (Costa 1982). True estuaries, such as the San Francisco Bay, which receives flow from the Sacramento and San Joaquin rivers, are defined by having continual freshwater input. Humboldt Bay receives only minor seasonal freshwater inflow.

Humboldt Bay is approximately 14.1 mi (22.7 km) long and 4.2 mi (6.8 km) wide with a surface area at Mean High Water (MHW) of 24.5 mi^2 (63.5 km^2) (Costa 1982). The surface area at MHW reported by Swanson (2015) is slightly greater (26.5 mi^2 [68.65 km^2]) as it includes portions of the Mad River, Freshwater Slough, and Martin's Slough that connect to Arcata Bay, the shallow northern basin in Humboldt Bay (**Figure 1-1**). The other three areas of Humboldt Bay are South Bay, Entrance Bay, and the Main Channel that connects Arcata Bay to the other basins to the south. The Entrance Bay is the deepest portion, and contains, as its name suggests, the harbor mouth of Humboldt Bay, through which the water held in the remainder of the estuary is exchanged regularly with that of the coastal ocean. The Entrance Bay and Main Channel are regularly dredged to allow for navigation of large vessels, while Arcata Bay and South Bay are shallow and include large areas of mudflats and eelgrass beds that are periodically exposed during low tides.

The two largest areas of Humboldt Bay are Arcata Bay (14.28 mi^2 [37.0 km^2] at MHW) and South Bay (6.91 mi^2 [17.9 km^2] at MHW). Arcata Bay occurs to the north and is fed by various creeks. A long sandspit dune complex runs the length of its western side, and the north and east sides of the bay are bounded by marshes. Arcata Bay is shallow and wide, consisting of vast mudflats with drainage channels, and six islands. The South Bay, located just south of the Entrance Bay, is smaller than Arcata Bay. South Bay is also contained by a coastal sandspit and mainland marshes, and has a benthic environment made up of mudflats and their dendritic networks of channels, which facilitate tidal drainage.

Most of the freshwater in the Humboldt Bay estuary comes from creeks draining into Arcata Bay (around 85%), with only 3% of the freshwater entering into South Bay, and the remaining 12% falling as direct precipitation onto the estuary. However, compared to the saline water input from the ocean during daily tidal fluctuations, the freshwater input is extremely minimal. Therefore, the salinity of the bay (around 33.6 ppt) remains very near that of the coastal ocean (Barnhart et al. 1992).

Tides in Humboldt Bay follow a semi-diurnal pattern with two high and two low tides daily. Data from the NOAA tide station on the eastern shore of the Samoa Peninsula just to the north of the entrance channel (**Figure 1-1**) presented by Swanson (2015) show that the mean tidal elevation at the entrance to Humboldt Bay is 4.89 ft (1.49 m), with a maximum diurnal range (MHHW to MLLW) of 6.9 ft (2.1 m) (**Table 2-1**). Costa (1982) presented data showing that tides in Arcata Bay generally exhibit an increase in amplitude and a lag in phase from those observed at the mouth of the bay due to restriction to tidal flow between the two locations.

Table 2-1. Average tidal data from the NOAA North Spit, Humboldt Bay station from Swanson (2015).

Tidal Datum	Water Surface Elevation (ft [m], NAVD88)
MLLW	-0.33 (-0.10)
MLW	0.92 (0.28)
MSL	3.37 (1.03)
MHW	5.81 (1.77)
MHHW	6.52 (1.99)

Due to the shallow depths in Arcata and South bays, daily tidal fluctuations can result in maximum daily changes in the surface area of Humboldt Bay of up to 14.9 mi^2 (38.5 km^2) (MHHW – MLLW) (**Table 2-1**) (Swanson 2015). During these tidal extremes, the volume of water exchanged with the ocean can average 4,023 million ft^3 (Mft^3) (114 million m^3 [Mm^3]) (**Table 2-1**). The volume of water exchanged is reflected in that navigation is limited to smaller vessels in narrow tidal channels in Arcata and South Bay at low tide. The volume of the average tidal prism (MHW – MLW) for Humboldt Bay calculated from the data in **Table 2-2** is 3,118 Mft^3 (88.3 Mm^3).

Table 2-2. Surface area and volume for Humboldt Bay at various average tidal levels presented in Swanson (2015) from a hydrodynamic model (Anderson 2015 *unpublished data*).

Tidal Datum	Surface Area (mi^2 [km^2])	Volume (ft^3 x 10^6 [m^3 x 10^6])
MLLW	11.8 (30.6)	3,450 (97.7)
MLW	15.8 (40.9)	3,920 (111.0)
MSL	23.6 (61.1)	5,230 (148.1)
MHW	26.5 (68.6)	7,038 (199.3)
MHHW	26.7 (69.1)	7,473 (211.6)

Tidal exchange in the different regions of Humboldt Bay varies in part because peripheral areas do not flush as quickly as the channels (Barnhart et al. 1992). For example, Barnhart et al. (1992) state the tidal prism of Arcata Bay is approximately equal to the volume of North Bay Channel and thereby limits flushing Arcata Bay with ocean water. Turbulent mixing of nearshore and bay waters occurs primarily in the entrance channel and Entrance Bay (**Figure 2-1**).

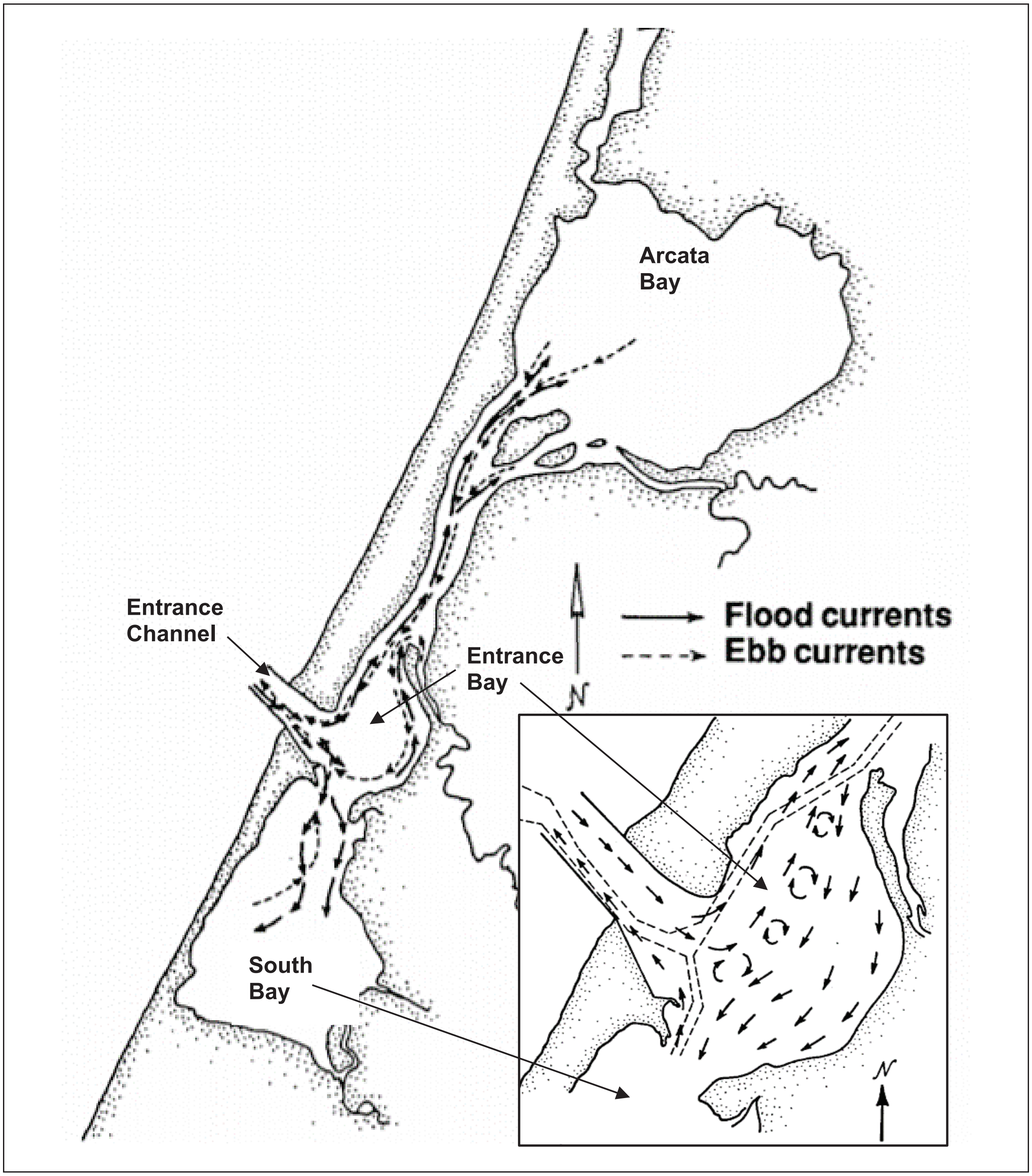

Figure 2-1. Ebb and flood tidal current patterns in Humboldt Bay with inset showing circulation into South Bay. Figures from Costa (1982).

The circulation in the Entrance Bay described in Costa (1982) is further detailed in the inset shown in **Figure 2-1**. On ebbing tides, the larger water mass exiting the North Bay Channel causes some of the water to be pushed to the eastern shore of the Entrance Bay and enter South Bay. This phenomenon was verified using anchored streamers and as stated by Costa (1982) indicates that "…activities in the northern parts of Humboldt Bay can affect the water masses in the extreme southern part of the bay."

Although the tidal prism of Humboldt Bay can be up to 54% of the MHHW volume, the volume of water replaced by new ocean water on an incoming tide will depend on several factors that affect mixing in the nearshore environment (Barnhart et al. 1992). Density differences between the ocean water and water from Humboldt Bay due to temperature and salinity differences may result in stratification that limits mixing in the nearshore environment (Gast and Skeesick, 1964). Other factors affecting mixing would include wind, waves, and the speed and direction of nearshore currents in the vicinity of the entrance channel. Ebb tide water from the bay may simply flow back into the bay during periods with low currents and calm sea conditions that are not sufficient to cause mixing or move water away from the mouth of the bay. According to Costa (1982), flushing of the bay has been estimated to occur from as few as 7 tidal cycles to as many as 40 tidal cycles. Swanson (2015) presents a more detailed estimate of flushing times in the bay which is consistent with Costa (1982). Swanson estimates flushing in 30 days for shallow areas in the upper reaches of Arcata Bay. It is likely that flushing times are considerably less for the area around the two proposed intakes because they are closer to entrance to the bay than areas described in these studies.

2.2 Biological Resources of Humboldt Bay

Humboldt Bay is a complex ecosystem with a diversity of habitats and biota that provides valuable resources for California. These resources support local fisheries and aquaculture operations, including a successful oyster culture industry that produces about 70% of the oysters grown in California (HT Harvey 2015). These resources are also ecologically important to the area, hosting over 400 species of plants, 300 species of invertebrates, 100 species of fishes, and 260 species of birds. The birds include species that rely on the bay as they travel the Pacific Flyway, a major migratory route for many western waterfowl.

The different benthic habitats in the Bay are shown in **Figure 2-2**, including the areas for oyster mariculture that occur in Arcata Bay. Although the figure shows a greater diversity of habitat types in Arcata Bay than in South Bay, the underlying habitat type in most of the areas designated as oyster mariculture, macroalgae, eelgrass, and intertidal is mudflats in both areas. The habitat around the intakes is mostly subtidal due to their location in the channel, although eelgrass occurs along the edges of the channel. The subtidal habitat likely consists of unconsolidated sand and soft sediments. Although the map indicates that eelgrass occurs along the shoreline in the areas of the intakes, the depth of the intakes, especially the RMT II intake, would limit any impacts to existing eelgrass.

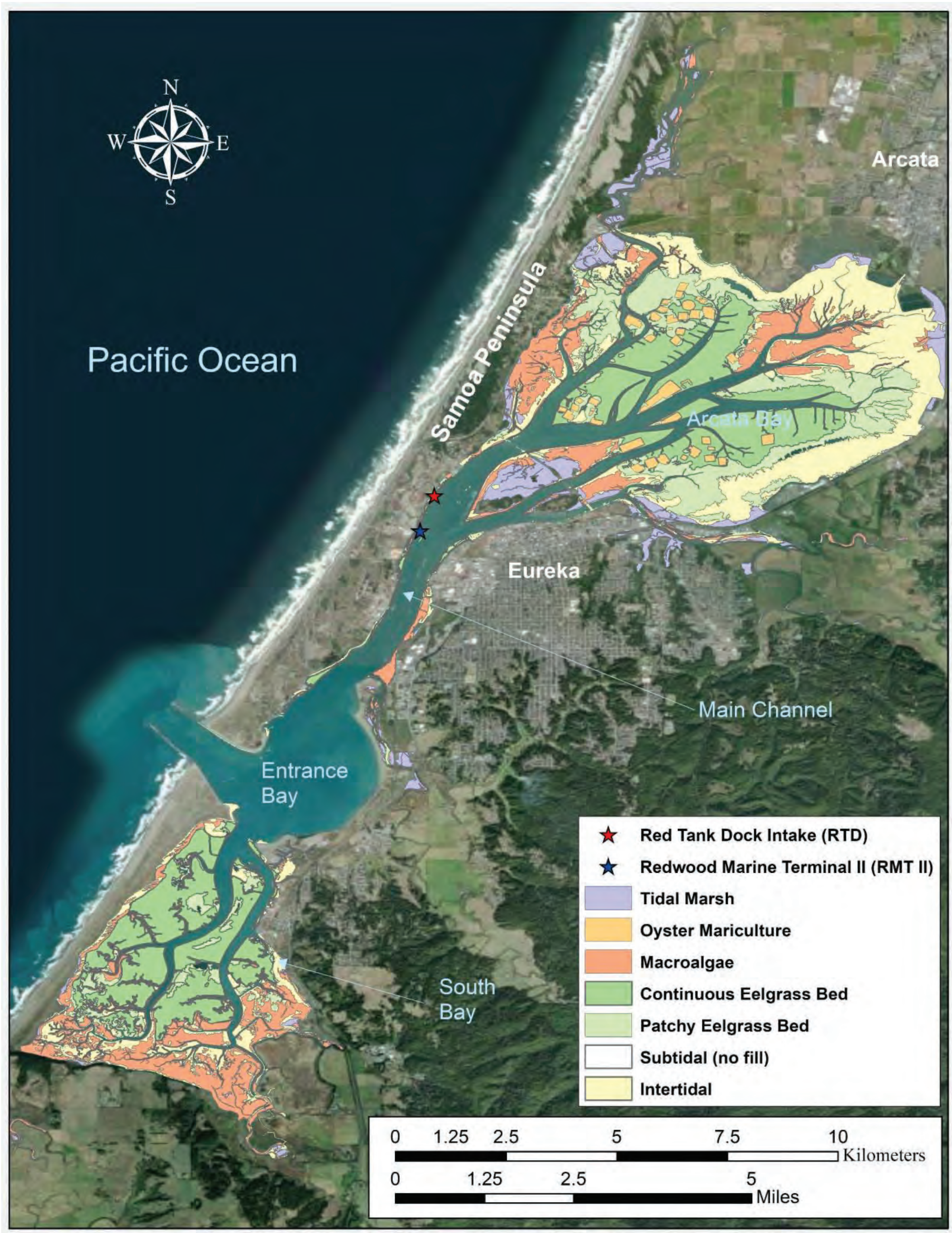

Figure 2-2. Map showing the classified benthic habitats in Humboldt Bay. Accessed 4/12/2023 at https://coast.noaa.gov/digitalcoast/data/.

2.2.1 Eelgrass Beds and Marshland Habitat

Approximately 20% of the benthic environment of the Humboldt Bay estuary's intertidal zone consists of eelgrass beds. Eelgrass plays many important ecological roles in bays and estuaries. They stabilize soft sediment substrate within the bay, reducing erosion and increasing water clarity that is beneficial to many other parts of the ecosystem. They also provide habitat structure that support a myriad of marine life. They are a nursery habitat for juvenile invertebrates and fishes, including commercially important species such as Dungeness crab (*Metacarcinus magister*). They are a deposition site for Pacific Herring (*Clupea pallasii*) eggs, as well as a direct food source for migratory brant geese (Merkel & Associates 2017). Despite its smaller size, South Bay has historically contained the majority of the eelgrass habitat in Humboldt Bay. This may be due to activities in Arcata Bay such as oyster farming that affects the establishment and growth of eelgrass in otherwise suitable habitat (HT Harvey 2015). Historically, the bay was once surrounded by a vast marshland consisting of salt, brackish, and freshwater gradients, though it has been drastically reduced by coastal development and diking, leading to a 90% decline from its natural state. Despite this decline in acreage, the marshland of Humboldt Bay estuary still provides a vital ecological function not only for the local resident species that inhabit these marshes year-round, but also for the migratory waterfowl that stop in the bay during their biannual passage (Barnhart et al. 1992).

2.2.2 Fishes

Earlier studies of fishes in Humboldt Bay referenced in Barnhardt et al. (1992) list that 110 species of fish inhabit Humboldt Bay at some point during their life cycles, although a more recent study by Gleason et al. (2007) that involved extensive sampling of multiple habitats in 2000 and 2001 found only 67 species.

The report by Barnhardt et al. (1992) compiles data from several past studies on fishes into an appendix that includes information on the habitat occupied by each species and whether the species abundance is rare, occasional, common, or abundant. The most abundant fishes in major species groupings are also discussed. The most abundant sharks were identified as the Sevengill Shark (*Notorynchus cepedianus*) and the Leopard Shark (*Triakis semifasciata*), which are fished both commercially and recreationally in the bay. Bat Rays (*Myliobatis californica*) are caught recreationally and abundant in the bay. The herring roe fishery was active in Humboldt Bay when Barnhardt et al. (1992) was published, and Pacific Herring were discussed as a separate species group with Northern Anchovy in the report. Pacific Herring enter Humboldt Bay in the winter to spawn, leaving their eggs clinging to eelgrass blades and man-made structure in Arcata Bay. Pacific Herring also play a critical role as a food source for other recreationally and/or commercially important species such as Lingcod (*Ophiodon elongatus*), sharks, and waterfowl. Northern Anchovy (*Engraulis mordax*) enter the bay in the spring and are targeted by Albacore (*Thunnus alalunga*) fishermen for live bait. The report also discusses the importance of Humboldt Bay as refuge and passageway for Chinook (*Oncorhynchus tshawytscha*) and Coho salmon (*O. kisutch*), as well as Steelhead (*O. mykiss*) and Cutthroat (*O. clarkii*) trout. Humboldt Bay estuarine areas serve as a nursery for juvenile salmonids, while the bay's freshwater tributaries serve as the spawning grounds to which adults return after maturing in the Pacific Ocean (Monroe 1973).

According to Gleason et al. (2007), several species of surfperches are found within Humboldt Bay, with the Shiner Surfperch (*Cymatogaster aggregata*) being the most abundant. Shiner Surfperch were found to be the second most abundant fish in Humboldt Bay after Threespine Stickleback (*Gasterosteus aculeatus*), comprising 14.9% of the fishes caught in a bay-wide sampling effort. A catch monitoring survey of recreational fishermen in Humboldt Bay found that surfperches made up 53% of all fishes caught by hook and line (Gotshall et al.1980). Surfperch also certainly represents an important forage fish in the bay, thus making them both directly and indirectly important to commercial and recreational fisheries.

Though typically associated with hard substrates, certain rockfish species reside within the bay. Studies by Gleason et al. (2007) showed that while Black Rockfish (*Sebastes melanops*) were the most abundant rockfish species in the bay. However, they represented less than 1% of the total fishes collected during the studies. Despite their relatively low abundance in the surveys by Gleason et al. (2007) Black Rockfish are often targeted and caught by recreational anglers. The Kelp Greenling (*Hexagrammos decagrammus*) and Lingcod are also targeted by anglers, primarily around the jetties that form the mouth of the bay. English Sole (*Parophrys vetulus*) and Speckled Sanddab (*Citharichthys stigmaeus*) are the most commonly caught flatfishes in the bay, but Dover Sole (*Solea solea*) and Starry Flounder (*Platichthys stellatus*) are also abundant.

The only currently available reference on larval fishes in Humboldt Bay is an ichthyplankton study by Eldridge and Bryan (1972) that involved year-long sampling in 1969. Five locations were sampled inside Humboldt Bay including a station along a sandy beach along the Main Channel approximately one mi (1.6 km) down the channel from Tuluwat Island (**Figure 1-1**) at a depth of 9.8–16.4 ft (3.0–5.0 m). Two other stations were located in Arcata Bay: one along the Eureka shoreline to the east of Tuluwat Island and one to the north of the island. The highest average number of larvae per tow was collected at the two stations in Arcata Bay, while the station north of Tuluwat Island had the highest numbers of species collected during the study. The most abundant species at those stations were Pacific Herring and Bay Goby (*Lepidogobius lepidus*). Overall, 37 species of fish larvae were collected during the study. Bay Goby was the most abundant species followed by Pacific Herring, Longfin Smelt (*Spirinchus thaleichthys*), and Arrow Goby (*Clevelandia ios*).

The average abundances of fish larvae in the Eldridge and Bryan (1972) study were much lower than the averages for more recent entrainment studies done along the coast of California from San Francisco to San Diego.[9] Eldridge and Bryan (1972) reported fish larvae within Humboldt Bay averaged 0.05 larvae per m^3 at two of the stations and almost 0.3 larvae per m^3 at the station north of Tuluwat Island. Fish larvae inside bays and estuaries in studies compiled from throughout California averaged 1.83 larvae per m^3. Within San Francisco Bay, fish larvae

[9] Data from Appendix E – Entrainment and Impingement Estimates (Steinbeck, 2010) in Final Substitute Environmental Document for Water Quality Control Policy on the Use of Coastal and Estuarine Waters for Power Plant Cooling, May 4, 2010.

averaged 0.95 larvae per m^3 (Tenera 2005). Abundances from studies along the coast averaged 0.95 larvae per m^3, the same value measured from the study in San Francisco Bay. These low abundances are likely due to the differences in the mesh size of the nets used in the sampling for the two studies. The Humboldt Bay study used a 0.02 in. (0.57 mm) mesh net, while the entrainment studies used a 0.013 in. (0.335 mm) mesh. As noted in Eldridge and Bryan (1972), their study design targeted both larval and juvenile fishes. The sampling likely underestimated the actual abundance of fish larvae, especially for species that hatch at very small sizes such as some of the flatfishes and croakers.

2.2.3 Special Status Fishes

In addition to salmonids, Endangered Species Act listed species within Humboldt Bay include the federally listed Tidewater Goby (*Eucyclogobius newberryi*), Green Sturgeon (*Acipenser medirostris*) and state-listed Longfin Smelt (LFS).[10,11] Although freshwater deltas and bays provide important habitat for both Tidewater Goby and LFS, surveys of fishes in Humboldt Bay in recent years have resulted in limited data on these listed species. Frimodig and Goldsmith (2008) found Tidewater Goby in the Elk River, Wood Creek, and McDaniel Slough. Surveys by the California Department of Fish and Game (now California Department of Fish and Wildlife [CDFW]) collected LFS during surveys in Humboldt Bay every year between 2003 and 2009 except for 2004 (CDFG 2009).

A Memorandum of Understanding (MOU) for this study was issued by the California Department of Fish and Wildlife on January 3, 2021 (CDFW MOU) for the potential take of larval and juvenile Longfin Smelt (*Spirinchus thaleichthys*) and Coho Salmon (*Oncorhynchus kisutch*).

The larvae for both Tidewater Goby and LFS have limited tolerance of salinities found in the ocean water that usually occurs in Humboldt Bay. Tidewater Goby larvae can tolerate salinities up to 10 ppt (Swenson 1999). Baxter et al. (1999) reported that newly hatched LFS larvae have a salinity tolerance of 2–6 psu after a few weeks, and as they move downstream can tolerate salinities around 8 psu. The salinity tolerance reported by Baxter et al. (1999) is supported by more recent laboratory studies on salinity tolerances of early LFS larvae which showed highest survival and growth at salinities of 5 and 10 psu (Yanagitsuru et al. 2021a). The same studies showed that salinities of 20 psu presented osmoregulatory problems for the larvae and levels of 32 psu resulted in almost 100% mortality. The salinity of Humboldt Bay is around 33.6 ppt, very near that of the coastal ocean (Barnhart et al. 1992). Although adult Tidewater Goby are restricted in Humboldt Bay to areas with low salinities, adult LFS have been found in many areas of the bay and even offshore (Garwood 2017). A previous study of larval fishes in the late 1960s in Humboldt Bay determined that LFS larvae were "common" in Humboldt Bay (Eldridge and Bryan 1972). As a result of concerns regarding potential effects of the intakes on LFS larvae, it was necessary to obtain the MOU from CDFW for LFS larvae prior to starting the sampling for

[10] https://www.fws.gov/arcata/es/fish/Goby/goby.html. Viewed February 12, 2021.

[11] https://wildlife.ca.gov/Conservation/Fishes/Longfin-Smelt. Viewed February 12, 2021.

this study. The original MOU issued January 3, 2022 allowed a take of 100 LFS larvae, which was amended on February 14, 2022 to allow a take of 200 LFS larvae. The allowed take level was not exceeded during the study.

2.2.4 Dungeness Crab

Dungeness crab is an important commercial species for the fisheries that operate along the northern California coast in the vicinity of Humboldt Bay. Although fewer landings were recorded in the ports of Humboldt Bay and Eureka than in Crescent City in 2019, the Dungeness crab fishery reported the highest value of any fishery operating out of the ports in the Eureka area.[12]

In addition to supporting the Dungeness crab fishery in the coastal waters, estuarine areas like parts of Humboldt Bay are important habitat for juvenile stage crabs (Armstrong et al. 2003). Dungeness crab have a complex life history that involves multiple larval stages. Larvae hatch from eggs carried under the carapace of the female crabs as pre-zoea in December and then pass through the development of five stages of zoea larvae over a period of approximately four months (Poole 1966, Reed 1969, Lough 1976). The pre-zoea and zoea stages of Dungeness crab larvae are difficult to distinguish from the zoea larvae of other species of crabs. After maturing to the megalops stage, the larvae utilize coastal upwelling events to migrate back to nearshore or estuarine environments (Shanks and Roegner 2007). When the megalopae develop into juveniles, they settle onto the benthos of nearshore and estuary environments. After 1.5–2 years they begin to emigrate out into the ocean and seek deeper habitat. Age 3-4 individuals are usually big enough to enter the fishery and have reached the retainment size of 5.8 in. (14.6 cm).

2.2.5 Mariculture

Humboldt Bay provides suitable habitat for mariculture such as farming Pacific oyster (*Crassostrea gigas*), which is a prevalent practice within the Arcata Bay arm of the larger Humboldt Bay system. A seaweed farming effort is now operating in the main channel. The resulting growth of seaweed should be beneficial to water quality in the bay by removing CO_2, increasing O_2 and nutrients, and contributing to the overall health of the ecosystem as well as providing nursery habitat for larval and juvenile fishes. A small-scale recreational fishery also historically existed for the softshell clam (*Mya arenaria*), which is not a native resident of Humboldt Bay but was either intentionally or accidentally introduced (Barnhart et al. 1992).

2.2.6 Waterfowl

According to Shapiro and Associates (1980), over 100 species of migratory waterfowl spend part of the year in and around Humboldt Bay. Including resident (non-migratory) birds, 251 species of terrestrial birds and waterfowl can be observed in Humboldt Bay or its adjacent marshlands. Species that are important to recreational hunters such as the American widgeon (*Mareca*

[12] https://wildlife.ca.gov/Fishing/Commercial/Landings#260042586-2019. Accessed 02/19/2021.

americana), mallard (*Anas platyrhynchos*), and many others forage in the eelgrass beds, mudflats, and marshland communities that exist within the Humboldt Bay estuary. These birds support 25,000 hunter-days in Humboldt Bay each year (Monroe 1973). One of the primary motives for the creation of the Humboldt Bay National Wildlife Refuge was to restore a substantial wintering population of brant geese to the bay (Barnhart et al. 1992). Humboldt Bay is a critically important ecosystem for migratory waterfowl such as brant geese. In addition to migratory waterfowl, Humboldt Bay also provides habitat for large numbers of other species of birds. For example, one recent study in the bay estimated over 203,000 individual shorebirds representing 26 distinct species (Colwell & Feucht 2018).

3.0 Methods

This section describes the sampling design, the methods used in the field collection and laboratory processing of meroplankton samples for the study, and the methods used in the modeling and analysis of the data using the ETM to determine the potential effects due to entrainment from the proposed RMT II and RTD intakes on the eastern shore of the Samoa Peninsula (**Figure 1-1**). The methods for the calculation of estimates of the Area of Production Foregone (APF) using the ETM are also presented.

3.1 Study Design

3.1.1 Sampling Locations

As described in the previous section of this report, Humboldt Bay consists of four areas (**Figure 1-1**). The largest by surface area is Arcata Bay, which is separated from the Pacific Ocean by the Samoa Peninsula where the RMT II and RTD intakes are located. The other three regions of Humboldt Bay are South Bay, Entrance Bay, and the Main Channel that connects Arcata Bay to the other basins to the south. All of the regions of the bay were included in the source water sampling because the tidal current flows described by Costa (1982) show that the waters from all of the bay regions are mixed in the Entrance Bay (Section 2.1 and **Figure 2-1**). Sampling locations were located in each of the regions of Humboldt Bay (**Figure 3-1**). Sampling locations at both the RMT II (E1) and RTD (E2) intakes were used to estimate the concentrations of meroplankton subject to entrainment. There were also six source water stations that were used to estimate the concentrations of meroplankton in the different areas of the bay (stations SW1–6). The source water is defined as the area encompassing larvae potentially subject to entrainment.

Samples were collected at both intakes to allow for calculations of entrainment effects separately for each intake as they will be operated at different intake volumes and potentially on different schedules. Collecting samples from both intakes will potentially help determine the amount of mixing that occurs during tidal exchange based on the differences across the gradient of stations from the Entrance Channel (SW4) through the Main Channel (SW3) into the Samoa Channel where the two intake stations are located and finally into Arcata Bay (SW2) (**Figure 3-1**). The locations of the source water sampling locations were selected based on input from oceanographers and researchers with expertise on the biology and circulations patterns of the Humboldt Bay system.

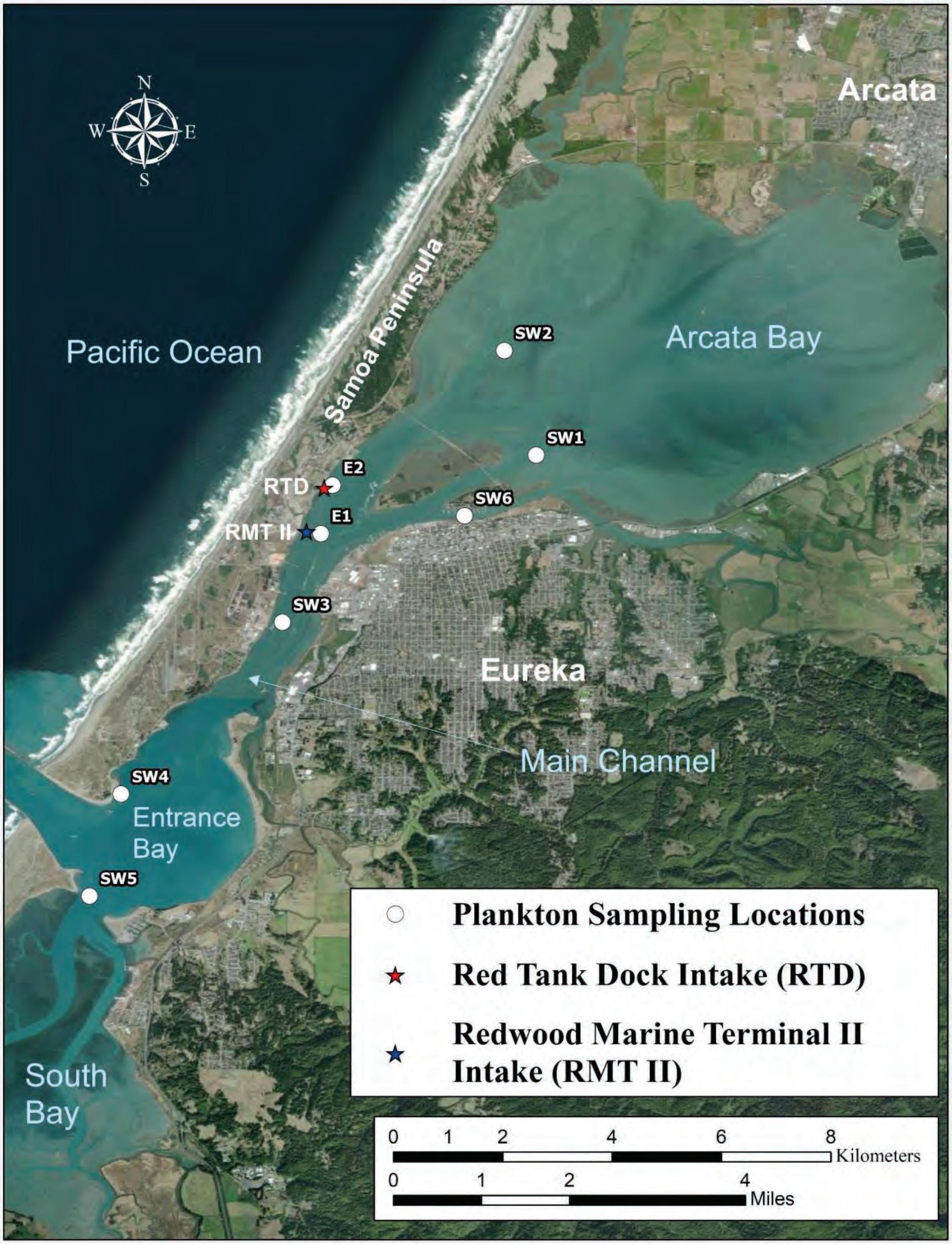

Figure 3-1. Map of the entrainment (E) and source water (SW) sampling stations.

3.1.2 Sampling Methods

The methods used for sample collection were similar to those developed and used by the California Cooperative Oceanic and Fisheries Investigation (CalCOFI) in their larval fish studies (Smith and Richardson 1977) that have been conducted since the 1950s, and subsequently have been used in other intake assessments in California conducted over the past 25 years (e.g., Tenera 2005). The sampling at the two entrainment (E1 and E2) and six source water stations (SW1–6) shown in **Figure 3-1** were sampled once a month starting on January 11, 2022 and continuing through the final survey on December 6, 2022. The field collection at each sampling location involved towing a bongo frame featuring two 2.3 ft (0.7 m) diameter openings. Each opening is equipped with a 0.01 in. (335 µm) mesh plankton net, codend (collection bucket), and calibrated flowmeter. The frame and nets were lowered from the surface to a depth of less than 3.3 ft (1.0 m) above the seabed and towed back to the surface at a speed of between one and two knots.

The plankton nets were towed until a target volume ranging from 10,567–13,209 gal (40–50 m^3) of seawater per net was collected. This target volume was determined in the field by checking the readings on the flowmeters attached to the nets. Prior to and after each tow, the flowmeter counter values were recorded on sequenced waterproof datasheets to allow for calculation of the volume of water filtered by each net. At the completion of each tow, the frame and nets were retrieved from the water and the collected material was rinsed into the codends attached to the end of the nets. During the months of January–April, November, and December, the contents of both nets were transferred into a single labeled jar and preserved in 95% undenatured ethanol to allow DNA verification of the identifications of all unspeciated fish larvae from the taxonomic family Osmeridae which includes LFS. The DNA analysis of the samples collected during these months was conducted by the research laboratory of Dr. Sean Lema at California Polytechnic State University, San Luis Obispo. The samples collected during May–October were preserved in a solution of 5–10% buffered formalin-seawater solution, because LFS larvae were not expected to be present during those months and the larval identifications did not need to be verified using genetic analysis.

Each survey consisted of sampling all eight stations during one daytime cycle and again during a nighttime cycle to characterize potential diel variation. Surveys were made without regard to tide cycle, due to the large area and number of stations that were surveyed. An AML Oceanographic AML-3 multiparameter sonde was used to collect data on water temperature and salinity at each station during sampling. A different CTD unit was used on the first survey in January which failed and as a result no CTD data were collected at any of the stations during that survey. Long-term continuous data on other hydrographic parameters are available from instrumentation maintained by the Central & Northern California Ocean Observing System (CeNCOOS) at stations located in- Humboldt Bay.

Previous ETM analyses excluded larval fishes that were too large to fit through mesh screens on the ocean intakes, even though these fishes were collected in the ETM field studies. For example, at power plants in California where the intake screens were fitted with 3/8 in. (9 mm) traveling screens ETM analyses assumed that larvae or juvenile fishes with notochord lengths (NL) of 1.2 in. (30 mm) or larger were not subject to entrainment. WWS modules covering the intakes proposed for this project will consist of a slot opening of 0.04 in. (1 mm). For the purposes of this study and analysis, we assumed larvae with NLs of 0.98 in. (25 mm) or greater would not be subject to entrainment due to the smaller mesh size on the screens for these intakes. This decision was made based on experience on previous studies including data on head capsule dimensions that support the assumption that fish larvae at this size would not be entrainable. All larval and juvenile fishes collected during the sampling with NLs of 0.98 in. (25 mm) and greater were identified, length recorded or estimated, and then returned to the bay as gently and as soon as possible as required in Section 2081(a) of the MOU issued for the project by CDFW for the potential take of larval and juvenile LFS, and Coho Salmon (*Oncorhynchus kisutch*).

Field data were recorded on preprinted data sheets formatted for entry into a computer database for analysis and archiving. All of the data were recorded on sequenced data sheets, entered into an Access® computer database, and then verified for accuracy against the original data sheets.

3.1.3 Target Organisms

The sample processing described below in Section 3.1.4 included the following targeted groups of larval fish and invertebrate zooplankton:

1. Megalopal stages of Brachyuran. The Brachyuran crabs includes species of crabs targeted by commercial fisheries including Dungeness, brown (*Romaleon antennarium*), yellow (*Metacarcinus anthonyi*), and red (*Cancer productus*) rock crabs;
2. Small juvenile squid; and
3. Fish eggs and larvae.

The invertebrate larval groups included in the processing were selected because they can be effectively sampled using a 0.01 in. (335 µm) mesh net and can generally be identified to species. This size mesh is used because it effectively samples fish eggs and larvae, is required in the Desalination Amendment, and has been the standard mesh used on previous entrainment studies in California.

The processing of the samples from the study will not include the processing of fish eggs. There are several reasons to exclude fish eggs:

- Most fish eggs cannot be identified to lower taxonomic levels without DNA analysis of each egg. Many species within a family or order of fishes have eggs of similar sizes and morphological characteristics, especially at very early developmental stages.
- Using the ETM, larval durations for the fish taxa analyzed can be adjusted to account for the entrainment of eggs by assuming that the rate of entrainment is the same for eggs and larvae and increasing the larval duration to include the duration of the egg stage. While this increases the level of uncertainty associated with the modeling results, the level of uncertainty would be much greater in determining the percentage of unidentified eggs that cannot be sourced to a specific species of fish.
- It is very difficult or impossible without considerable additional analysis to determine if all of the collected eggs are fertilized and viable.

The taxa included in the ETM assessment were identified following the completion of all the sample processing. The ETM assessment focuses solely on fish larvae that are small enough to be entrained through the 0.04 in. (1 mm) intake openings. Although megalops stage crab larvae were also processed from the samples, these larvae are too large to pass through the intake openings and therefore are not analyzed as [part of the intake assessment. For informational purposes, the sampling results for the crab larvae are presented in this report.

The larval fish taxa analyzed using the ETM were selected based on their abundances in the samples at the two entrainment stations (E1 and E2), and the number of surveys in which they were collected. The taxa comprising approximately 95% of the total larvae collected at the two entrainment stations were analyzed unless a taxon occurred in less than three surveys. The reasons for these criteria are 1) to analyze the most abundant taxa being entrained because these are the most likely to be impacted by the effects of entrainment, and 2) to only analyze taxa with data that provide robust estimates from the ETM. For taxa in low abundance, it is also unlikely that enough larvae would be available to provide adequate data on the lengths of the larvae to obtain reasonable estimates of their age in days, which is an important parameter for the ETM. The ETM is also based on having multiple estimates of *PE* for the calculations. This requires that taxa are collected from at least three surveys to provide a robust estimate of P_M from the ETM.

An exception to the above criteria would be any species listed on Federal or California endangered species lists. In Humboldt Bay, this would include LFS. LFS or other listed species collected at the entrainment stations will be included in the analysis to estimate the annual entrainment of the species, a requirement under the CDFW MOU issued for the potential take of LFS or salmonids during the sampling for the project.

3.1.4 Sample Processing

Samples from the field were shipped to the Tenera laboratory in San Luis Obispo. After at least 72 hours, the samples originally preserved in 5–10% buffered formalin-seawater solution were transferred into a solution of 70–80% ethanol preservative; the samples initially preserved in 95% ethanol remained in that preservative during processing. When samples were particularly dense, a Folsom plankton splitter was used to divide the samples into smaller, more manageable subsamples representing ½, ¼, or some other fraction of the original composite sample. As required in the CDFW MOU for the potential take of larval and juvenile LFS, the entire volumes of the samples collected from the January–April and November–December 2022 surveys were processed. This was required to ensure an accurate count of LFS larvae was recorded. Processing consisted of examining the collected material under a dissecting microscope and removing and counting all the fish eggs, fish larvae, and crab megalopa larvae. The eggs and larvae were placed in labeled vials and then identified to the lowest possible taxonomic level. The developmental stage of fish larvae (yolk-sac, preflexion, flexion, postflexion, or transformation stage) was also recorded.

Fish specimens that were not able to be identified to the species level were instead identified to the lowest taxonomic classification possible. Some of the taxa collected are difficult to identify to the species level due to the similarity between larvae of related species. Myomere counts (muscle segments), and pigmentation patterns are commonly used to identify larval fishes;

however, this can be problematic for some species. For example, several species of the Gobiidae family of fishes[13] share similar characteristics during early life stages, making identification to the species level uncertain (Moser 1996). In other cases, the larvae may have been damaged or fragmented during collection making identification problematic. Larvae were only counted if the fragment included the head capsule of the larvae. Other fragments were recorded but not included in the counts used in any analyses. Overall, unidentified larvae comprised 0.65% of the total fish larvae removed from the samples.

DNA Analysis Methods

The taxonomic identification of all unidentified Osmeridae larvae and LFS was verified using DNA (deoxyribonucleic acid). The DNA analysis was conducted by the research laboratory of Dr. Sean Lema at California Polytechnic State University, San Luis Obispo. The following are the methods used in the analysis.

Genomic DNA was isolated from each larva using the DNeasy Blood and Tissue Kit (Qiagen, Valencia, CA, USA) and then quantified using a P300 NanoPhotometer (Implen, Inc.). For each specimen, a 592 bp nucleotide region of the mitochondrial cytochrome c oxidase subunit-I (CO1) gene was amplified in a polymerase chain reaction (PCR) containing 25 µL of GoTaq® G2 Hot Start PCR Master Mix (Promega Corp., Madison, WI, USA), 1 µL each of forward and reverse primer (50 mM), 3 to 18 µL of nuclease-free H2O, and 5 to 20 µL of DNA template. Relative amounts of nuclease-free water and DNA template varied according to the concentration of extracted DNA from a specimen. PCR was performed using a nested set of degenerate oligonucleotide primers custom designed to a consensus region of partial sequences of the CO1 gene from LFS. These sequences were aligned to partial CO1 sequences from other smelt (Family Osmeridae) known to occur in or near Humboldt Bay: Night Smelt (*Spirinchus starksi*), Surf Smelt (*Hypomesus pretiosus*), Whitebait Smelt (*Allosmerus elongatus*), and Eulachon (*Thaleichthys pacificus*). All PCR products were examined on 1.2% agarose gels with SYBR™ Safe DNA Gel Stain (Thermo Fisher Scientific), and products with bands of expected size were cleaned (QIAquick PCR Purification Kit, Qiagen, Valencia, CA, USA) and then Sanger sequenced with the same primers used for the PCR. The resulting partial CO1 sequences were then assembled using Sequencher v.5.4 software (Gene Codes Corporation, Ann Arbor, MI USA). Species identification was determined by Basic Local Alignment Search Tool (BLAST) comparison of each partial CO1 gene sequence for the species to sequences within the GenBank database of the National Center for Biotechnology Information (https://www.ncbi.nlm.nih.gov/).

Larval Measurements

Notochord length and head capsule dimensions were measured for a representative number of larval fish from each survey from the two entrainment stations (E1 and E2) and the two closest source water stations (SW2 and SW3) using a video capture system and image analysis software. The length data were used to estimate the age of larvae and the period of time that they would

[13] The Gobiidae are the taxonomic category of fishes that includes all the species of gobies, which are small fishes that can be abundant in bays, estuaries, and nearshore areas.

have been subject to entrainment. The length and head capsule measurements of the larvae with NLs of less than 0.98 in. (25 mm) were used to determine the size of the larvae from each species that would not be subject to entrainment. The data from the two closest source water stations (SW2 and SW3) were included to provide a larger number of larvae from each taxon for the length measurements. It was assumed that the larvae from those two source water stations would be similar in size to the larvae collected at the entrainment stations and would not bias the estimates for the age calculations.

3.1.5 Quality Assurance/Quality Control Program

A QA/QC program was implemented for the field and laboratory components of the study. The field survey procedures were reviewed with all field personnel prior to the start of the study and all field personnel were given printed copies of the procedures. Field personnel were trained at the start of the project and then training was continued throughout the project to ensure that the field sampling procedures were implemented properly. In addition to training, a periodic review of sampling procedures was undertaken by project managers and quality control assessments were completed during the study to ensure that the field sampling continued to be conducted properly.

A detailed QA/QC program was also applied to all laboratory processing. The laboratory procedures were reviewed with all laboratory personnel prior to the start of the study. All laboratory personnel were also given printed copies of the procedures. The laboratory processing initially involved the removal of larvae from the samples, which was performed by a team of trained sorters, and then the larvae were identified to the lowest taxonomic level by specialist taxonomists. Separate QA/QC procedures were developed for sorters and taxonomists.

During the initial training period for each sorter, their first ten samples were re-sorted by a designated QC sorter. During re-sorting, any sorters would fail QA/QC standards if they missed more than one of the target organisms when the total number of larvae in the sample was less than 20. For samples with 20 or more larvae the sorter had to maintain a sorting accuracy of 90%. After a sorter had sorted ten consecutive samples with greater than 90% accuracy, the sorter had one of their next ten samples randomly selected for a QA/QC check. If the sorter failed to achieve an accuracy level of 90%, their next ten samples were re-sorted by the QC sorter until they me the required level of accuracy. If the sorter maintained the required level of accuracy, one of their next ten samples was re-sorted by QC personnel.

A similar QA/QC program was implemented for the taxonomists identifying the organisms in the samples. During the initial training period for each taxonomist, their first ten samples were completely re-identified by a designated QA/QC taxonomist. Taxonomists were required to maintain a 95% identification accuracy level for these first ten samples. After the taxonomist had identified ten consecutive samples with greater than 95% accuracy, the taxonomist had one of their next ten samples checked by a QA/QC taxonomist. If the taxonomist maintained an accuracy level of 95%, then they will continue to have one of ten samples checked by a QA/QC taxonomist. If a taxonomist fell below this level, then the next ten consecutive samples the taxonomist had identified were checked for accuracy. Samples were re-identified until ten consecutive samples met the 95% criterion. Identifications were verified with taxonomic voucher collections maintained by Tenera.

3.1.6 Initial Data Processing and Entrainment Estimates

For samples that were split with the Folsom splitter (see Section 3.1.2), counts of eggs and larvae were multiplied by the denominator of the fraction (e.g., doubled for half-splits, 4x for quarter splits, etc.). Once split samples had been adjusted, sample counts were combined with sample volumes to calculate the concentrations (ρ) of larvae in each sample, expressed as larvae per 1,000 m^3 in the data summaries. These concentrations were used to estimate the average number of larvae entrained each day ($\hat{E}_{day}$) for each taxon analyzed as follows:

$$\hat{E}_{day} = \bar{\rho}_{E_{day}} \cdot \hat{V}_{E_{day}}, \quad \text{Equation 1}$$

where $\hat{E}_{day}$ is the estimated entrainment per day, $\bar{\rho}_{E_{day}}$ *is the* average entrainment concentration per day for the taxon based on the two sampling cycles, and $\hat{V}_{E_{day}}$ is the maximum intake volume for the RMT II (7.29 mgd [29,980 m^3]) and RTD (3.96 mgd [14,990 m^3]) intake. The associated variance estimator for daily entrainment is calculated as follows:

$$Var(\hat{E}_{day}) = \left[\frac{\hat{V}_{E_{day}}{}^2 S^2}{n_{day}}\right], \quad \text{Equation 2}$$

where S^2 is the variance calculated from n_{day} samples collected during a 24-hour period, usually two (e.g., one day, one night sample). These estimates of daily entrainment are then expanded into entrainment estimates for each survey period by multiplying $\hat{E}_{day}$ by the number of days in each survey. The associated variance estimator is corrected as follows:

$$Var(\hat{E}_{Survey}) = \left[\frac{\hat{V}_{E_{day}}{}^2 S^2 d^2}{n_{day}}\right], \quad \text{Equation 3}$$

where d is the number of days in each single-survey period, which was approximately 30, but varied depending on the number of days between surveys.

The annual estimates are calculated by summing the entrainment and variance estimates for all 12 surveys. These variance estimates for each taxon are used in calculating the standard errors presented with the entrainment results.

3.1.7 Larval Age Estimation

A fundamental assumption in the ETM is that the population of larvae subject to entrainment are exposed to entrainment for a period of time equivalent to the age of the larvae collected at the entrainment station.

The approach used to calculate the age of larvae, and therefore the period of time that larvae for each taxon are exposed to entrainment, has evolved over time. Early studies used the average and maximum lengths of the larvae to calculate a range of estimates for each taxon. However, the lengths of the larvae collected for most species show a large variation in hatch length and the published hatch lengths for many taxa are much larger than most measurements from entrainment studies. In some taxa, the published larval hatch lengths are greater than the average length of larvae collected in the entrainment studies. For example, in a study by Garrido et al (2015), the hatch length of Pacific Sardine from their samples varied from 2.57–4.18 mm. According to Moser (1996), the hatch length of Pacific Sardine varies from 3.5–3.8 mm.

Larval length is right-skewed because many more small larvae are collected than large larvae. Therefore, hatch length in this study was calculated as the median length of larvae plus the first percentile length divided by 2. This calculation usually results in a value close to the hatch size reported in the literature (e.g., Moser 1996). Calculated hatch lengths were checked for each of the taxa analyzed against published estimates of hatch size.

To be consistent with the ETM that provides estimates of entrainment effects that are less subject to interannual variation in abundance, the goal of determining the length of time that the larvae are exposed to entrainment should be to provide an unbiased estimate that is also representative of the larger population that is also less subject to interannual variation in abundance. Bootstrapping is an iterative statistical process that involves the random resampling of a population dataset with replacement to provide an approximate distribution of values such as a variance, median, mean, or standard variation. Bootstrapping can be used to generate a large sample size of hatch length estimates. This statistical procedure was used to provide a better representation of the sampling distribution and variation of the population. One-thousand random samples of 100 length measurements were drawn for the NL measurements for each taxon with replacement. The random samples were proportionally allocated among the surveys based on the fractions of the population present in the source water. Statistics calculated from the bootstrap samples were used to calculate the NL estimates used in calculating the period of time the larvae were exposed to entrainment.

As explained in the Addendum on Longfin Smelt provided for the Initial ETM Assessment, small larvae of this species have limited tolerances of salinities greater than 10–12 psu and would not survive the salinities levels that are close to seawater (~32 psu) that normally occur in the area of the intakes. The larvae are likely dead at the time of collection when salinities are at these levels and should not be included in the ETM analyses from the study. Therefore, data on NL are also important in determining the proportion of larvae subject to entrainment for certain species that may not be able to tolerate salinity conditions in that area of the Bay. This is important for Longfin Smelt, a species listed as threatened under the California Endangered Species Act.[14]

[14] https://wildlife.ca.gov/Conservation/Fishes/Longfin-Smelt. Viewed February 12, 2021.

3.1.8 Measurements for WWS Efficiency

Recent studies on larval fish entrainment at most of California's coastal power plants have resulted in an extensive database on larval fish composition, seasonal abundance, and size frequencies. Details on these studies are provided in Steinbeck (2010). A study by Tenera (2011) involved re-measuring a subset of the most abundant larval fishes collected during studies at several of the power plants listed in Steinbeck (2010). The data from all the studies used in Tenera (2011) were collected using the same 0.013 in. (335 µm) Nitex mesh nets used in this study, the nets were towed in the immediate vicinity of CWIS intakes at the coastal power plants. The study (Tenera 2011) involved measuring a randomly selected subset of larvae for several taxa from the entrainment samples collected during the studies at the facilities. The body length (standard [notochord] length [NL]), head width, and head depth (**Figure 3-2**) were measured for each specimen to the nearest 0.004 in. (0.1 mm) using a digital camera mounted on a dissecting microscope interfaced with digital imaging analysis software. The analysis of notochord length and head capsule dimensions in Tenera (2011) was done using an allometric regression model where head capsule dimension was assumed to be a power function of notochord length. This type of regression model is used to describe changes in body shape with growth (e.g., Fuiman 1983, Gisbert et al. 2002, and Pena and Dumas 2009).

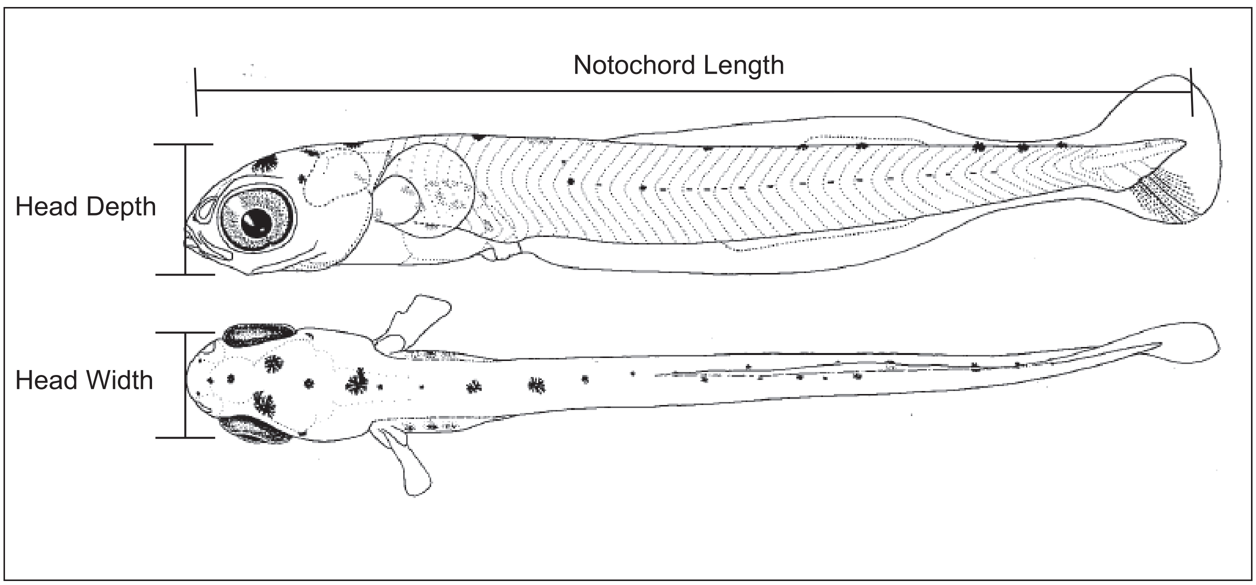

Figure 3-2. Illustration of the measurement locations for notochord length and head depth (height) and width of a preflexion stage larval fish. Larval fish is a jacksmelt from Moser (1996).

The same approach used in Tenera (2011) was used on the measurements from the larvae collected during this study. The set of parameter estimates from the allometric regression models of the data were used to estimate head capsule dimensions in relation to larval length for the seven taxa analyzed in this study. In theory, individuals with head capsules larger than the 0.04 in. (1.0 mm) slot opening would be excluded from entrainment, even if the approach vector was perpendicular (head-on) to the screen. Length-specific probabilities of entrainment were calculated for the slot opening using estimates of variability around the allometric regressions from the analyses in Tenera (2011). To describe the effects of this variation on head capsule dimensions, a Monte Carlo simulation, which is a statistical model used to predict stochastic outcomes by repeated random sampling, was used to generate the proportion reduction in entrainment for each length class. The Monte Carlo simulation allowed for the incorporation of morphological variation seen due to the variation in the relationship between larval fish length and head capsule dimension. In order to relate each 1 mm (0.04 in.) length increment to the potential for entrainment, it was necessary to incorporate this variation in body length (NL) to head capsule dimension in the model. The simulation generated 1,000 estimates of head width and head depth for each millimeter size class of notochord length (from a minimum up to a maximum length determined for the taxon) using the estimated standard errors for each regression parameter. Errors for the regression parameters were assumed to be normally distributed. Full details on the methodology are provided in Tenera (2011).

Data on head capsule dimensions was important in identifying larvae that were too large to become entrained. This was determined using measurements of the width and depth of the head capsule for the larvae. Using head capsule dimensions should be a conservative approach for determining which size larvae would not be entrained by the one mm slot openings used on the intake screens for the project. Tenera has measurements for thousands of fish larvae and has developed mathematical models that provide the relationship between larval fish length and head capsule dimensions for at least some of the fishes likely to be collected during the study. The analyses associated with these models have been used in previous studies at desalination plants and in the development of the Desalination Amendment. The results from these previous studies will be used for comparison with the results for the same taxa from this study where possible.

3.2 Analysis

The analysis of the data includes calculations of standard statistics on the numbers of taxa collected during the sampling and graphical analyses of those abundance patterns. The primary method used to estimate the effects of entrainment is the ETM, which is mandated for use in the assessment of intake systems by regulatory agencies in California. The ETM methodology used in California was developed by scientists at Tenera and academic institutions (Steinbeck et al. 2007) and has been used on numerous projects throughout California (e.g., MBC and Tenera 2005, Tenera 2005, Tenera 2008, Tenera 2010, Tenera 2014a, Tenera 2014b). The ETM is described in the following sections.

3.2.1 Empirical Transport Model (ETM)

The assessment for this project used the ETM to estimate the potential impacts to fish and invertebrate larvae due to entrainment. The basis of the ETM is an estimate of the daily mortality resulting from proportional entrainment (*PE*). The *PE* is an estimate of the number of larvae lost due to entrainment as a proportion of all the larvae in the source water that are potentially subject to entrainment (Steinbeck et al. 2007). One of the advantages of the ETM is that the *PE* provides a relative measure of the impacts due to entrainment that should be more representative than methods that provide an absolute measure of the numbers of entrained larvae. Absolute measures of impact based on annual estimates of the number of larvae entrained will change considerably over the years because of numerous physical and biological factors that affect larval production and survival. For example, CalCOFI data on changes in average annual larval fish abundances reported in McClatchie et al. (2018) show variation as high as four orders of magnitude among years. This high level of variation in larval abundance is due to changes in ocean conditions from year to year. This level of variation makes conclusions about absolute numbers of entrainment losses from any particular year almost meaningless without long term study.

While absolute losses would be expected to vary considerably among years, the variation in the proportional losses to a fish population due to entrainment, represented by the *PE*, will likely be considerably less and will largely depend on the operation of the facility. This feature also allows regulators to directly track potential losses to source water populations of larvae and other plankton by just tracking the changes in operation of a facility.

For these reasons, the ETM has been the preferred approach for assessing entrainment impacts in California since it provides a relative measure of impact integrated over some time period (called proportional mortality [P_M] in the ETM terminology) that should vary much less over time than absolute levels of impact, such as an estimate of total entrained fishes.

The ETM is a demonstrably useful method for assessing impacts because the P_M provides the same type of information used in fisheries management. That is, the estimates of P_M are similar to estimates of the effects of fishing mortality on a population and, in this context, can be interpreted relative to other sources of mortality. Fisheries managers reduce the level of fishing mortality on a population by limiting the number of fishers targeting a population or closing areas of a population to fishing. These adjustments are calculated on a relative or proportional basis since estimates of natural and fishing mortality are calculated from survival proportions. Interpreted using these standard measures used by fisheries managers, an estimate of P_M that is very low relative to other natural sources of mortality and levels of natural variation, provides evidence that entrainment effects on that organism are not likely to be significant to the source water population subject to entrainment. Another important consideration that only applies to the assessment of impacts using the ETM estimate of P_M is that the mortality is occurring to the stock of larvae in the source water body that are subject to entrainment and not an adult population.

The ETM approach used in this study and in other intake assessments from California use a modified version of the ETM first proposed by the U.S. Fish and Wildlife Service to estimate mortality rates resulting from cooling water withdrawals by power plants along the Hudson River in New York (Boreman et al. 1978, 1981). The ETM provides an estimate of incremental mortality (a conditional estimate of entrainment mortality in absence of other mortality; Ricker 1975) based on estimates of the fractional loss to the source water population of larvae represented by entrainment. The conditional mortality is represented by estimates of proportional entrainment *(PE*) that are calculated for each survey and then expanded to predict regional effects on populations using the ETM. Variations of this model have been discussed in MacCall et al. (1983) and have been used to assess impacts at most of the studies of coastal power plants in California (MacCall et al. 1983, Steinbeck et al. 2007).

A definition of the source water population is critical to the ETM. The source water is the region or volume of water over which the *PE* is estimated, and the source water population is an estimate of the number of larvae in that region. In addition to the instantaneous source water volume, the estimated source water for each taxon varies depending on the number of days that the larvae are potentially exposed to mortality due to entrainment. The number of days the larvae are exposed to entrainment is calculated based on measurements of the length of the larvae collected in the impacted area. The lengths of the larvae are divided by estimates of daily growth rates to estimate the age in days of the larvae at different lengths. The data from the sampled source water are used in calculating the estimates of *PE*, which is then extrapolated to the entire source water body in the ETM as defined below.

The estimate of *PE* is the central feature of the ETM (Boreman et al. 1981, MacCall et al. 1983). *PE* estimates, which range from 0 to1, are calculated for each individual survey period *i* as the estimated numbers of larvae entrained into the intake per day as a proportion to the larval population estimated within the source water as follows:

$$PE_i = \frac{N_{E_i}}{N_{S_i}} = \frac{\bar{\rho}_{E_i} V_{E_i}}{\bar{\rho}_{S_i} V_{S_i}}, \qquad \text{Equation 4}$$

where N_{E_i} and N_{S_i} are the estimated numbers of larvae entrained and in the source water per day in survey period i, respectively; $\bar{\rho}_{E_i}$ and $\bar{\rho}_{S_i}$ are the average concentrations of larvae from the intake and source water sampling per day in survey period i, respectively; and V_{E_i} and V_{S_i} are the estimated volumes of the intake and sampled source water per day in survey period i, respectively.

Survival over one day is, therefore, $1 - PE_i$, and survival over the estimated number of days (q) that the larvae are susceptible to entrainment is $(1 - PE_i)^q$. In addition, the estimates of PE_i for each taxon of larvae from each survey are assumed to be representative of the cohort of larvae vulnerable to entrainment during the survey period.

Although it is typically easy to obtain a reasonably accurate estimate of the volume of the intake, estimating the extent and volume of the source water is more difficult. The source water volume may be fixed for studies inside enclosed embayments or may vary among survey periods for studies on the open coast, which are subject to changes in the speed and direction of ocean currents. The situation for Humboldt Bay, which is open to the ocean, falls in between those of the closed embayment and open coast.

One other important component of the ETM is an estimate of the number of days (q) that a taxon being analyzed is planktonic and exposed to entrainment. Typically, this period is estimated using length data from the larvae measured from the entrainment samples for each taxon. Estimates of the maximum length and hatch length are calculated and the period of exposure to entrainment estimated by dividing the difference between the lengths by an estimated larval growth rate usually obtained from scientific literature. The estimates of *PE* and period of exposure or site-specific planktonic larval duration (PLD) q, are combined in the ETM to

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provide an estimate of the proportional mortality (P_M) to a source water population due to entrainment. The basic formulation of P_M is:

$$P_M = 1 - \sum_{i=1}^{n} f_i (1 - PE_i)^q \quad \text{Equation 5}$$

where f_i = the fraction of the source water population from the year present during survey i of n (usually monthly) based on the number of days in each survey period, and q = period in days that the larvae are exposed to entrainment mortality represented by the PE_i. As described above, the value of q is based on the age of larvae calculated using values estimated from the length measurements for each taxon.

3.2.1.1 ETM Calculations

This section describes how the components of the ETM are calculated using the data collected during the field sampling described in Section 3.1.2. The daily intake volumes used in both the Initial ETM Assessment and this study were based on the maximum flow rates for the intakes shown in **Table 1-1**. The daily maximum intake flows for the RMT II and RTD intakes (Station E1 and E2, respectively)) based on the maximum flow rates are 7.92 and 3.96 mgd (29,980 and 14,990 m^3), respectively.

One of the most critical steps in assessing environmental impacts of the proposed seawater intakes using the ETM is the estimation of the source water volume. Any measurement of species abundance in the vicinity of the intakes must be compared against the available population, which involves estimating the volume over which the population is dispersed. In the case of tidally dominated lagoons, such as Humboldt Bay, that volume is most often associated with the tidal prism, i.e., the volume of water that is exchanged with the open ocean over a tidal cycle.

In the ocean, the estimate of the volume of source water is influenced by the number of days that larvae are susceptible to entrainment because over that period, currents transport plankton to the point of entrainment. In bays and estuaries with little freshwater input, currents are mainly tidally driven. Water exchange can be significant and can result in moving larvae both away from and toward the point of entrainment.

Previous impact assessments at power plants located along open coastal sandy beach areas in southern California showed that the homogeneity of the habitat resulted in concentrations of larvae that were, on average, rather uniform throughout the sampled source water (e.g., MBC and Tenera 2005, Tenera and MBC 2008). The *PE* estimate used in the ETM is typically calculated as the ratio of the estimated numbers of larvae entrained to the population at risk in the sampled source water (Steinbeck et al. 2007). In the Initial ETM Assessment prepared by Tenera (2021) for this project, a simplifying assumption was made that the estimated *PE* could be calculated as the ratio of the volume of water entrained to the volume of the sampled source water. This simplification was used in the original formulation of the ETM to estimate impacts due to an intake along a river (Boreman et al. 1978, 1981). Although a river is a much simpler system to model because of the generally unidirectional flow of water, the volumetric assumption that larvae are uniformly distributed throughout the source water does not compromise the empirically derived calculation of the source water population extent. Instead, it allows for calculation of *PE* without the underlying biological data from the intake and source water volumes. The potential for using this volumetric modeling approach for intake assessment was shown to be applicable at certain locations by Steinbeck et al. (2016). This approach is especially useful for initial project planning and permitting, which was the purpose of the Initial ETM Assessment (Tenera 2021).

The Initial ETM Assessment (Tenera 2021) provided ETM results using three source water estimates: a highly conservative estimate that used the volume of Humboldt Bay as a closed system (Model M1 in **Table 3-1**), a much less conservative model that incorporated the volume of the tidal prism for the entire bay that assumed total mixing during each tidal cycle (Model M2 in **Table 3-1**), and a model that also included the tidal prism for the entire bay and accounted for differing exchange rates in each section of the bay (Model M3 in **Table 3-1**). Model M1 represented the lowest rate of mixing, Model M2 represented the highest rate of mixing, and Model M3 was between the other two models. Mixing is important to the ETM because it increases the volume of the source water body and subsequently, increases the size of the source water population from which entrainment occurs, resulting in a lower estimate of P_M for a larger rate of mixing.

Table 3-1. Initial ETM Assessment Study estimates of P_M for three source water models for Humboldt Bay. The values in this table represent the proportion (percentage) of the source water population of larvae at risk due to entrainment by the two intakes located off the Samoa Peninsula. Reproduced from Table 4-1 in Initial ETM Assessment (Tenera 2021). Model M3 is bolded as it is the selected model for use in this study.

	Pacific Herring	Arrow Goby	Bay Goby	Northern Anchovy	Maximum Turnover
Larval Durations (d) Models	6.8	17.4	4.3	24.3	30
M1 – Closed	0.00208 (0.208%)	0.00532 (0.532%)	0.00132 (0.132%)	0.00743 (0.743%)	0.00916 (0.916%)
M2 – Tidal Prism	0.00023 (0.023%)	0.00025 (0.025%)	0.00022 (0.022%)	0.00025 (0.025%)	0.00026 (0.026%)
M3 – Exchange Ratios	0.00075 (0.075%)	0.00096 (0.096%)	0.00062 (0.062%)	0.00101 (0.101%)	0.00104 (0.104%)

These models, their assumptions, and supporting results from the historical literature are presented in the Initial ETM Assessment. The results using this range of source water estimates were provided in that report to allow environmental managers and regulators to compare the range of effects of the intakes. This exercise was useful and provided that evidence could also be presented to rule out the truly worst-case, most conservative model which could support isolated populations near the proposed seawater intake that do not exchange regularly with the broader Humboldt Bay and open ocean waters and therefore represents a much smaller source water volume and population. This most conservative model would result in much higher, and unrealistic, estimates of population impacts when considering that Barnhart et al. 1992 estimated that the tidal prism of Humboldt Bay can be up to 54% of the MHHW volume. Therefore, one of the goals of this study was to identify the model that provided the most appropriate representation of the dynamics of Humboldt Bay. This study used the data from Swanson (2105) for the four sub-bay regions and the flushing rates for each of the regions that he calculated based on the model results from Anderson (2015).

Figure 3-3. Map of Humboldt Bay showing regions used in calculating volumes. From Swanson (2015; Figure 18).

The use of volumetric ratio models for the Initial ETM Assessment was possible due to the extensive hydrographic modeling data for Humboldt Bay presented in Swanson (2015). These data were, in turn, based on previous studies by Costa (1982), Barnhart et al. (1992), and unpublished data from a study by Andersen (2015). These data included estimated tidal flushing rates, areas, and volumes for the four regions of the Bay. These data were used in the Initial ETM Assessment along with a range of assumptions regarding tidal flushing rates and turnover of waters in the Bay to provide a corresponding range of ETM estimates of P_M. The same data on the source water characteristics of Humboldt Bay used in the previous study are also used in this study.

The three models presented in the Initial ETM Assessment (Tenera 2021) utilized different approaches to account for tidal exchange in Humboldt Bay (**Table 3-1**). Previous studies of fish larvae in Humboldt Bay (e.g., Eldridge and Bryan 1972) showed differing abundances and composition of larvae in each region of the Bay. Therefore, the model used in the Initial ETM Assessment that incorporated estimates from each of the four regions of Humboldt Bay shown in **Figure 3-3**: Arcata Bay, Main Channel, Entrance Bay, and South Bay was expected to be the most appropriate model for this study. The approach to verifying this model is provided below in Section 3.2.1.2.

The intakes are proposed to be located near the junction of the Main Channel and the Samoa Channel off the Samoa Peninsula, across from the city of Eureka (**Figure 1-2**). Swanson (2015) describes the physical oceanography of the various regions of Humboldt Bay and states that at MLLW the North Bay Channel and the Main Channel can contain half the tidal prism from Arcata Bay, and at MHHW can contain twice the tidal prism from Entrance Bay (citing unpublished data from Andersen 2015). Swanson presents areas and volumes of the components of Humboldt Bay (Swanson 2015 citing unpublished data from Andersen 2015) as well as discussing estimates of flushing times for each region. The regions delineated are similar to previous studies with some simplification for modeling. The areas and volumes for the four subregions are provided in **Table 3-2**.

One of the simplest methods for calculating the retention or turnover time is dividing the estuary volume by the tidal prism (V_{TP}, Shelden and Alber 2006)

$$\varepsilon = \frac{V_B}{V_{TP}},$$

where ε is the retention time, V_B is the estuary volume, and V_{TP} is the average tidal range (MHW-MLW volumes). However, this simple calculation does not reflect different sub-regional retention rates or their populations. Swanson (2015) presents flushing rates for the four sub-bay regions in Humboldt Bay. Using Swanson's data for the four sub-bay regions (**Table 3-2**), the overall MHHW volume weighted flushing rate was 0.24 per day, resulting in a retention time of 4.16 days (**Table 3-3**). These values were used in the calculation of the ETM model results for Model M3.

Table 3-2. Areas and volumes for four Humboldt Bay sub-bay regions at five tidal datums. From Swanson (2015 using data from Andersen 2015).

	Arcata Bay		Main Channel		Entrance Bay		South Bay	
Tidal Datum	Surface Area (mi^2 [km^2])	Volume (ft^3 x 10^6 [m^3 x 10^6])	Surface Area (mi^2 [km^2])	Volume (ft^3 x 10^6 [m^3 x 10^6])	Surface Area (mi^2 [km^2])	Volume (ft^3 x 10^6 [m^3 x 10^6])	Surface Area (mi^2 [km^2])	Volume (ft^3 x 10^6 [m^3 x 10^6])
MLLW	4.79 (12.41)	578 (16.36)	1.84 (4.77)	1,062 (30.08)	2.96 (7.67)	1,425 (40.36)	2.25 (5.83)	385 (10.91)
MLW	6.65 (17.22)	766 (21.70)	1.88 (4.87)	1,134 (32.11)	2.97 (7.69)	1,517 (42.95)	4.34 (11.24)	503 (14.24)
MSL	12.06 (31.23)	1,361 (38.53)	2.10 (5.44)	1,269 (35.92)	3.10 (8.03)	1,736 (49.15)	6.38 (16.52)	866 (24.52)
MHW	14.28 (37.00)	2,364 (66.94)	2.22 (5.75)	1,413 (40.01)	3.11 (8.05)	1,927 (54.56)	6.91 (17.90)	1,333 (37.74)
MHHW	14.42 (37.35)	2,600 (73.61)	2.29 (5.93)	1,456 (41.24)	3.12 (8.08)	1,991 (56.37)	6.91 (17.90)	1,427 (40.42)

The availability of flushing rates for the four sub-bay regions from the hydrodynamic model used in Swanson (2015) provided justification for the development of Model M3 (**Table 3-1**) that uses flushing rates that account for the variation among source water areas as follows:

$$P_M = 1 - \sum_{i=1}^{12} f_i \left(1 - \left[\frac{N_{E_i}}{N_{B_i} + \left[(q \cdot 1.93) \cdot \left(\left(N_{SB_i} \cdot 0.04\right) + \left(N_{EB_i} \cdot 0.31\right) + \left(N_{MCh_i} \cdot 0.14\right) + \left(N_{AB_i} \cdot 0.02\right)\right)\right]}\right]\right)^q \quad \text{Equation 6}$$

where for each survey i, N_E is calculated as shown in Equation 4, N_B is the estimated number in Humboldt Bay at MSL, N_{SB} the estimated number of larvae in the South Bay, N_{EB} the estimated number of larvae in the Entrance Bay, N_{MCh} the estimated number of larvae in the Main Channel, and N_{AB} the estimated number of larvae in Arcata Bay all at MSL. The estimate for each subregion is multiplied by its corresponding estimated flushing rate from Swanson (2015) (**Table 3-3**). This ETM model, identified as Model M3 in **Table 3-1**, accounts for the variation in flushing rates between areas.

In the model in Equation 6, the estimated numbers for each subregion is calculated based on the average concentrations of larvae from the stations in each region in **Figure 3-1** as follows: N_{SB} is calculated using the data from Station SW5 in the South Bay, N_{EB} is calculated using the data from Station SW4 in the Entrance Bay, N_{MCh} is calculated using the data from stations SW3, E1, E2, and E6 in the Main Channel, and N_{AB} is calculated using the data from stations SW1 and SW2 in Arcata Bay. The numbers from all four regions of the bay are combined to provide the estimate of N_B for Humboldt Bay.

Table 3-3. Flushing rates for the four Humboldt Bay sub-bay regions from Swanson 2015 (using data from Andersen 2015) and calculated volume weighted flushing rate.

Sub-Bay Region	Flushing rate τ per tidal cycle[1]	MHHW Volume (ft^3 x 10^6 [m^3 x 10^6])	Volume Weighted τ per tidal cycle	Volume Weighted τ per day
Arcata Bay	0.02	2,600 (73.61)		
Main Channel	0.14	1,456 (41.24)		
Entrance Bay	0.31	1,991 (56.37)		
South Bay	0.04	1,427 (40.42)		
Sum		7,474 (211.64)	0.12	0.24

[1] Swanson calculated the flushing rate for the Main Channel as the MHHW volume-weighted average of the Entrance and Arcata Bay "since it connects the two".

3.2.1.2 Verification of Source Water Models

Identifying the most appropriate source water model for this study involved consultation with oceanographers and local experts on the hydrographic processes in the Bay. The model used to estimate the source water population subject to entrainment was verified using physical and biological data collected during the sampling. The locations of the two intakes for the project are along the channel formed by the north spit about 3.7 mi (6 km) from the Entrance Bay. The approach using both physical and biological data was used to evaluate indicators of the mixing length along the channel and its effect on biological populations. Acoustic Doppler Current Meter (ADCP) observations of Brown and Caldwell (2014) and circulation modeling results summarized by Claasen (2003) show that the tidal currents in the main channel of Humboldt Bay have amplitudes in the range of 0.5 m/sec to 1.0 m/sec. This means that particles within that flow would be displaced between 7 km and 14 km every tidal cycle, which is equal to or greater than the length of the main channel between the Harbor Entrance and the two intakes.

Changes in salinity and temperature among areas are commonly used to estimate the rates of mixing within estuaries (Sheldon and Alber 2006). Therefore, an instrument that measured conductivity (salinity) and seawater temperatures through the water column was deployed during the biological sampling at each station, except during the first survey in January due to instrument failure (**Figure 3-1**). A temperature recorder was also trailed through the water during each sampling cycle to record seawater temperatures throughout the bay. Humboldt Bay is not a true estuary and does not have a continuous source of freshwater input that would produce the types of gradients in temperature and salinity that would provide reliable data to determine mixing. Therefore, in addition to the analysis of temperature and salinity, differences among areas within the bay were calculated using the biological data collected during the sampling. This was done by calculating the Bray-Curtis similarity among all station pairs within each survey and cycle. The Bray-Curtis index measures the similarity between station pairs based on the composition of the taxa in the samples (Clarke and Warwick 2001) and is calculated as:

$$100 * \frac{2C_{ij}}{S_i+S_j},$$

where C_{ij} is the sum of the lowest count from each species common to both samples and S_i+S_j is the sum of the total fish larvae in both samples. Only the data on fish larvae were used in the analysis and did not include the group of unidentified fish larvae. The calculations were done using the PRIMER analysis package and included 189 samples and 60 different taxa on fish larvae. Predicted tide data for each minute from the NOAA tides and currents website (https://tidesandcurrents.noaa.gov/tide_predictions.html) for the North Sand Spit tide station in Humboldt Bay (Site 9418767) were downloaded and matched with the sampling times for all 189 samples. Approximate distances among the sampling locations were calculated from using ESRI ArcMap 10.8 based on the station locations shown in **Figure 3-1**. The relationships between distance and Bray-Curtis similarity were analyzed using regression. The relationships between stations were of special interest for the stations located along the North Sand Spit from the Harbor mouth (SW4), up past Station SW3 and the entrainment stations (E1 and E2), and into Arcata Bay and the location of Station SW2. These stations would be especially subject to strong tidal currents due to the narrowing of the channel along this stretch of the bay, especially in the areas where the intake stations are located across from where Tuluwat Island extends into the Samoa Channel (**Figure 1-2**).

3.2.1.3 Humboldt Bay Source Water Body Calculations

Using the data from Swanson (2015) for Arcata Bay, Main Channel, Entrance Bay, and South Bay in **Table 3-2**, the volume of V_B at MSL was 5,231 Mft^3 (148.12 Mm^3). At V_{TP} the volume was 3,117 Mft^3 (88.25 Mm^3). The retention time was 8.04 tidal cycles or 4.12 days. These values were used to populate parameters in Equation 6. Larval durations were calculated using the data on the length of the larvae collected during this study. The model results from the Initial ETM Assessment based on the maximum estimate of approximately 30 days for complete turnover of water in the bay based on information in Swanson (2015) could be used for larval stages of shellfish such as crabs that go through multiple larval stages before settling out of the plankton as juveniles.

3.2.1.4 ETM Assumptions

Several assumptions are associated with the estimation of P_M in this ETM:

1. The samples from each survey period i, represent a new and independent cohort of larvae.
2. The estimates of larval abundance for each approximately monthly survey period i represent a proportion of total annual larval production during that the i^{th} survey period.
3. The conditional probability of entrainment, PE_i, is constant within each survey period i.
4. The conditional probability of entrainment, PE_i, is constant within each of the size classes of larvae present during each survey period i.
5. The concentrations of larvae in the sampled source water are representative of the concentrations in the extrapolated source water.
6. Lengths and applied growth rates of larvae accurately estimate the period of time that the larvae are vulnerable to entrainment.

3.2.2 Calculation of Area of Production Foregone (APF) Estimates

Estimates of APF corresponding to each of the taxa analyzed by the ETM is calculated using the estimate of the area of Humboldt Bay at MSL (23.6 mi^2 [61.1 km^2]) in **Table 2-2** as follows:

$$APF = \widehat{P_{M_i}} A_{HB},$$

where $\widehat{P_{M_i}}$ is the ETM estimate of P_M for the i^{th} taxa and A_{HB} is the surface area of Humboldt Bay at MSL. Using the estimate of the entire area of Humboldt Bay in the APF calculations is conservative, especially for taxa that use specific habitat for spawning, since the entire area of the bay is not used as spawning habitat by most fishes.

4.0 Results

This section presents the results from the sampling completed January through December 2022. The sampling results for the major taxonomic groups are followed by the analyses used to verify the source water model that uses all of the data on larval fishes. Results for the most abundant individual taxa collected during the study as well as results for LFS larvae are presented. The results for the individual taxa include results on the measurements of the larvae and other data used to calculate estimates of *PE* for each survey and in the calculation of the ETM estimates of P_M for each of the two intakes in Humboldt Bay.

The data from each sample collected during the study are provided in Appendix A. Details on conditions during each sample including date, time, sample volume, sample depth, tide conditions, and temperature and salinity data are provided in Appendix B. Plots of temperature and salinity through the water column at each station during sampling are presented in Appendix C.

4.1 Sampling Overview

A total of 189 samples were collected during the sampling from January–December 2022 (**Table 4-1**). Surveys were completed approximately monthly, beginning on January 11, 2022 and ending on December 6, 2022. At each monthly survey, eight stations were sampled during the day and night, totaling 16 samples per survey. However, during the night-time cycle of the first survey, three of the source water stations were not sampled due to failure of the winch used to retrieve the plankton net. Since the numbers of days between the surveys were not the same, a start and end date was designated to provide the number of days within each survey period to provide a total of 365 days for the entire study. The surveys periods were used in calculating the annual entrainment estimates.

The sampling resulted in the collection of 60 different taxa of larval fishes from 28 different families. The taxa with the highest average concentrations were Arrow Goby and Bay Goby which are both in the Family Gobiidae (**Table 4-2**). These two taxa were abundant at all of the sampling locations but had the highest average concentrations at entrainment Station E1 where the intake for the existing RMT II intake is located (**Figure 3-1**). The other taxa with high average concentrations included Whitebait Smelt, Pacific Herring, Surf Smelt, and Pacific Tomcod. These taxa varied in abundance across all eight stations. The highest average concentrations of fish larvae occurred at entrainment Station E1 and source water Station SW2. This was likely due to the high concentrations of Arrow Goby larvae that are produced from the large expanses of mudflat habitat in Arcata Bay (**Figure 2-2**). The average concentrations at stations E2 and SW6 in Arcata Bay were also high (**Table 4-2**). The concentrations for Arrow Goby and Bay Goby at Station SW1 were lower, which may be due to the lower salinities measured at that station during the sampling (Appendix B), possibly due to freshwater outflow from tributaries entering Humboldt Bay from Eureka Slough, which is proximate to that station. The largest number of taxa were collected at source water Station SW5, which is located in South Bay but is also close to the Main Entrance (**Figure 3-1**). Station SW5 is also located in primarily mudflat habitat, which is typically not an area of high species diversity, but the high number of taxa may also be because the station is close to other habitats such as the harbor breakwaters and the open ocean. The lowest numbers of taxa occurred at source water stations SW1 and SW2 located in Arcata Bay, which are also situated in and surrounded by mudflat habitat. However, unlike SW5, stations SW1 and SW2 are not adjacent to other habitats and are the stations furthest from the open ocean, so may have low taxa diversity relative to other stations because of low adjacent habitat diversity. Overall, the taxa collected represent a mix of open ocean and bay species, with the relative abundances at the stations generally reflective of the taxa associated with the habitats in proximity to those stations.

Table 4-1. The table shows the dates of each survey, dates used in calculating surveys periods used in entrainment estimates, and numbers of samples collected each survey.

Survey Date	Number of Samples	Start Date	End Date	Interval (d)	Notes
1/11/2022	13	12/23/2021	1/26/2022	34	SW stations 4, 5, and 6 not sampled in cycle 2
2/10/2022	16	1/26/2022	2/27/2022	32	All samples collected
3/17/2022	16	2/27/2022	4/5/2022	37	All samples collected
4/26/2022	16	4/5/2022	5/10/2022	35	All samples collected
5/26/2022	16	5/10/2022	6/11/2022	32	All samples collected
6/28/2022	16	6/11/2022	7/13/2022	32	All samples collected
7/29/2022	16	7/13/2022	8/8/2022	26	All samples collected
8/18/2022	16	8/8/2022	9/4/2022	27	All samples collected
9/22/2022	16	9/4/2022	10/1/2022	27	All samples collected
10/11/2022	16	10/1/2022	10/24/2022	23	All samples collected
11/7/2022	16	10/24/2022	11/21/2022	28	All samples collected
12/6/2022	16	11/21/2022	12/23/2022	32	All samples collected
Total =	189				

The highest average concentrations of all fish larvae combined at the two entrainment stations occurred during the months of June through August with the highest concentrations occurring during the late June survey at Station E1, with an average concentration of 11,311 per 1,000 m^3 (average of samples 4 and 12, Survey 6 in Appendix A and **Figure 4-1**). Although one explanation for the large concentration during that survey could be that a large number of larvae transported out of Arcata Bay on an ebb tide were present during the sampling, the data in Appendix B show a flood tide during the sample collection. Therefore, it is likely that the high concentration reflects the extremely patchy nature of plankton abundance. The lowest average concentrations occurred during the fall and winter month surveys with the lowest average concentration occurring during the November survey at Station E1 with an average concentration of approximately 0.05 larvae per 1,000 m^3. In general, nighttime concentrations were higher than daytime concentrations. The months when this pattern was reversed generally occurred during the same months at both stations.

Table 4-2. Average larval concentration (# per 1,000 m3) and total sample counts of larvae collected from all stations (entrainment and source water) sampled in Humboldt Bay from January – December 2022.

		Mean Concentrations (# per 1,000 m^3) and Sample Counts in Parentheses							
Taxon	Common Name	E1	E2	SW1	SW2	SW3	SW4	SW5	SW6
Fish Larvae									
Clevelandia ios	Arrow Goby	1,025.14 (609)	340.82 (356)	190.19 (364)	905.62 (899)	102.43 (127)	4.98 (5)	4.89 (9)	449.11 (710)
Lepidogobius lepidus	Bay Goby	98.32 (208)	87.92 (187)	40.62 (49)	46.07 (100)	62.17 (153)	43.86 (75)	91.12 (222)	48.85 (107)
Allosmerus elongatus	Whitebait Smelt	70.83 (110)	60.50 (67)	9.90 (11)	15.04 (18)	52.87 (107)	203.11 (119)	19.88 (36)	14.26 (31)
Clupea pallasii	Pacific Herring	15.47 (37)	12.17 (30)	37.97 (105)	17.90 (47)	16.89 (63)	54.19 (139)	82.31 (197)	6.82 (16)
Hypomesus pretiosus	Surf Smelt	12.55 (9)	11.26 (11)	4.95 (8)	3.82 (5)	3.92 (8)	18.78 (13)	8.22 (7)	8.06 (17)
Microgadus proximus	Pacific Tomcod	20.72 (46)	5.12 (13)	2.23 (4)	1.05 (2)	23.91 (57)	11.95 (22)	4.19 (9)	1.32 (3)
Citharichthys sordidus	Pacific Sanddab	5.80 (13)	1.80 (4)	1.95 (1)	0.88 (2)	16.16 (47)	19.71 (22)	20.74 (49)	0.00 (0)
Leptocottus armatus	Pacific Staghorn Sculpin	8.29 (21)	7.44 (21)	6.61 (14)	6.83 (18)	8.28 (22)	8.52 (16)	9.27 (19)	7.46 (16)
Spirinchus starksi	Night Smelt	13.51 (33)	2.54 (6)	9.84 (6)	0.52 (1)	8.31 (23)	17.85 (24)	6.28 (16)	1.41 (3)
Hippoglossoides elassodon	Flathead Sole	2.40 (6)	0.44 (1)	0.00 (0)	0.44 (1)	3.41 (10)	10.09 (11)	10.38 (18)	0.00 (0)
Ammodytes hexapterus	Pacific Sand Lance	4.53 (10)	2.62 (7)	1.48 (4)	2.39 (6)	4.06 (12)	5.00 (10)	4.98 (10)	0.38 (1)
Artedius spp.	sculpins	2.53 (6)	2.90 (3)	1.05 (2)	1.65 (1)	5.55 (8)	6.64 (7)	1.89 (4)	0.84 (2)
Liparis spp.	snailfishes	5.38 (6)	7.24 (10)	2.00 (4)	1.46 (3)	1.78 (5)	1.67 (4)	1.32 (3)	0.73 (2)
larval/post-larval fish	unidentified larval fishes	0.78 (2)	0.79 (2)	1.25 (3)	6.86 (13)	1.95 (5)	4.18 (10)	1.86 (4)	1.24 (3)
Pleuronectoidei	flatfishes	0.00 (0)	0.00 (0)	1.95 (1)	0.00 (0)	2.76 (7)	1.45 (2)	11.49 (21)	0.37 (1)
Engraulis mordax	Northern Anchovy	2.22 (5)	0.82 (2)	3.62 (5)	3.09 (3)	3.68 (8)	0.86 (2)	2.40 (5)	0.81 (2)
Oligocottus/Clinocottus spp.	Sculpins	2.67 (6)	4.95 (12)	0.39 (1)	2.55 (6)	1.86 (5)	1.64 (3)	2.09 (5)	1.32 (3)
Cottus asper	Prickly Sculpin	5.08 (5)	2.11 (5)	0.92 (2)	0.00 (0)	0.68 (2)	2.46 (5)	1.35 (3)	0.83 (2)
Gillichthys mirabilis	Longjaw Mudsucker	0.36 (1)	1.19 (2)	1.23 (3)	5.31 (10)	0.90 (2)	0.33 (1)	0.00 (0)	3.26 (5)
Rhinogobiops nicholsii	Blackeye Goby	0.75 (2)	0.83 (2)	2.31 (2)	2.94 (2)	1.63 (4)	0.42 (1)	0.00 (0)	1.21 (3)
Sebastes spp. V_	KGB rockfish complex larvae	4.18 (3)	2.60 (7)	0.56 (1)	0.44 (1)	0.62 (2)	0.00 (0)	0.00 (0)	1.21 (3)
Spirinchus thaleichthys	Longfin Smelt	2.18 (6)	0.27 (1)	0.51 (1)	0.44 (1)	0.51 (1)	0.00 (0)	1.01 (1)	0.00 (0)

table continued

Table 4-2 (cont.). Average larval concentration (# per 1,000 m3) and total sample counts of larvae collected from all stations (entrainment and source water) sampled in Humboldt Bay from January – December 2022.

		Mean Concentrations (#per 1,000 m^3) and Sample Counts in Parentheses							
Taxon	Common Name	E1	E2	SW1	SW2	SW3	SW4	SW5	SW6
Sebastes spp. V	Blue Rockfish complex larvae	0.83 (2)	0.00 (0)	0.40 (1)	0.83 (2)	0.85 (2)	0.92 (2)	0.90 (2)	0.00 (0)
Atherinops affinis	Topsmelt	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	4.01 (10)	0.00 (0)	0.37 (1)
Parophrys vetulus	English Sole	0.85 (2)	0.00 (0)	0.36 (1)	0.00 (0)	0.32 (1)	0.56 (1)	0.85 (2)	0.48 (1)
Tarletonbeania crenularis	Blue Lanternfish	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.42 (1)	1.26 (3)	1.39 (3)	0.00 (0)
Bathymasteridae	ronquils	0.41 (1)	0.44 (1)	0.00 (0)	1.70 (2)	0.43 (1)	0.00 (0)	0.00 (0)	0.00 (0)
Isopsetta isolepis	Butter Sole	0.82 (2)	0.42 (1)	0.00 (0)	1.05 (2)	0.00 (0)	0.56 (1)	0.00 (0)	0.00 (0)
Genyonemus lineatus	White Croaker	0.00 (0)	0.40 (1)	0.48 (1)	0.00 (0)	0.00 (0)	0.83 (2)	0.96 (2)	0.00 (0)
Stenobrachius leucopsarus	Northern Lampfish	0.82 (2)	0.36 (1)	0.00 (0)	0.00 (0)	0.85 (2)	0.00 (0)	0.00 (0)	0.00 (0)
Oligocottus snyderi	Fluffy Sculpin	0.45 (1)	0.00 (0)	0.00 (0)	0.00 (0)	0.76 (2)	0.00 (0)	0.77 (2)	0.00 (0)
Ruscarius meanyi	Puget Sound Sculpin	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.26 (1)	0.00 (0)	1.67 (1)	0.00 (0)
Atherinopsis californiensis	Jacksmelt	0.00 (0)	1.85 (1)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Lipolagus ochotensis	Popeye Blacksmelt	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.40 (1)	1.43 (3)	0.00 (0)
Acanthogobius flavimanus	Yellowfin Goby	0.00 (0)	0.00 (0)	0.00 (0)	1.29 (1)	0.00 (0)	0.00 (0)	0.00 (0)	0.39 (1)
Porichthys notatus	Plainfin Midshipman	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	1.60 (2)
Pholidae	gunnels	0.52 (1)	0.00 (0)	0.00 (0)	0.00 (0)	0.41 (1)	0.00 (0)	0.44 (1)	0.00 (0)
Stichaeidae	pricklebacks	0.41 (1)	0.36 (1)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.52 (1)	0.00 (0)
Platichthys stellatus	Starry Flounder	0.00 (0)	0.00 (0)	0.00 (0)	1.29 (1)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Citharichthys stigmaeus	Speckled Sanddab	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.32 (1)	0.00 (0)	0.81 (2)	0.00 (0)
Cebidichthys violaceus	Monkeyface Prickleback	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.52 (1)	0.48 (1)
Syngnathidae	pipefishes	0.65 (1)	0.00 (0)	0.35 (1)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Chitonotus pugetensis	Roughback Sculpin	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.94 (1)	0.00 (0)	0.00 (0)
Icichthys lockingtoni	Medusa Fish	0.44 (1)	0.47 (1)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Scorpaenichthys marmoratus	Cabezon	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.42 (1)	0.00 (0)	0.48 (1)	0.00 (0)
Ruscarius creaseri	Roughcheek Sculpin	0.41 (1)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.48 (1)	0.00 (0)

table continued

Table 4-2 (cont.). Average larval concentration (# per 1,000 m3) and total sample counts of larvae collected from all stations (entrainment and source water) sampled in Humboldt Bay from January – December 2022.

		Mean Concentrations (#per 1,000 m³) and Sample Counts in Parentheses							
Taxon	Common Name	E1	E2	SW1	SW2	SW3	SW4	SW5	SW6
Trachipterus altivelis	King-of-the-Salmon	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.39 (1)	0.00 (0)	0.49 (1)
Actinopterygii	ray-finned fishes	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.48 (1)	0.38 (1)
Lyopsetta exilis	Slender Sole	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.42 (1)	0.39 (1)	0.00 (0)	0.00 (0)
Cottidae	sculpins	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.81 (2)	0.00 (0)	0.00 (0)	0.00 (0)
Nannobrachium regalis	Pinpoint Lanternfish	0.00 (0)	0.39 (1)	0.00 (0)	0.00 (0)	0.00 (0)	0.39 (1)	0.00 (0)	0.00 (0)
Artedius harringtoni	Scalyhead Sculpin	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.56 (1)	0.00 (0)	0.00 (0)
Pleuronectidae	Righteye Flounders	0.49 (1)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Radulinus spp.	sculpins	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.48 (1)
Stellerina xyosterna	Pricklebreast Poacher	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.48 (1)
Hexagrammos decagrammus	Kelp Greenling	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.48 (1)	0.00 (0)
Psettichthys melanostictus	Sand Sole	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.48 (1)	0.00 (0)
Clinocottus embryum	Calico Sculpin	0.41 (1)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Bathylagidae	blacksmelts	0.00 (0)	0.00 (0)	0.00 (0)	0.40 (1)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Osmeridae	smelts	0.35 (1)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Nannobrachium spp.	lanternfishes	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.33 (1)	0.00 (0)
Larval Fish Totals		1,311.55 (1,162)	561.05 (757)	323.12 (595)	1,031.84 (1,148)	330.60 (694)	428.89 (516)	298.66 (664)	554.64 (940)
# Larval Fish Taxa		34	28	24	25	33	31	35	27
Fish Eggs									
non-engraulidae eggs	non-engraulidae eggs	1,496.54 (2,009)	1,028.55 (2,085)	568.86 (1,011)	451.60 (791)	1,557.32 (1,665)	1,275.90 (1,664)	1,375.05 (1,485)	901.27 (1,945)
Engraulidae (eggs)	anchovy eggs	13.90 (25)	20.67 (18)	4.43 (12)	11.61 (10)	13.80 (25)	28.21 (66)	29.23 (42)	7.00 (11)
Fish Egg Totals		1,510.44 (2,034)	1,049.22 (2,103)	573.29 (1,023)	463.21 (801)	1,571.12 (1,690)	1,304.12 (1,730)	1,404.28 (1,527)	908.27 (1,956)
Larval Crabs									
Metacarcinus magister	Dungeness crab megalops	38.02 (93)	5.24 (12)	7.81 (4)	1.84 (4)	60.56 (179)	3.77 (5)	2.24 (6)	0.00 (0)

table continued

Table 4-2 (cont.). Average larval concentration (# per 1,000 m3) and total sample counts of larvae collected from all stations (entrainment and source water) sampled in Humboldt Bay from January – December 2022.

		Mean Concentrations (#per 1,000 m^3) and Sample Counts in Parentheses							
Taxon	Common Name	E1	E2	SW1	SW2	SW3	SW4	SW5	SW6
Cancer productus / Romaleon spp.	rock crab megalops	5.42 (6)	2.57 (6)	0.40 (1)	0.00 (0)	1.89 (5)	7.51 (9)	2.19 (6)	0.86 (2)
Romaleon antennarius / Metacarcinus gracilis	cancer crabs	1.64 (4)	0.00 (0)	0.45 (1)	0.00 (0)	0.00 (0)	0.00 (0)	1.23 (3)	0.00 (0)
Cancridae	cancer crabs megalops	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.51 (1)	0.00 (0)	0.00 (0)
Crab Larvae Totals		45.08 (103)	7.81 (18)	8.66 (6)	1.84 (4)	62.46 (184)	11.79 (15)	5.66 (15)	0.86 (2)

The highest average concentrations of all fish larvae combined at the six source water stations occurred during the months of May through August with the highest concentrations occurring during the May survey at Station SW2 and the August survey at stations SW2 and SW6 (see sample data in Appendix A and **Figure 4-2**). Although concentrations were generally lower during the fall and winter month surveys, the lowest average concentration occurred during the September survey at stations SW3 and SW5. Similar to the pattern at the entrainment stations, nighttime concentrations were generally higher than daytime concentrations for most surveys. The months when this pattern was reversed varied among the stations which probably reflects differences in species composition among the stations.

There was a total of 37 separate taxa of larval fishes, not including unidentified larvae, collected at the two entrainment stations (E1 and E2) with a total estimated annual entrainment by the two intakes of approximately 17.8 million larvae (**Table 4-3**). Although the daily intake volume at the RTD Intake (Station E2) accounts for one-third of the total flow, the total entrainment of fish larvae at Station E2 only accounted for approximately 17% of the total annual estimated entrainment due to differences in the composition and abundances of the larvae at the two locations. The taxon with the highest estimated entrainment was Arrow Goby which comprised over 75% of the total estimated entrainment at the two intakes, largely due to the high concentrations for the June survey samples (Appendix A). Bay Goby and Whitebait Smelt had the second and third highest estimated entrainment. Including Arrow Goby only seven taxa contributed greater than one percent to the total entrainment and collectively comprised over 95% of the total entrainment.

The fish eggs collected during the study were categorized as either engraulid or non-engraulid eggs. The categorization is based on the shape of the eggs. Eggs from species in the Family Engraulidae, such as Northern Anchovy are barrel-shaped, whereas most other fish eggs are circular. At the entrainment stations, the highest average concentrations of fish eggs occurred during the months of June through September with the highest concentrations occurring during the late August survey at Station E1 with a concentration of 7,184 fish eggs per 1,000 m^3 (**Figure 4-3**). The concentrations were also highest during the August survey at Station E2. The abundance patterns for the concentrations of fish eggs were very similar at the two entrainment stations. The lowest average concentrations occurred from December through May. There was no obvious pattern of abundance related to night and day conditions. This may be because most fish eggs are slightly buoyant due to the presence of oil globules in the yolk. Therefore, unlike fish larvae which may migrate vertically through the water column through the day, eggs for many species of fish tend to stay near the surface and would be less susceptible to entrainment at the submerged intakes.

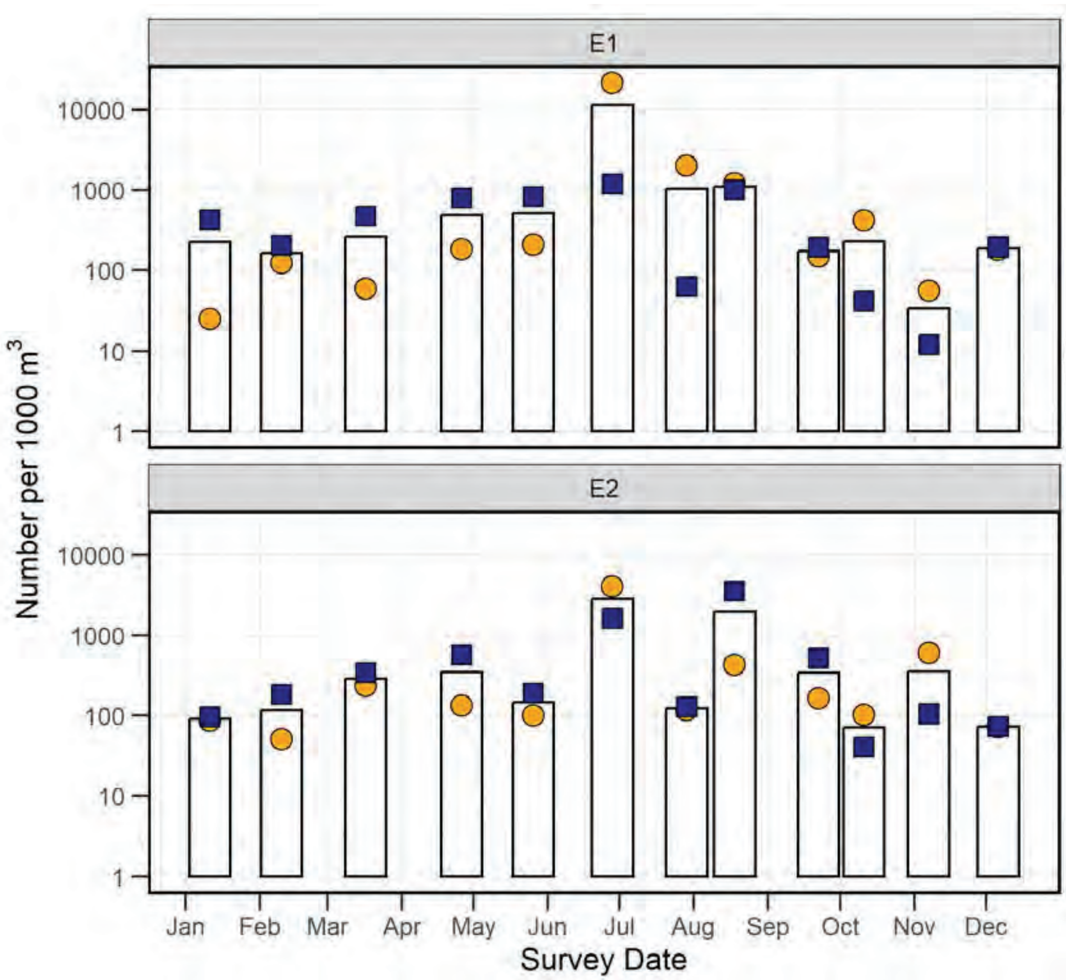

Figure 4-1. Total average concentrations of all fish larvae (height of bar) collected during monthly surveys at entrainment stations E1 and E2 from January 2022–December 2022. Concentrations from daytime (orange circles) and nighttime (blue squares) are also shown. Dates of the surveys correspond to the centers of the bars.

The highest average concentrations of fish eggs at the six source water stations occurred during the months of June through September, with the highest concentrations occurring during the August survey at stations SW2, SW3,and SW5 (**Figure 4-4**). The abundance patterns for the concentrations of fish eggs were very similar at the two Arcata Bay stations (SW1 and SW2), and at stations SW3, SW4, and SW5. These patterns probably reflect the difference in species composition for the stations in those two areas. At both sets of stations, the abundances were generally lowest during the winter month from December through February. Similar to the results for the entrainment stations (**Figure 4-3**), there was no clear pattern of concentrations varying between night and day samples.

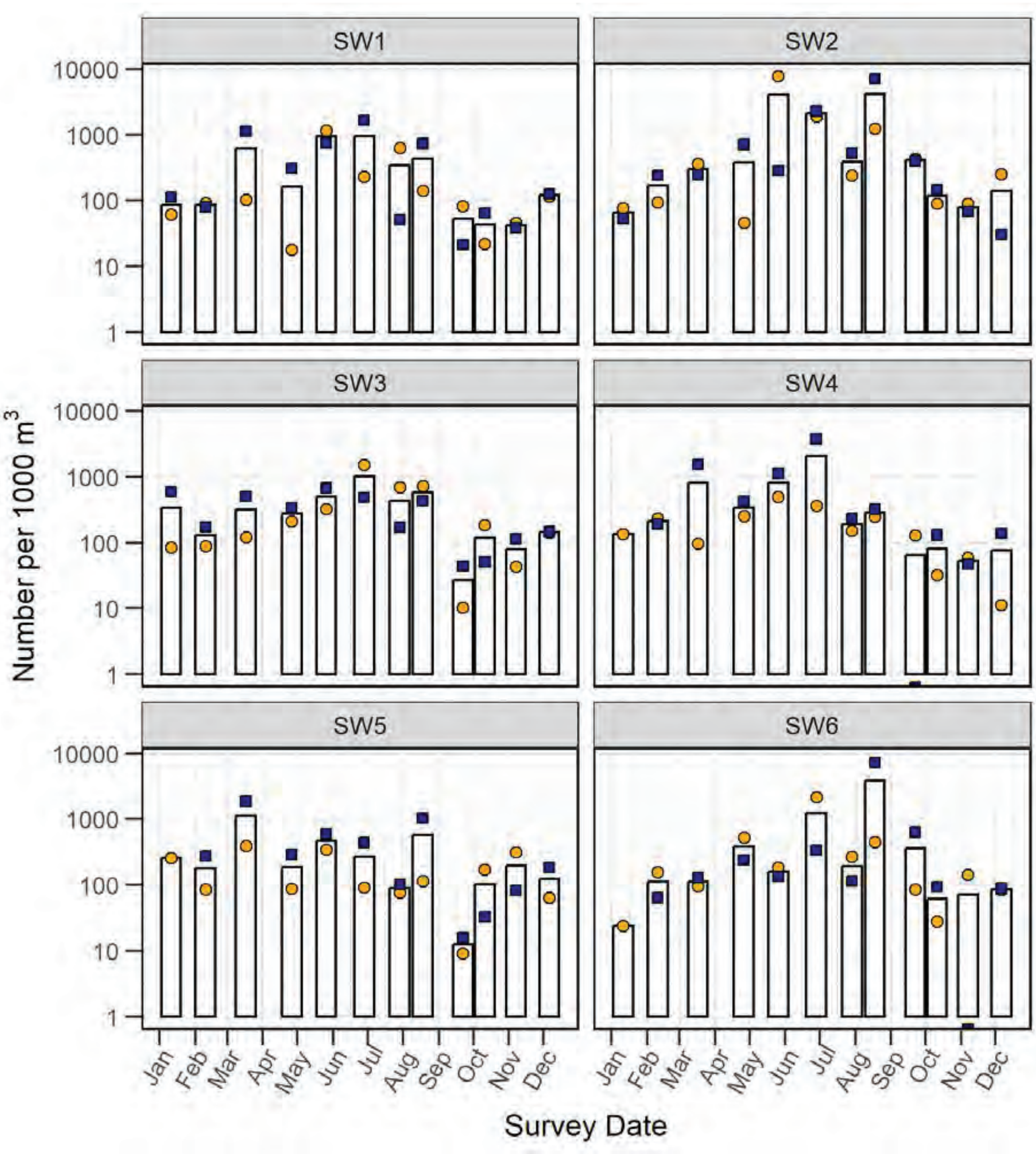

Figure 4-2. Total average concentrations of all fish larvae (height of bar) collected during monthly surveys at source water stations SW1–SW6 from January 2022–December 2022. Concentrations from daytime (orange circles) and nighttime (blue squares) are also shown. Dates of the surveys correspond to the centers of the bars.

Based on the concentration of fish eggs recorded at the entrainment stations and the anticipated volume of water entrained by the proposed project, the total estimated annual entrainment of fish eggs for the proposed project is 20,441 million (**Table 4-3**). Only approximately 0.5 million of these were anchovy eggs. A large proportion of these eggs are buoyant and would not be subject to entrainment due to the submerged intakes.

Table 4-3. Total annual estimated entrainment (standard errors in parentheses) for all larvae from intake stations E1 and E2 and both stations combined calculated from sampling in Humboldt Bay from January – December 2022 based on daily intake volumes for the RMT II (Station E1) and RTD (Station E2) intakes of 7.92x10[6] gal (29,980 m[3]) and 3.96x10[6] gal (14,990 m[3]), respectively.

Taxon	Common Name	Station E1 (1,000s)	Station E2 (1,000s)	Total (1,000s)	Percent of Total	Cumulative Percent
Larval Fishes						
Clevelandia ios	Arrow Goby	11,552 (10,271)	1,827 (1,040)	13,379 (10,323)	75.13%	75.13%
Lepidogobius lepidus	Bay Goby	969 (339)	444 (143)	1,413 (368)	7.93%	83.06%
Allosmerus elongatus	Whitebait Smelt	828 (447)	355 (222)	1,183 (499)	6.64%	89.70%
Microgadus proximus	Pacific Tomcod	253 (112)	32 (9)	285 (112)	1.60%	91.31%
Clupea pallasii	Pacific Herring	201 (158)	78 (20)	279 (159)	1.56%	92.87%
Hypomesus pretiosus	Surf Smelt	142 (115)	62 (49)	205 (125)	1.15%	94.02%
Spirinchus starksi	Night Smelt	162 (115)	16 (12)	178 (115)	1.00%	95.02%
Leptocottus armatus	Pacific Staghorn Sculpin	100 (39)	44 (5)	143 (39)	0.80%	95.82%
Liparis spp.	snailfishes	65 (39)	43 (26)	108 (47)	0.61%	96.43%
Citharichthys sordidus	Pacific Sanddab	66 (16)	10 (8)	76 (18)	0.43%	96.85%
Cottus asper	Prickly Sculpin	60 (45)	13 (11)	74 (46)	0.41%	97.27%
Ammodytes hexapterus	Pacific Sand Lance	52 (17)	15 (4)	68 (17)	0.38%	97.65%
Sebastes spp. V_	KGB rockfish complex	49 (38)	17 (5)	66 (39)	0.37%	98.02%
Oligocottus / Clinocottus spp.	sculpins	33 (1)	32 (9)	64 (9)	0.36%	98.38%
Artedius spp.	sculpins	31 (15)	17 (12)	48 (20)	0.27%	98.65%
Hippoglossoides elassodon	Flathead Sole	27 (24)	3 (3)	29 (24)	0.16%	98.81%
Spirinchus thaleichthys	Longfin Smelt	26 (22)	2 (2)	28 (22)	0.16%	98.97%
Engraulis mordax	Northern Anchovy	24 (17)	4 (0)	28 (17)	0.16%	99.12%
Stenobrachius leucopsarus	Northern Lampfish	11 (0)	2 (2)	13 (2)	0.08%	99.20%
Isopsetta isolepis	Butter Sole	10 (10)	3 (3)	13 (11)	0.07%	99.27%
larval/post-larval fish	unidentified larvae	8 (6)	5 (3)	13 (7)	0.07%	99.34%
Rhinogobiops nicholsii	Blackeye Goby	8 (6)	4 (3)	12 (7)	0.07%	99.41%
Sebastes spp. V	Blue Rockfish complex	11 (11)	0 (0)	11 (11)	0.06%	99.47%
Atherinopsis californiensis	Jacksmelt	0 (0)	11 (11)	11 (11)	0.06%	99.53%
Parophrys vetulus	English Sole	10 (10)	0 (0)	10 (10)	0.06%	99.59%
Gillichthys mirabilis	Longjaw Mudsucker	3 (3)	5 (4)	9 (5)	0.05%	99.64%
Bathymasteridae	ronquils	6 (6)	3 (3)	8 (6)	0.05%	99.69%
Stichaeidae	pricklebacks	5 (5)	2 (2)	8 (6)	0.04%	99.73%
Syngnathidae	pipefishes	6 (6)	0 (0)	6 (6)	0.04%	99.76%

table continued

Table 4-3 (cont.). Total annual estimated entrainment (standard errors in parentheses) for all larvae from intake stations E1 and E2 and both stations combined calculated from sampling in Humboldt Bay from January – December 2022 based on daily intake volumes for the RMT II (Station E1) and RTD (Station E2) intakes of 7.92x10^6 gal (29,980 m^3) and 3.96x10^6 gal (14,990 m^3), respectively.

Taxon	Common Name	Station E1 (1,000s)	Station E2 (1,000s)	Total (1,000s)	Percent of Total	Cumulative Percent
Icichthys lockingtoni	Medusa Fish	4 (4)	2 (2)	6 (5)	0.04%	99.80%
Pholidae	gunnels	6 (6)	0 (0)	6 (6)	0.03%	99.83%
Oligocottus snyderi	Fluffy Sculpin	6 (6)	0 (0)	6 (6)	0.03%	99.86%
Pleuronectidae	righteye flounders	6 (6)	0 (0)	6 (6)	0.03%	99.90%
Clinocottus embryum	Calico Sculpin	5 (5)	0 (0)	5 (5)	0.03%	99.93%
Ruscarius creaseri	Roughcheek Sculpin	5 (5)	0 (0)	5 (5)	0.03%	99.95%
Osmeridae	smelts	4 (4)	0 (0)	4 (4)	0.02%	99.98%
Genyonemus lineatus	White Croaker	0 (0)	2 (2)	2 (2)	0.01%	99.99%
Nannobrachium regalis	Pinpoint Lanternfish	0 (0)	2 (2)	2 (2)	0.01%	100.00%
Totals		14,754 (10,290)	3,055 (1,075)	17,809 (10,346)		
Fish Eggs						
non-engraulidae eggs	non-engraulidae eggs	15,090 (1,540)	5,095 (1,025)	20,185 (1,850)	98.75%	98.75%
Engraulidae (eggs)	anchovy eggs	141 (67)	115 (97)	256 (118)	1.25%	100.00%
Totals		15,231 (1,607)	5,210 (1,122)	20,441 (1,967)		

The crab megalops larvae collected during the sampling were categorized into four taxa groups: *Metacarcinus magister*, *Cancer productus*/*Romaleon* spp., *Romaleon antennarius*/*Metacarcinus gracilis*, and unidentified Cancridae. The megalops larval stage is the final stage in the larval development of all species of crabs including the Family Cancridae which includes Dungeness crab and several species of rock crabs that are important targets of recreational and commercial fisheries. The crab megalops collected during the study were all larger than 0.16 in. (4 mm) and would not be subject to entrainment. The most abundant taxa of crab megalops larvae collected during the sampling was Dungeness crab (**Table 4-2**).

The highest average concentrations of all crab megalops larvae combined at the two entrainment stations occurred during the months of March–June and in November with the highest concentrations occurring during the May survey at both stations (**Figure 4-5**). Megalops larvae were generally only collected during the night surveys except for the May survey at Station E1 and the November survey at Station E2.

The highest average concentrations of all crab megalops larvae combined at the source water stations occurred during the month of May with the highest concentrations occurring during the May survey at Station SW3 (**Figure 4-6**). Megalops larvae were generally only collected during the night surveys at the stations in Arcata Bay (SW1, SW2, and SW6), while crab larvae were collected in both day and samples at the other stations.

There are no entrainment totals for crab megalops larvae shown in **Table 4-3** since these larvae are too large to be entrained by the intakes due to the small slot openings.

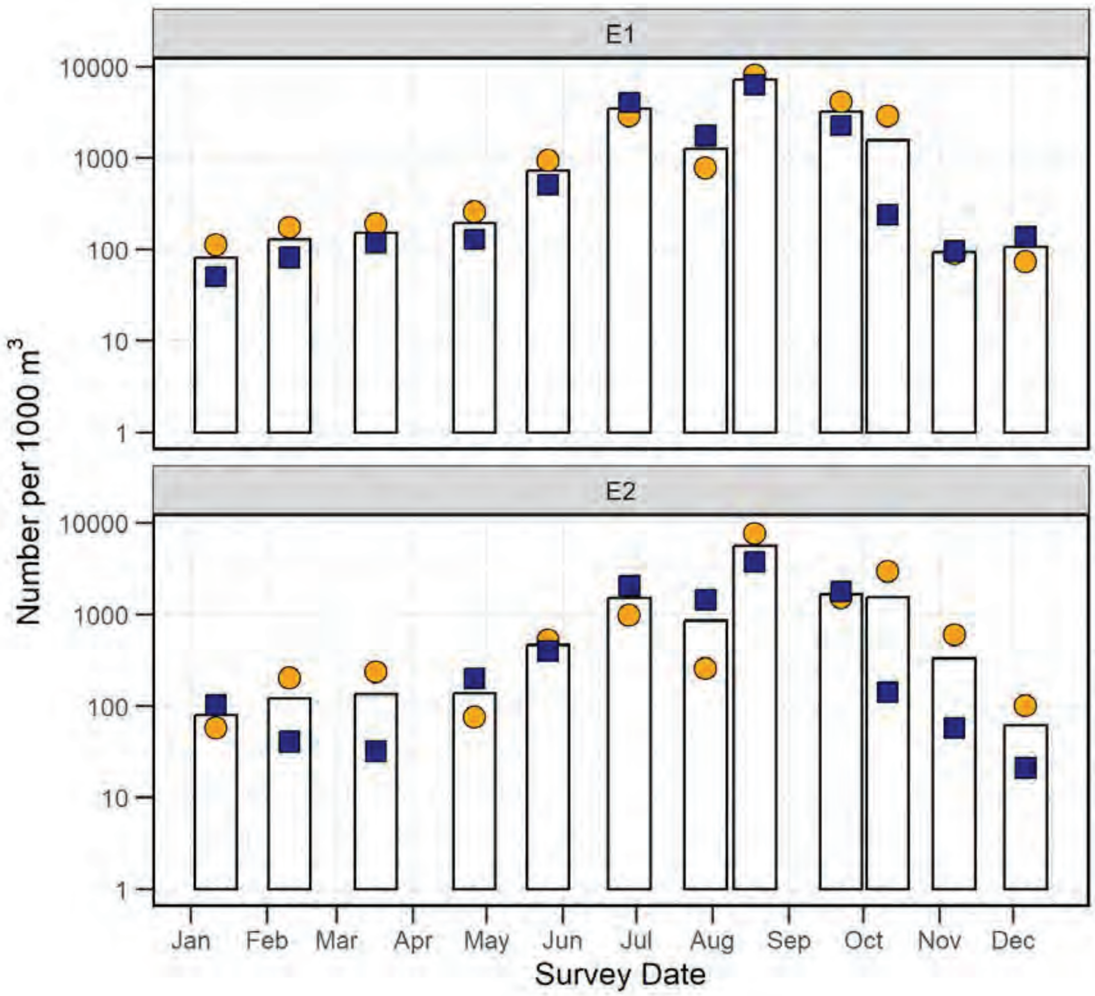

Figure 4-3. Total average concentrations of all fish eggs (height of bar) collected during monthly surveys at entrainment stations E1 and E2 from January 2022–December 2022. Concentrations from daytime (orange circles) and nighttime (blue squares) are also shown. Dates of the surveys correspond to the centers of the bars.

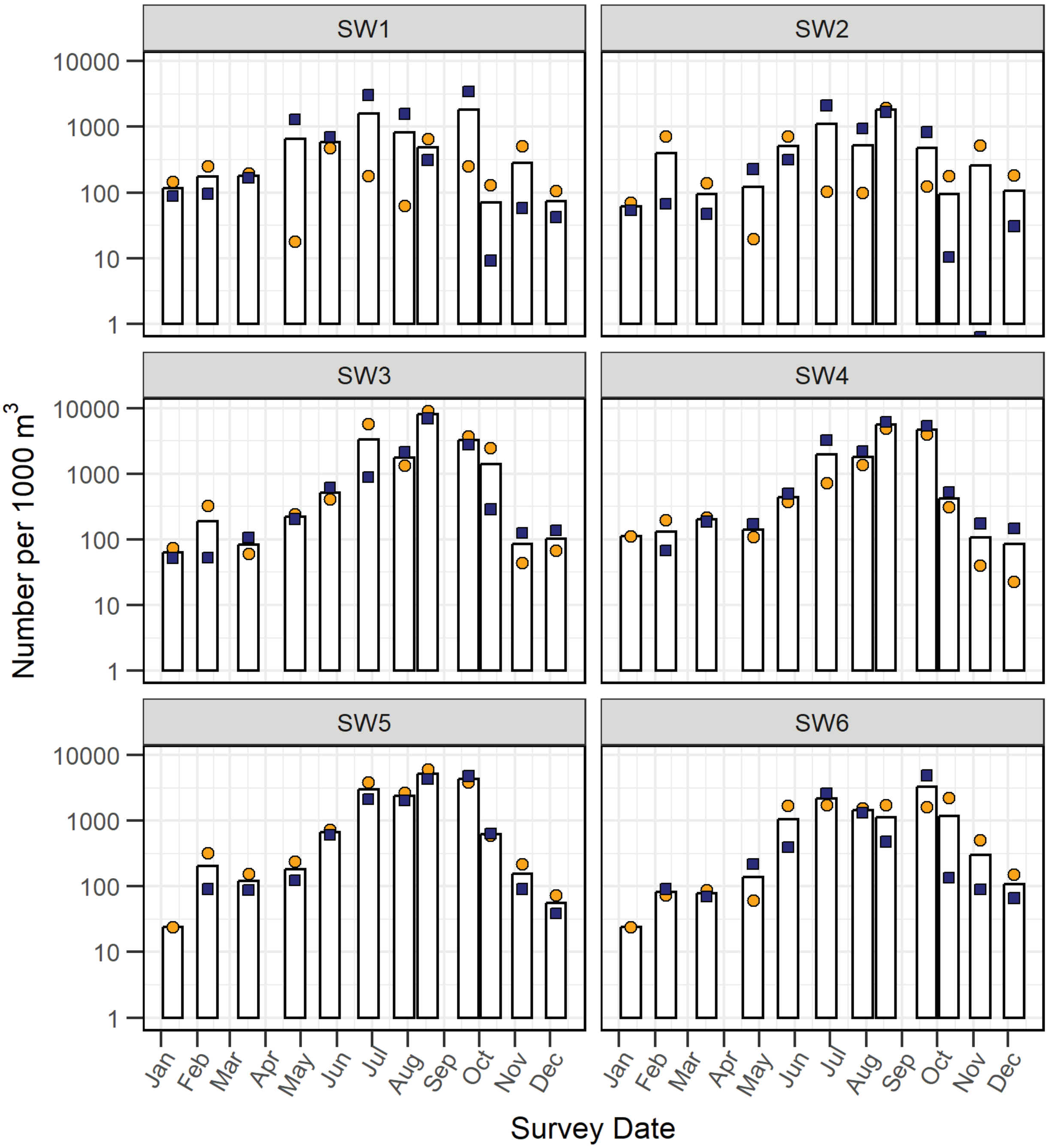

Figure 4-4. Total average concentrations of all fish eggs (height of bar) collected during monthly surveys at source water stations SW1–SW6 from January 2022–December 2022. Concentrations from daytime (orange circles) and nighttime (blue squares) are also shown. Dates of the surveys correspond to the centers of the bars.

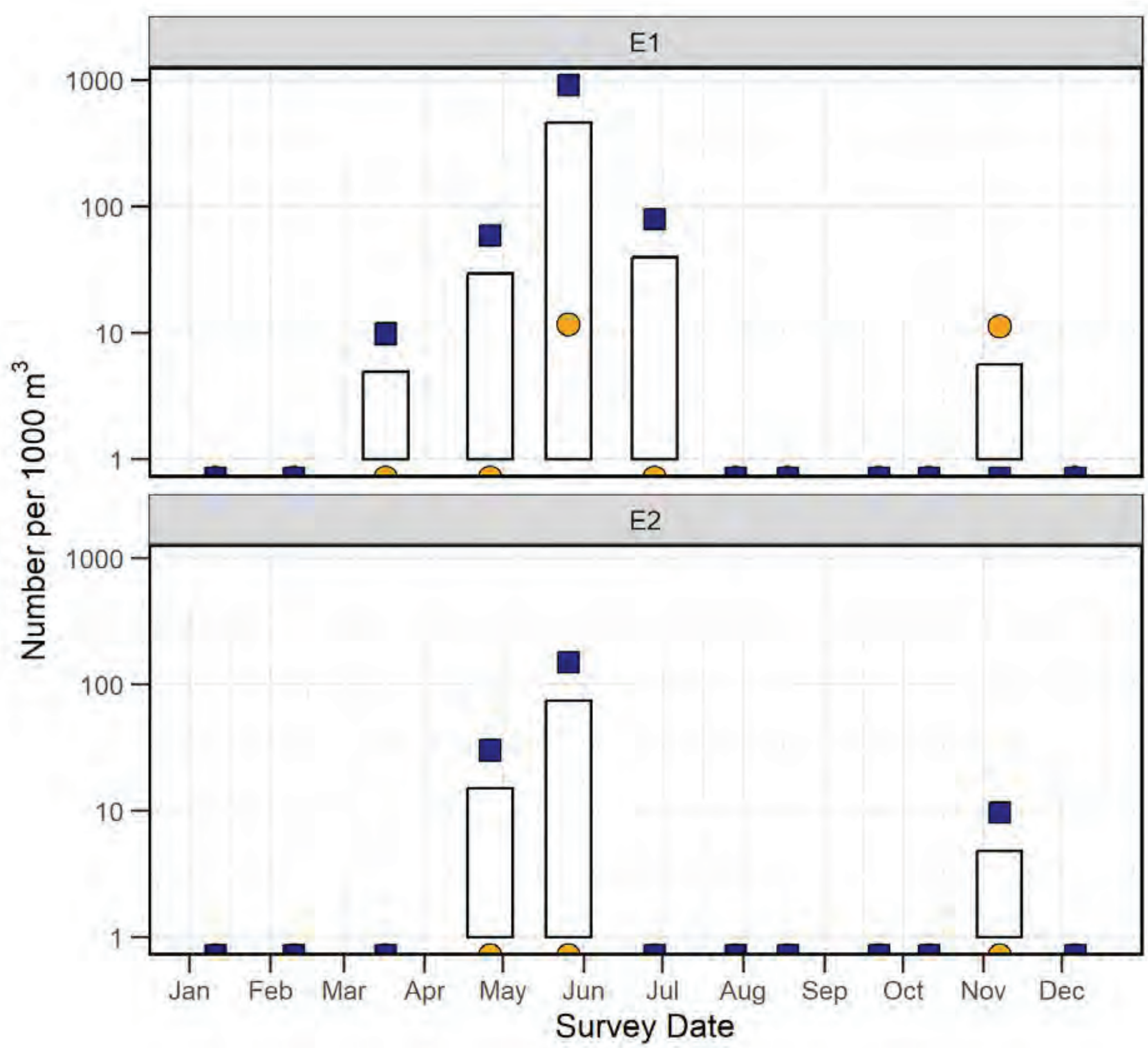

Figure 4-5. Total average concentrations of all crab megalops larvae (height of bar) collected during monthly surveys at entrainment stations E1 and E2 from January 2022–December 2022. Concentrations from daytime (orange circles) and nighttime (blue squares) are also shown. Dates of the surveys correspond to the centers of the bars.

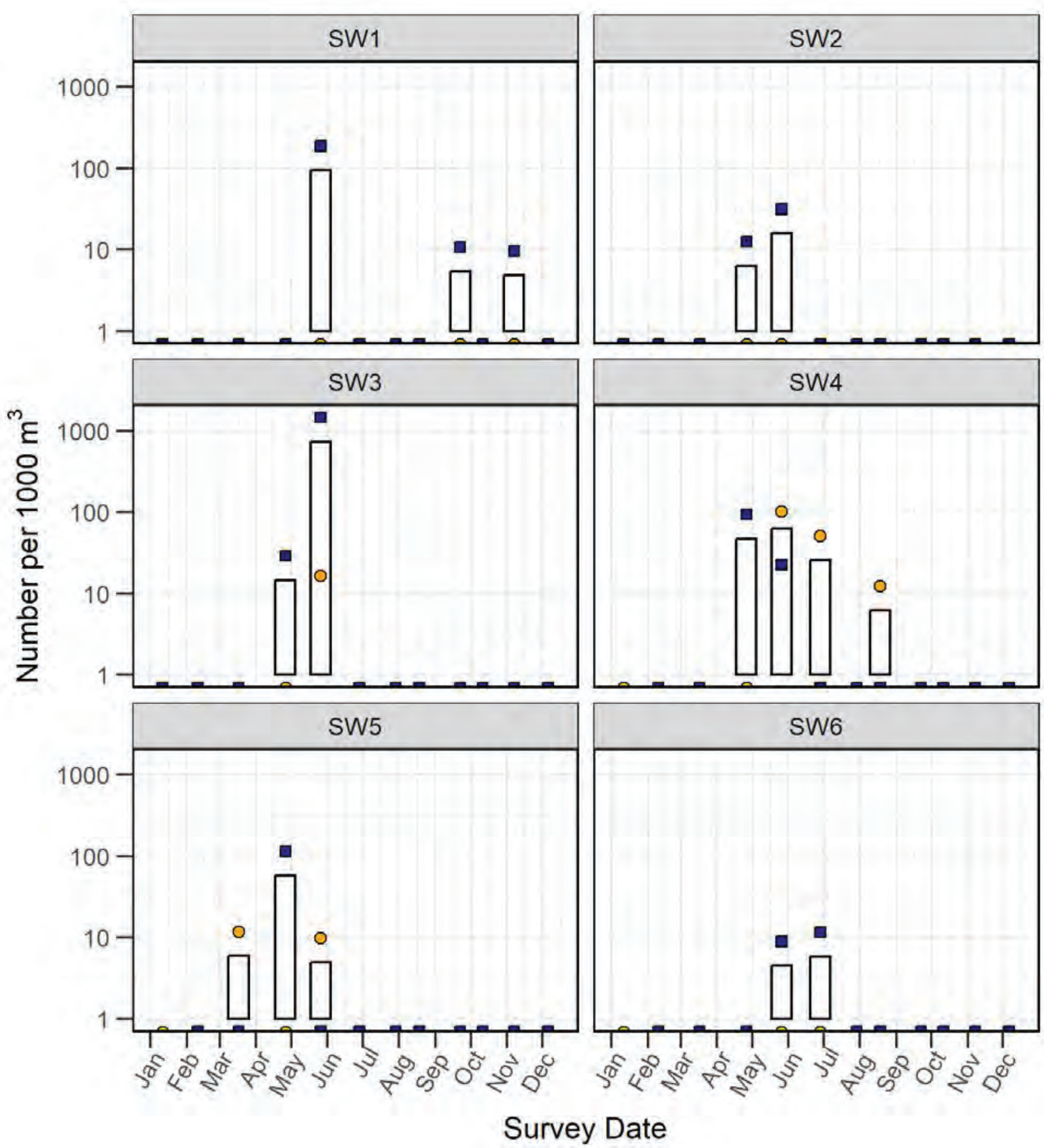

Figure 4-6. Total average concentrations of all crab megalops larvae (height of bar) collected during monthly surveys at entrainment stations E1 and E2 from January 2022–December 2022. Concentrations from daytime (orange circles) and nighttime (blue squares) are also shown. Dates of the surveys correspond to the centers of the bars.

4.2 Taxa Profiles

Seven taxa of fishes were selected for evaluation of entrainment effects based on their abundance in the sampling for the study. These seven taxa comprised almost 95% of the total abundance of larval fishes at the two entrainment stations (**Table 4-3**). Four of the seven taxa (Surf Smelt, Pacific Staghorn Sculpin, Arrow Goby, and Pacific Herring) were included in the top ten most abundant taxa in a study of adult fishes in Humboldt Bay (Gleason et al. 2007). Two of the other taxa, Bay Goby and Arrow Goby, along with Pacific Herring and Pacific Staghorn Sculpin were four of the five most abundant taxa of fish larvae collected by Eldridge and Bryan (1972). Although Night Smelt were in slightly higher abundance than Pacific Staghorn Sculpin at the entrainment stations, the Night Smelt were only collected during two surveys at the entrainment stations resulting in only two estimates of *PE* for the ETM calculations. As a result, Pacific Staghorn Sculpin were selected to be included in the ETM analyses since this taxon also represented a different habitat type than that occupied by Night Smelt which is probably similar to Whitebait Smelt in its habitat preferences.

The seven taxa selected for ETM analysis are:

- Arrow Goby *(Clevelandia ios)*
- Bay Goby (*Lepidogobius lepidus*)
- Whitebait Smelt (*Allosmerus elongatus*)
- Pacific Herring (*Clupea pallasi*)
- Pacific Tomcod *(Microgadus proximus)*
- Surf Smelt *(Hypomesus pretiosus)*
- Pacific Staghorn Sculpin *(Leptocottus armatus)*

Information is also provided on Longfin Smelt (LFS), a species listed in 2009 by the State of California as threatened under the California Endangered Species Act. The natural history and life history parameters of these taxa are described in the following sections as background for interpreting the results of the entrainment modeling which relies on life history information for each taxon. Other fishes and invertebrates with larvae that could be subject to entrainment at the two intakes are discussed, but model results using estimated larval durations are only presented in Section 5.0 for these seven taxa.

4.2.1 **Arrow Goby** *Clevelandia ios*

Native distribution of the Arrow Goby. Range of colors indicate degree of suitability of habitat which can be interpreted as probabilities of occurrence. Red indicates highest probability of occurrence, yellow indicates lowest. *(Kaschner et. al. 2019)*

(Greg Goldsmith, USFW)

***Range*:** Vancouver Island, British Columbia to southern Baja California

Life History: Size up to 2.24 in. (57 mm); age at maturity from 1– 2 yr; Life span ≥3 yr; spawns year-round in bays and estuaries; demersal adhesive eggs with fecundity from 300–1,100 eggs per spawning event with multiple spawning (2–5 per yr).

Habitat: Mud and sand substrates of bays and estuaries; commensally in burrows of shrimps and other invertebrates.

Fishery: None

The family Gobiidae is composed of small, demersal fishes that are found worldwide in shallow tropical and subtropical environments (Moser 1996). The family contains around 1,875 species in 212 genera (Nelson 1994). Twenty-one goby species from 16 genera occur from the northern California border to south of Baja California (Moser 1996). Arrow Goby is one of several species of gobies that are abundant in mudflat habitat in coastal embayments and estuaries in California. The Arrow Goby was the ninth most abundant species collected during a study in 2000–2001 on the fishes of Humboldt Bay (Gleason et al. 2007). It was the fourth most abundant taxon of larval fish collected during a study of ichthyoplankton during 1969 in Humboldt Bay by Eldridge and Bryan (1972).

Goby larvae look distinctly different from other families of larval fishes in California. The larvae, however, are similar to each other at all stages of their development, making them difficult to identify to species. In very early developmental stages, the Arrow Goby shares morphologic and meristic similarities with other species including the Bay Goby (*Lepidogobius lepidus*). Moser (1996) indicates that Arrow Goby, Cheekspot Goby (*Ilypnus gilberti*), and the Shadow Goby (*Quietula y-cauda*) cannot be differentiated during any larval stage. Brothers (1975) reported difficulty in separating developed Arrow and Cheekspot goby larvae that were less than 2.6 in. (65 mm) long. However, of these three species, only Arrow Goby occurs in Humboldt Bay.

Members of the family Gobiidae share many life history characteristics. Adult gobies are oviparous and produce demersal eggs that are elliptical in shape, typically adhesive, and attached to a nest substratum at one end (Wang 1986, Matarese et al. 1989, Moser 1996). Most species, including the Arrow Goby, inhabit burrows in mud flats and other shallow regions of bays and estuaries (Miller and Lea 1972). The fecundity of the Arrow Goby ranges from 750 to 1,000 eggs (Wang 1986), and spawning may occur multiple times per year (Brothers 1975). No data on the seasonality of the larvae was reported in the only available study on fish larvae from Humboldt Bay (Eldridge and Bryan 1972). Goby larvae hatch at a length of 0.08–0.12 in. (2–3 mm) (Moser 1996) and enter the plankton following hatching and remain in this pelagic phase until they transform and become benthic-oriented juveniles.

The duration of the planktonic phase varies greatly within the family and is not well described for most species. The period of entrainment risk used in the ETM model was estimated using a larval Arrow Goby growth rate of 0.008 in. (0.198 mm) per day calculated from data in Brothers (1975).

Sampling Results

The Arrow Goby was the most abundant taxa of fish larvae collected during the sampling from January–December 2022 (**Table 4-2** and **Table 4-3**). A total of approximately 13.4 million Arrow Goby were estimated to be entrained during the year, comprising over 75% of the total estimated entrainment of larval fishes. They were the most abundant taxa at all of the stations except for stations SW4 and SW5 (**Table 4-2**). They were also in much higher abundance at Station E1 than E2, which resulted in correspondingly higher entrainment at Station E1 for this taxon (**Table 4-3** and **Figure 4-7**). Arrow Goby larvae were collected from all the surveys from at least one of the entrainment stations except for the surveys in January and February. The peak abundance for this taxon occurred during the June survey at both entrainment stations. The average concentration for Station E1 during the late June survey was 10,673 per 1,000 m^3 (sample 4, Survey 6 in Appendix A). As suggested above, this could have been due to a large number of Arrow Goby produced in Arcata Bay passing through the sampling area on an ebb tide, but the data in Appendix B show a flood tide during the sample collection, and it is likely that the high concentration for that sample is a reflection of the extremely patchy nature of plankton abundance. The highly variable nature of ichthyoplankton abundance is reflected in the concentrations of Arrow Goby larvae in the two samples collected during Survey 6. The concentration was 21,346/1000 m^3 in the day sample and zero in the night sample.

Arrow Goby were collected in highest abundance at the source water stations in Arcata Bay (SW1, SW2, and SW6) which are dominated by mud flat habitat, the preferred habitat for this species (**Figure 4-8**). They were collected in only three surveys at source water Station SW4 which is located just upcoast from the Harbor Entrance along the North Sand Spit, which most likely has sandier habitat than the areas in Arcata Bay.

The length frequency of the 204 Arrow Goby larvae measured from the study that were less than 0.98 in. (24.89 mm) shows that the largest numbers of larvae were very close in notochord length (NL) to the estimated hatch length (**Figure 4-9**). The average NL was 0.15 in. (3.89 mm) and the smallest and longest larvae measured were 0.09 and 0.84 in. (2.35 and 21.35 mm) NL, respectively. These measurements are used to calculate bootstrap estimates of the minimum and maximum lengths used in calculating the period of larval exposure to entrainment for the ETM.

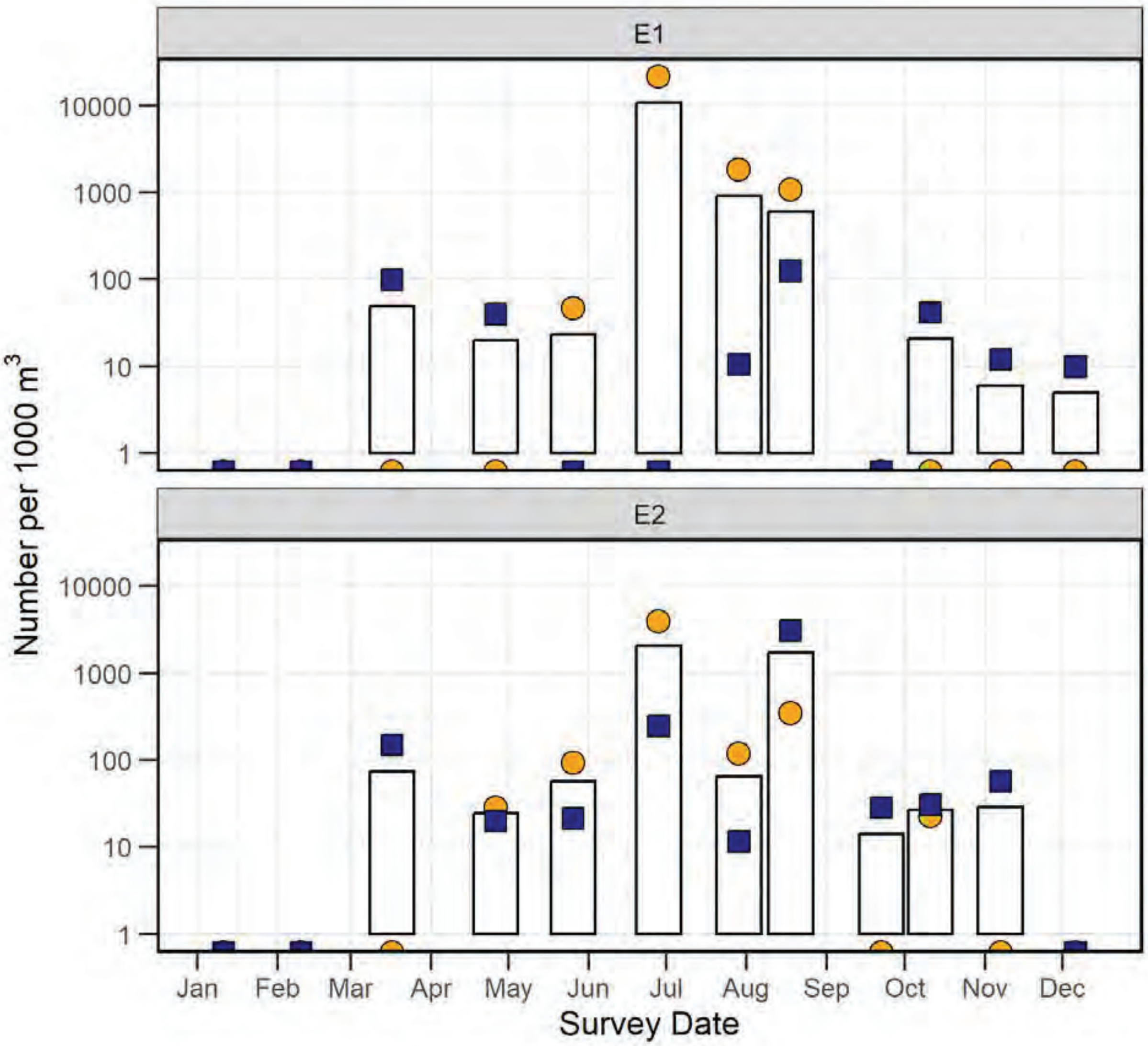

Figure 4-7. Total average concentrations of Arrow Goby larvae (height of bar) collected during monthly surveys at entrainment stations E1 and E2 from January 2022–December 2022. Concentrations from daytime (orange circles) and nighttime (blue squares) are also shown. Dates of the surveys correspond to the centers of the bars. Note use of log-scale due to magnitude of some of the abundances.

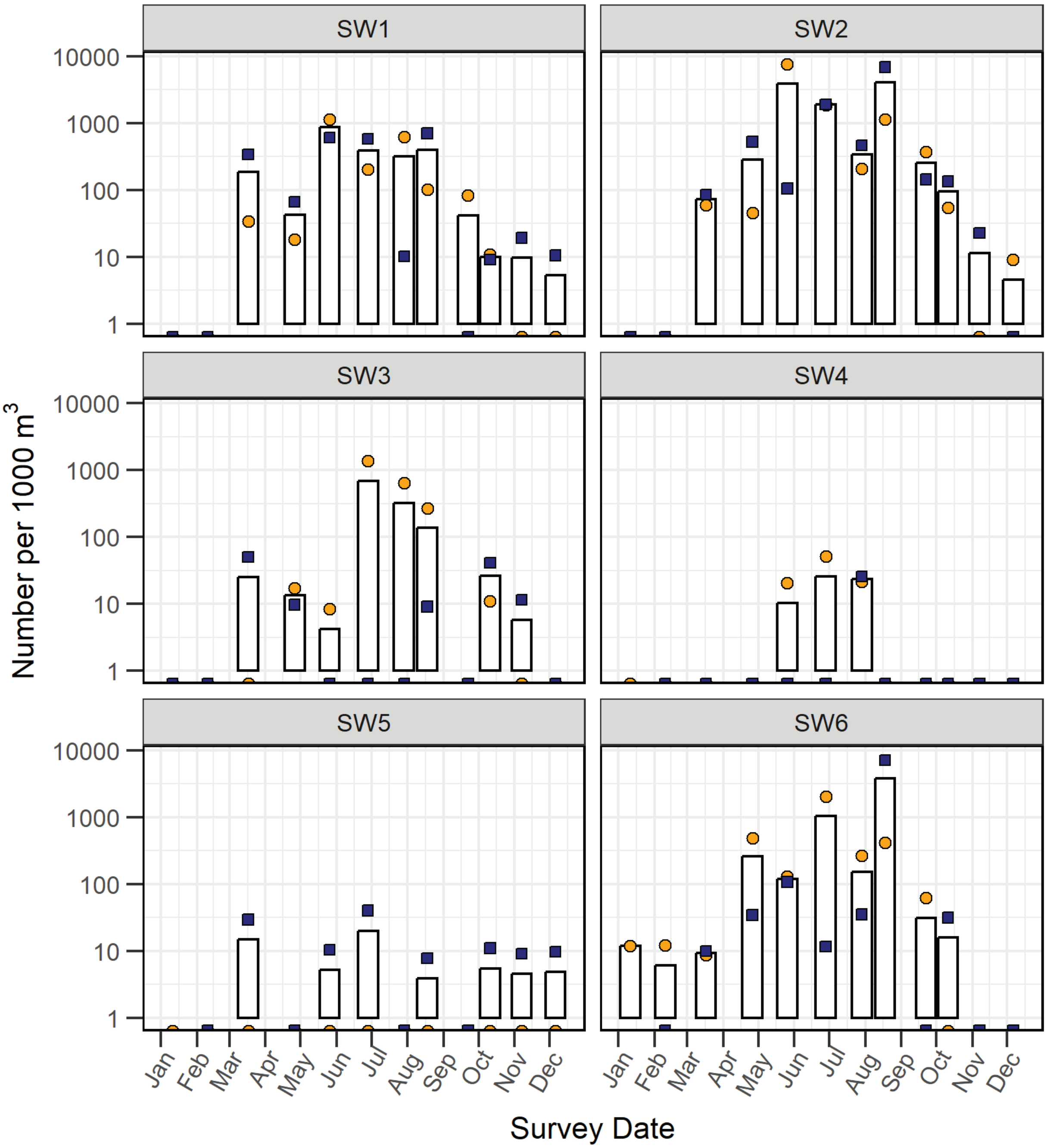

Figure 4-8. Total average concentrations of Arrow Goby larvae (height of bar) collected during monthly surveys at source water stations SW1–SW6 from January 2022–December 2022. Concentrations from daytime (orange circles) and nighttime (blue squares) are also shown. Dates of the surveys correspond to the centers of the bars. Note use of log-scale due to magnitude of some of the abundances.

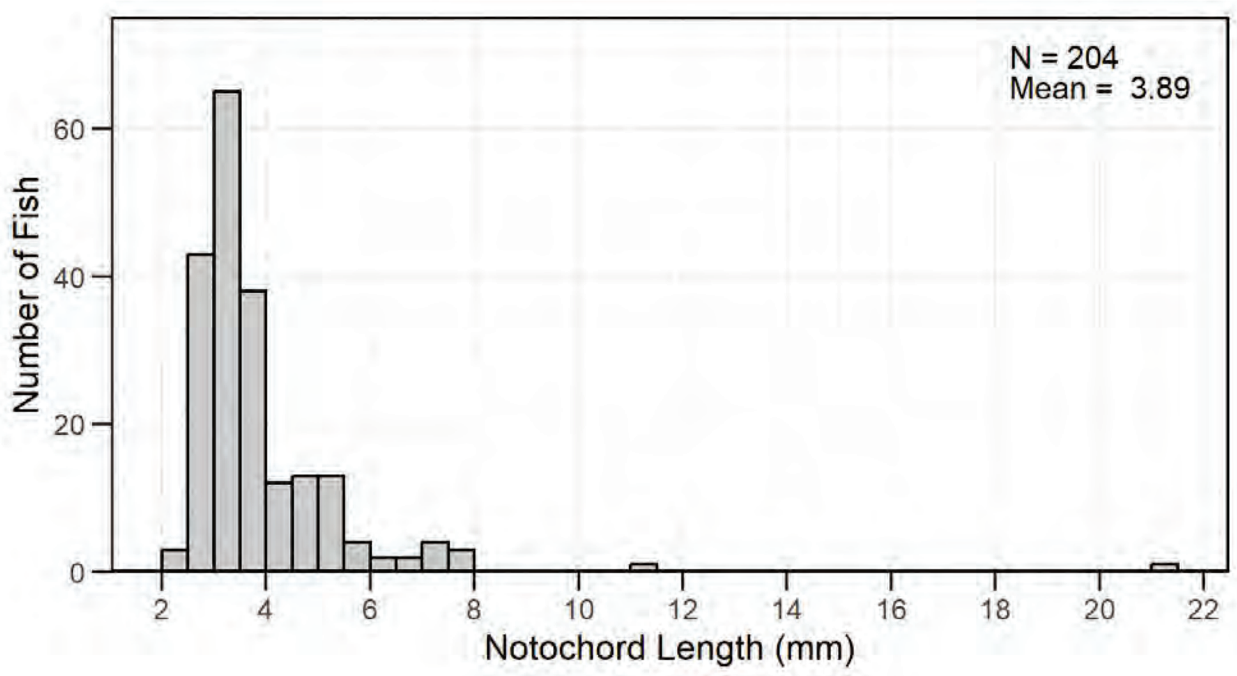

Figure 4-9. Length frequency of Arrow Goby measured from larvae collected from stations E1, E2, SW2, and SW3 from January 2022–December 2022.

4.2.2 **Bay Goby** *Lepidogobius lepidus*

Native distribution of the Bay Goby. Range of colors indicate degree of suitability of habitat which can be interpreted as probabilities of occurrence. Red indicates highest probability of occurrence, yellow indicates lowest. *(Kaschner et. al. 2019)*

Range: From Cedros Island, Baja California to Vancouver Island, British Columbia.

Life History: Size: to 4.3 in. (108 mm); age at maturity: one to two years old; fecundity: no information available; demersal, adhesive eggs; lifespan: seven plus years.

Habitat: Intertidal mudflats, shallow pools.

Fishery: None.

The Bay Goby is a common bottom-dwelling inhabitant of bays and estuaries along the Pacific Coast of North America. It ranges from Vancouver Island, British Columbia to Cedros Island, Baja California (Miller and Lea 1972). Bay Goby larvae were the most abundant taxon of fish larvae collected in 1969 in Humboldt Bay by Eldridge and Bryan (1972). They were not particularly abundant in the sampling of fish populations in Humboldt Bay by Gleason et al. (2007).

The Bay Goby is generally considered a shallow-water marine species but may occur on mud and mud-sand substrata down to depths of 200 ft (61 m) (Miller and Lea 1972). They are common on intertidal mudflats in invertebrate burrows and shallow pools when the tide is out (Grossman 1979). Like many marine-estuarine species they are tolerant of variations in salinity and temperature.

Reports differ on the longevity of Bay Goby. They are reported to live for about seven years, which is considered unusually long for a small fish species (Grossman 1979). Life span estimates of two to three years have been derived from length frequency data.

Based on differences in ova size/development from fish collected during April and May off Hunters Point Power Plant in San Francisco Bay and in Moss Landing Harbor, Bay Gobies have been characterized as asynchronous multiple spawners (Wang 1986). Most Bay Goby do not become reproductively mature until their second year, but a few mature during their first year (Wang 1986). Because Bay Goby use invertebrate burrows for predator avoidance and protection against dehydration during low tides, it is thought that this species, like many other goby species, may also use burrows for spawning (Grossman 1979, Wang 1986). No fecundity information is available for the species. Eggs are demersal, spherical/elliptical in shape, and have an adhesive anchoring point (Wang 1986).

Bay Goby larvae occur with the larvae of Arrow Goby, Cheekspot Goby, and Yellowfin Goby *Acanthogobius flavimanus* in San Francisco Bay (Wang 1986, Grossman 1979). In a study by Wang (1986), the greatest abundance of Bay Goby larvae was collected in San Francisco Bay from November through May, with peak numbers occurring in April and May. No data on the seasonality of Bay Goby were reported in the only available study on fish larvae from Humboldt Bay (Eldridge and Bryan 1972). Newly hatched larvae are small (0.12 in. [3 mm] or less) and nearly transparent (Wang 1986) and may have a planktonic life phase of 3 to 4 months (Grossman 1979, Wang 1986). Completion of the transformation stage (beginning of the juvenile phase) for Bay Goby larvae occurs around 1.1. in. (29 mm) (Moser 1996). There are no reported larval growth rates for Bay Goby, but a growth rate of 0.01 in. (0.22 mm) per day was calculated by using the size difference between hatch length (0.1 in. [2.85 mm]) and transformation length (1.0 in. [26.5 mm]) (Moser 1996, Wang 1986) divided by an average planktonic duration of three to four months (105 days) from Grossman (1979).

Juveniles (and adults) occupy the burrows of blue mud shrimp *Upogebia pugettensis*, geoduck clams *Panope generosa* and other burrowing animals for shelter and predator avoidance (Grossman 1979). Juvenile and adult Bay Goby growth was described by Grossman (1979). Growth is initially rapid, with 50% of their total growth (length) occurring within the first two years. Following this period of rapid growth, increases in length slow to about 0.24 in. (6 mm) per year.

Bay Goby are thought to be an important food item in the diet of a variety of vertebrate and invertebrate predators. Their abundance, small size, and extended planktonic duration make Bay

Goby larvae an important link in the food web of bay/estuarine systems (Wang 1986). Their abundance as juveniles and adults suggests that they remain an important forage species throughout all life stages. Pacific Staghorn Sculpin and California Halibut are among the many fish predators of other adult gobies (Brothers 1975). It is assumed that these fishes and sharks and rays that inhabit estuarine systems also prey on Bay Goby (Grossman 1979).

Sampling Results

Bay Goby was the second most abundant taxa of fish larvae collected during the sampling from January-December 2022 (**Table 4-2** and **Table 4-3**). A total of approximately 1.4 million Bay Goby were estimated to be entrained during the year, comprising about 8% of the total estimated entrainment of larval fishes. Bay Goby were the second most abundant taxa at all of the stations except for stations SW4 and SW5 (**Table 4-2**). At Station SW4, they were the third most abundant and at SW5 they ranked as the most abundant species collected. They were collected during all surveys from at least one of the entrainment stations except for the surveys done in February and March (**Figure 4-10**). The peak abundance for this taxon occurred during the August survey at entrainment Station E1 and during the September survey at entrainment Station E2. Bay Goby were collected in highest abundance at source water stations SW3 and SW5 (**Table 4-2** and **Figure 4-11**). Station SW5 is located near the entrance to the South Bay, which also has large areas mud flat habitat but also receives ocean influence since it is close to the Entrance Bay.

The length frequency of the 175 Bay Goby larvae measured from the study shows that a large number of the larvae were less than the estimated hatch NL of 0.1 in. (2.85 mm) (**Figure 4-12**). The average NL was 0.12 in. (3.06 mm) and the smallest and longest larvae measured were 0.08 and 0.18 in. (2.06 and 4.54 mm) NL, respectively. These measurements are used to calculate bootstrap estimates of the minimum and maximum lengths used in calculating the period of larval exposure to entrainment for the ETM.

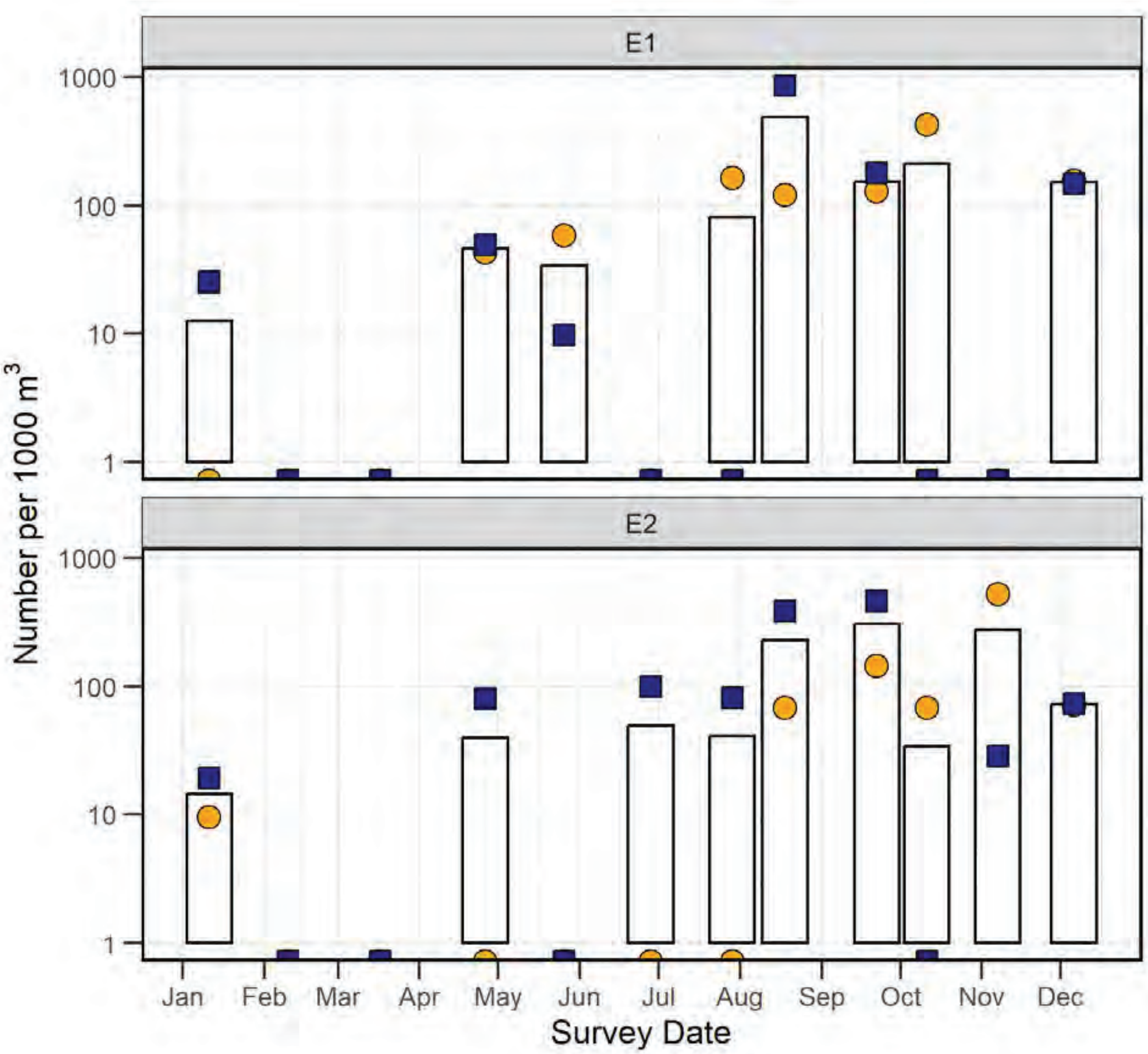

Figure 4-10. Total average concentrations of Bay Goby larvae (height of bar) collected during monthly surveys at entrainment stations E1 and E2 from January 2022–December 2022. Concentrations from daytime (orange circles) and nighttime (blue squares) are also shown. Dates of the surveys correspond to the centers of the bars. Note use of log-scale due to magnitude of some of the abundances.

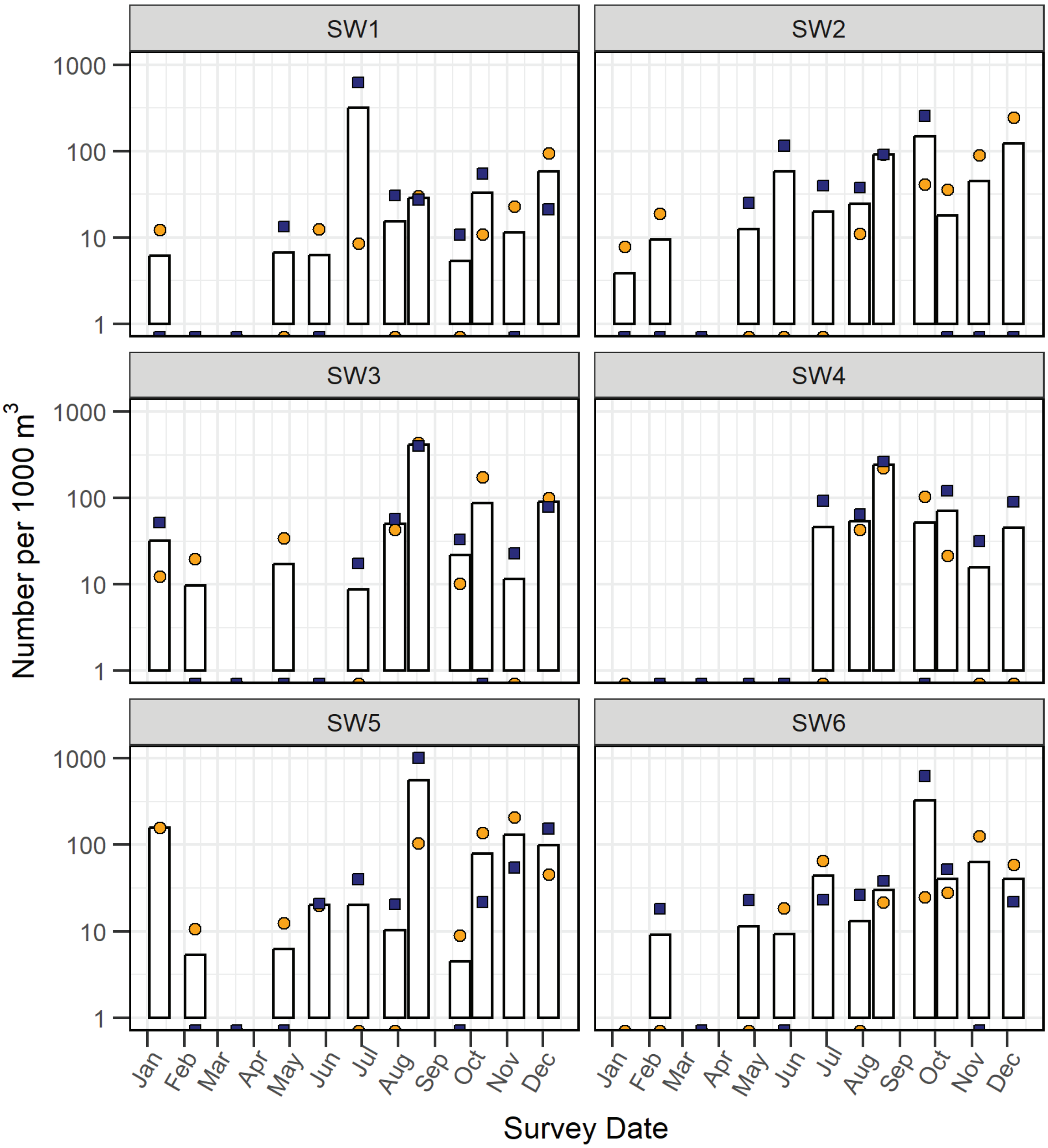

Figure 4-11. Total average concentrations of Bay Goby larvae (height of bar) collected during monthly surveys at source water stations SW1–SW6 from January 2022–December 2022. Concentrations from daytime (orange circles) and nighttime (blue squares) are also shown. Dates of the surveys correspond to the centers of the bars. Note use of log-scale due to magnitude of some of the abundances.

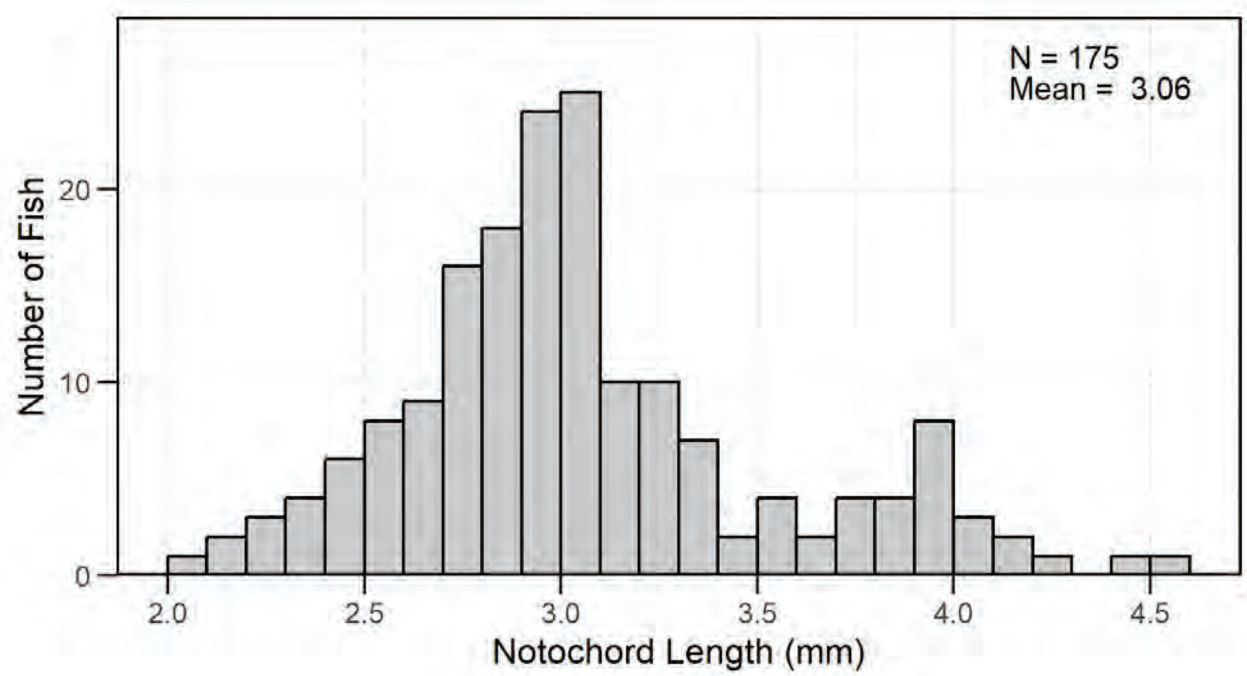

Figure 4-12. Length frequency of Bay Goby measured from larvae collected from stations E1, E2, SW2, and SW3 from January 2022–December 2022.

4.2.3 **Whitebait Smelt** *Allosmerus elongatus*

Native distribution of Whitebait Smelt. Range of colors indicate degree of suitability of habitat which can be interpreted as probabilities of occurrence. Red indicates highest probability of occurrence, yellow indicates lowest. *(Kaschner et. al. 2019)*

(Photo Credit: Guidesly, 2023)

***Range*:** Vancouver Island, British Columbia to San Francisco, California.

Life History: Size up to 9 in. (228.6 mm) Life span: 1-3 years. Ocean spawner; spawns in subtidal banks. Osmerid eggs in general are 0.031-0.043 in. (0.8-1.1 mm) in diameter, demersal, adhesive, and have a characteristic double chorion and numerous oil globules.

Habitat: A schooling nearshore and pelagic fish, found in bays, estuaries, and along the open coast. Generally found in depths between 3-300 ft (0.9-91.4 m).

Fishery: Primarily, recreationally fished. A past commercial fishery did exist.

The family Osmeridae is composed of small, soft-rayed fishes that can be found in marine, estuarine, and freshwater habitats (Hart 1973). The family contains six genera with 15 species (Fricke et al. 2020). Six of these species are native to California's coastal and estuarine waters (Sweetnam et al. 2001). Of these six, four are commonly found in Humboldt Bay; Surf Smelt, Night Smelt (*Spirinchus starksi*), LFS, and Whitebait Smelt (Miller and Lea 1972). Whitebait Smelt are occasionally found within bays but are more common outside the bay (Fritzsche and Cavanagh 2007). However, in 2000-2001, they were observed in 3 different sites within Humboldt Bay during a fish diversity study but, their abundance ranked at less than <0.1% (Gleason et al. 2007).

There is very little known about Whitebait Smelt. They are considered to be a relatively uncommon species throughout their range with a few locally abundant areas such as San Francisco Bay, San Pablo Bay, and Humboldt Bay (Sweetnam et al. 2001). Whitebait Smelt are a pale, greenish, color, they have a small adipose fin that is directed backwards and a sharply marked silver stripe along their sides (Hart 1973). They can be differentiated from other osmerids by the unique presence of a large canine on the roof of their mouth (Miller and Lea 1972).

Like other smelt, they live in large schools and feed on zooplankton and small fishes (Love, 2011). They tend to favor productive inshore areas and bays; however, they are only rarely caught in estuaries or coastal waters. Spawning is thought to take place in sandy, subtidal areas. Young-of-the-year remain translucent and are considered "post-larval" until they are almost three inches (76.2 mm) in length (Sweetnam et al. 2001). They live one to three years and reach lengths of nine inches (Sweetnam et al. 2001, Love, 2011). The succession of even year classes in San Francisco Bay may suggest a two-year maturity schedule (Sweetnam et al. 2001).

Whitebait Smelt development has not yet been described, however, molecular and morphological analyses show that Whitebait Smelt and Longfin Smelt are sister taxa (McAllister 1963, Wilson and Williams 1991, Ilves and Taylor 2009), therefore for our modeling purposes we used the larval growth rates of Longfin Smelt, which were estimated at 0.01 in. (0.17 mm) per day based on data from studies in San Francisco Bay by Lewis (2020) and an estimated hatch length of 0.22 in. (5.5 mm).

Sampling Results

Whitebait Smelt was the third most abundant taxa of fish larvae collected during the sampling from January–December 2022 (**Table 4-2** and **Table 4-3**). A total of approximately 1.2 million Whitebait Smelt were estimated to be entrained during the year, comprising over 7% of the total estimated entrainment of larval fishes. They were the most abundant species collected at Station SW4 and were often the third most abundant taxa at many of the other stations (**Table 4-2**). They were collected during all the surveys from at least one of the entrainment stations except for the surveys in October, November, and December (**Figure 4-13**). The peak abundance for this taxon occurred during the June survey at both entrainment stations. Whitebait Smelt were collected in highest abundance at the source water station just upcoast from the Harbor Entrance along the North Sand Spit (SW4) (**Figure 4-14**). There is likely sandier habitat at this station than some of the other sites and this matches the preferred habitat and breeding ground for this taxon. Their lowest abundance levels were in Arcata Bay at stations; SW1, SW2, and SW6 which are dominated by mud flat habitat.

The length frequency of the 240 Whitebait Smelt larvae measured from the study had an average NL of 0.25 in. (6.41 mm) and the smallest and longest larvae measured were 0.16 and 0.63 in. (4.13 and 16.02 mm) NL, respectively (**Figure 4-15**). These measurements are used to calculate bootstrap estimates of the minimum and maximum lengths used in calculating the period of larval exposure to entrainment for the ETM.

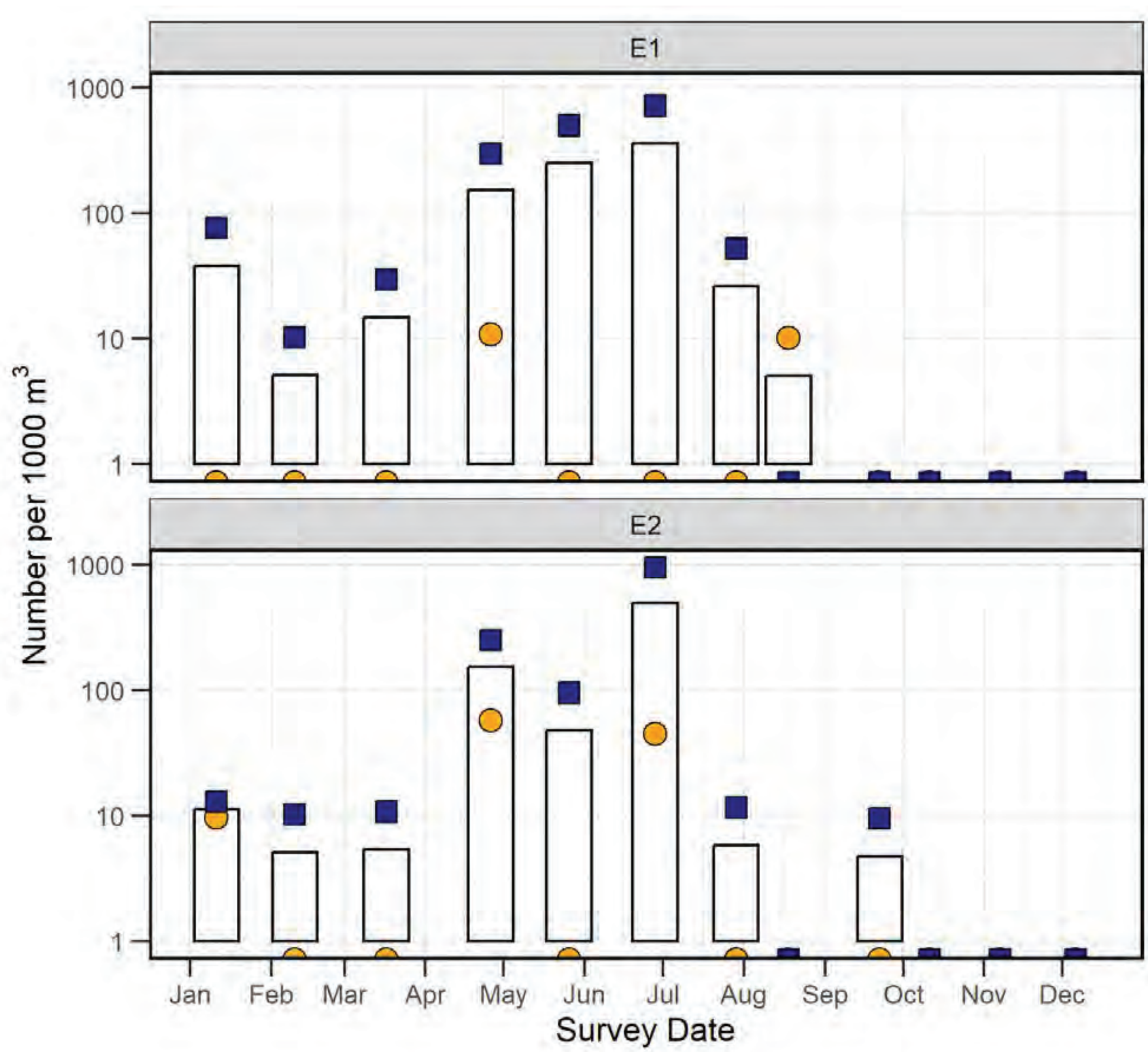

Figure 4-13. Total average concentrations of Whitebait Smelt larvae (height of bar) collected during monthly surveys at entrainment stations E1 and E2 from January 2022–December 2022. Concentrations from daytime (orange circles) and nighttime (blue squares) are also shown. Dates of the surveys correspond to the centers of the bars. Note use of log-scale due to magnitude of some of the abundances.

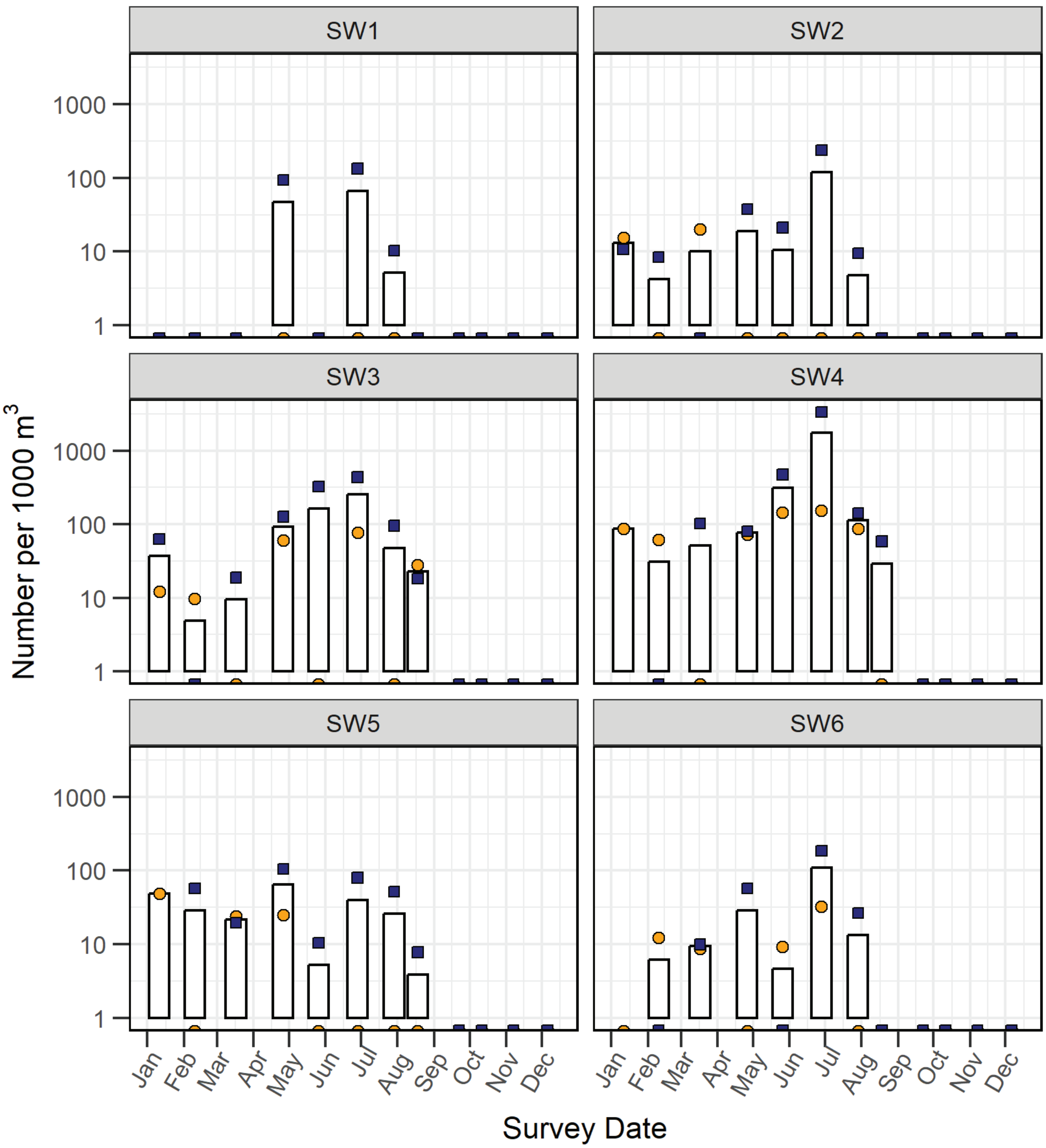

Figure 4-14. Total average concentrations of Whitebait Smelt larvae (height of bar) collected during monthly surveys at source water stations SW1–SW6 from January 2022–December 2022. Concentrations from daytime (orange circles) and nighttime (blue squares) are also shown. Dates of the surveys correspond to the centers of the bars. Note use of log-scale due to magnitude of some of the abundances.

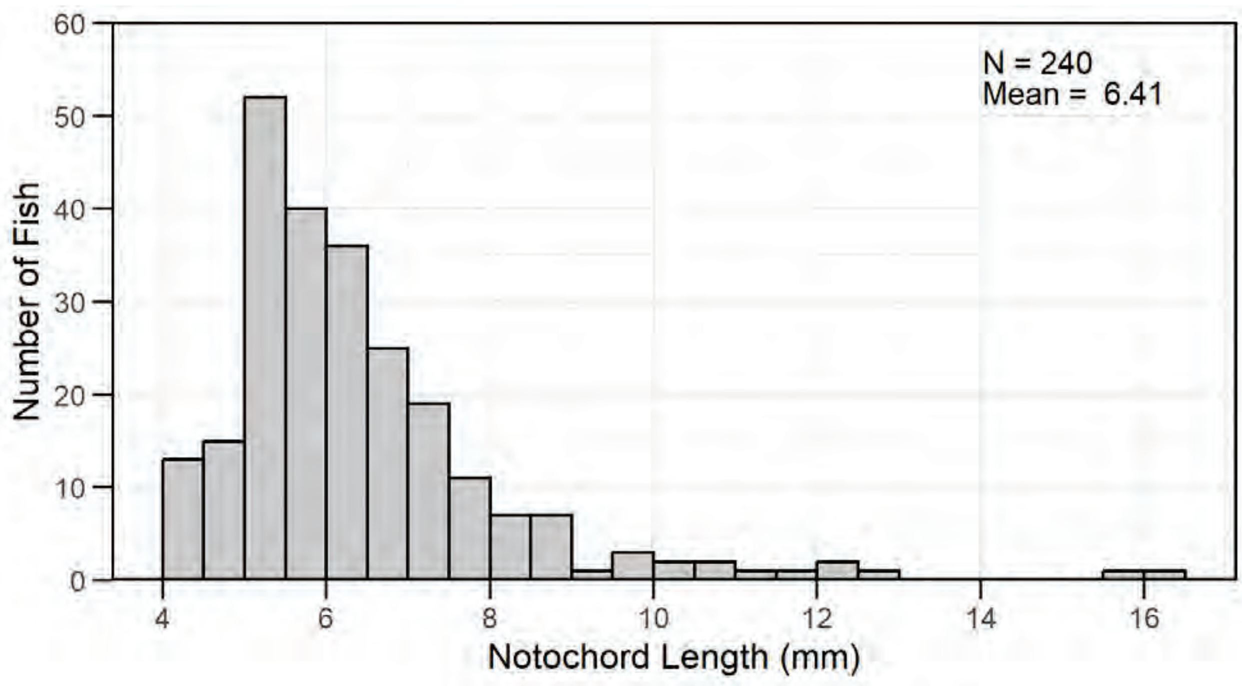

Figure 4-15. Length frequency of Whitebait Smelt measured from larvae collected from stations E1, E2, SW2, and SW3 from January 2022–December 2022.

4.2.4 **Pacific Herring** *Clupea pallasii*

Native distribution of Pacific Herring. Range of colors indicate degree of suitability of habitat which can be interpreted as probabilities of occurrence. Red indicates highest probability of occurrence, yellow indicates lowest. *(Kaschner et. al. 2019)*

Photo credit: Todd Miller, 2019

Range: From northern Baja California to Toyama Bay, Japan, westward to the Yellow Sea.

Life History: Size: up to 18 in. (46 cm) and 1.2 lb (550 g); Age at maturity: two to three years old; Fecundity: 4,000 to 130,000 eggs; Life span: variable (Alaska to 19 years, California to 11 years)

Habitat: A schooling species found near shore to hundreds of miles offshore; spawns in intertidal and sub-tidal zones in bays and estuaries.

Fishery: Commercial: previously valuable roe fishery; Recreational: small pier and shore angler fishery.

Pacific Herring belong to the order Clupeiformes, which contains some of the world's most numerous and economically important fishes (e.g., herring, sardine, anchovy). The distribution of Pacific Herring extends from Baja California to the north Pacific and westward to Japan and the Yellow Sea (Miller and Lea 1972). In North America, Pacific Herring range from Baja California north to arctic Alaska (PSMFC 1999) and are most abundant off Alaska and British Columbia. In California, most of the populations are found in the San Francisco and Tomales bay areas (Fitch and Lavenberg 1975). Pacific Herring are found from nearshore areas to hundreds of miles off the coast (Love 1996). In Humboldt Bay, Pacific Herring was the tenth most abundant species of adult fish collected in a study from 2000–2001 (Gleason et al. 2007) and was the second most abundant taxon of fish larvae collected during a 1969 study (Eldridge and Bryan 1972).

Pacific Herring are small, streamlined marine fishes, measuring up to 18 in. (457.2 mm) in length and weighing up to 1.2 lb (550 g) (PSMFC 1999). Fitch and Lavenberg (1975) report that in California they may live to 11 years of age and may exceed 12 in. (304.8 mm) in length. More recently, Leet et al. (2001) indicated that herring may live nine to 10 years, but individuals older than seven years are rare. California Pacific Herring reach first maturity at two years, and 100% are mature by three years at a length of 6.5–7 in. (165.1–177.8 mm) (Love 1996, Leet et al. 2001).

In California, spawning is known to occur in San Diego Bay, San Luis River, Morro Bay, Elkhorn Slough, San Francisco Bay, Tomales Bay, Bodega Bay, Russian River, Noyo River, Shelter Cove, Humboldt Bay, and Crescent City Harbor (Leet et al. 2001). California's largest spawning population of Pacific Herring occurs in San Francisco Bay (Leet et al. 2001). Fish begin entering protected coastal bays, estuaries, and shallow nearshore environments as early as two months to three weeks prior to spawning (Eldridge 1977). Decreased salinity may be a cue to initiate spawning (Leet et al. 2001).

Males and females spawn simultaneously over a period of one to seven days (Miller and Schmidtke 1956). The fertilized eggs, broadcast mostly at night, are adhesive and commonly attach to eelgrass, algae, and other intertidal vegetation (Hardwick 1973), rocks, pilings and jetties. Thousands of females repeatedly deposit their eggs, which can result in egg masses from 10 to 15 layers thick (about 2 in. [50.8 mm]) (Love 1996). In large spawning runs, a 30 ft (9 m) wide band of herring eggs may span a distance of 20 miles (32.2 km) along the shoreline (Leet et al. 2001). Females are capable of spawning only once per season. After spawning, most herring return to the ocean (Eldridge 1977). The rate of egg development varies with surrounding water temperature; Pacific Herring eggs commonly hatch within 10 to 14 days at 53.2°–56.3°F (11.8°–13.5°C) (Wang 1986). Egg mortality has been estimated to range from 20% (Hourston and Haegele 1980) to as high as 99% (Hardwick 1973, Leet et al. 2001).

Pacific Herring early development is well described. The length at hatching is approximately 0.2–0.3 in. (5.6–7.5 mm) NL (Moser 1996). Shortly after hatching, and as the eyes become pigmented, the planktonic larvae move toward the surface. They tend to concentrate near the surface and can remain for a long time in the area of the spawning grounds. Some larvae, however, have been found several miles out to sea, drifting with the currents (Fitch and Lavenberg 1975). Stevenson (1962) cites Stevenson (1955), Outram (1958) and Tester (1948) to arrive at an estimate of larval herring mortality at 99.5%, with a range of 98.9 to 99.7%. It takes about 70 days (when they are approximately 1.0 in. [26 mm]) for the larvae to metamorphose into juveniles (Hay 1985). Metamorphosis is complete by 1.4 in. (35 mm) (Stevenson 1962). Juveniles range from 1.4–5.9 in. (35–150 mm), depending on geographical region (Reilly 1988).

The larval growth rate used to calculate the period of entrainment risk was based on data presented by Stevenson (1962) for larvae between 0.3 and 0.8 in. (8 and 20 mm). The average growth rate of 0.02 in. (0.52 mm) per day from his data is consistent with the rate reported by Alderdice and Hourston (1985) of 0.018 to 0.020 in. (0.48 to 0.52 mm) per day for the first 15 days after hatching. Based on these estimates, a larval growth rate of 0.019 in. (0.50 mm) per day was used to calculate the period of entrainment risk.

Humboldt Bay Pacific Herring Spawning and Fishery

Humboldt Bay is California's second largest bay, and one of the marine habitats utilized by Pacific Herring for spawning. Intertidal mudflats that cover large areas in the Arcata and South bays support eelgrass beds that provide the substrate upon which the vast majority of herring eggs, or "roe," are deposited (CDFW 2019). Approximately 4,700 acres of eelgrass habitat occur within Humboldt Bay (Merkel and Associates 2017). While spawning occurs yearly in both the Arcata and South bays, a higher biomass is typically observed in Arcata Bay, which was confirmed in a survey to determine areas utilized for spawning during the spawning seasons between 2014 and 2018 (CDFW 2019) (**Figure 4-16**).

A Pacific Herring fishery for herring roe has historically existed in Humboldt Bay. The fishery in the bay is minor compared to the fishery that previously existed in San Francisco Bay where most of the landings occurred (**Figure 4-17**). Spawning assessment surveys were conducted to produce a seasonal biomass quota for the bay's small-scale commercial industry. A 20-ton quota was established initially, and then a two-year stock assessment commenced. The assessment estimated a spawning stock biomass (SSB) of 372 tons in Humboldt Bay during the 1974–1975 season, and a 232-ton SSB the following season. This led to the determination that the bay could support a fishery with a 50-ton quota, which was then increased to 60 tons in 1982. Landings mostly hovered between 40 and 70 tons for the 15 years that followed this quota increase and were sourced from 4 annual permits. In the late 1990's and early 2000's, fishing effort curtailed with the decline in observed spawning biomass, to the point where only one permit was actively in use. By the end of the 2005–2006 season the fishery was discontinued due to the decline in the abundance of Pacific Herring. In 2007 only 7 tons of SSB were observed in the spawning assessment. Although no fishing has occurred in Humboldt Bay since 2006, during the 2017–2018 season four Herring permits for the bay were held by commercial fisherman anyways (CDFW 2019), perhaps in the case that the fishery should again become lucrative, be it through a return in the natural supply or a rise in consumer demand for what would certainly qualify as artisanal seafood.

Figure 4-16. Map showing habitat areas in Humboldt Bay with spawning areas for Pacific Herring identified in pink. Figure from CDFW 2019.

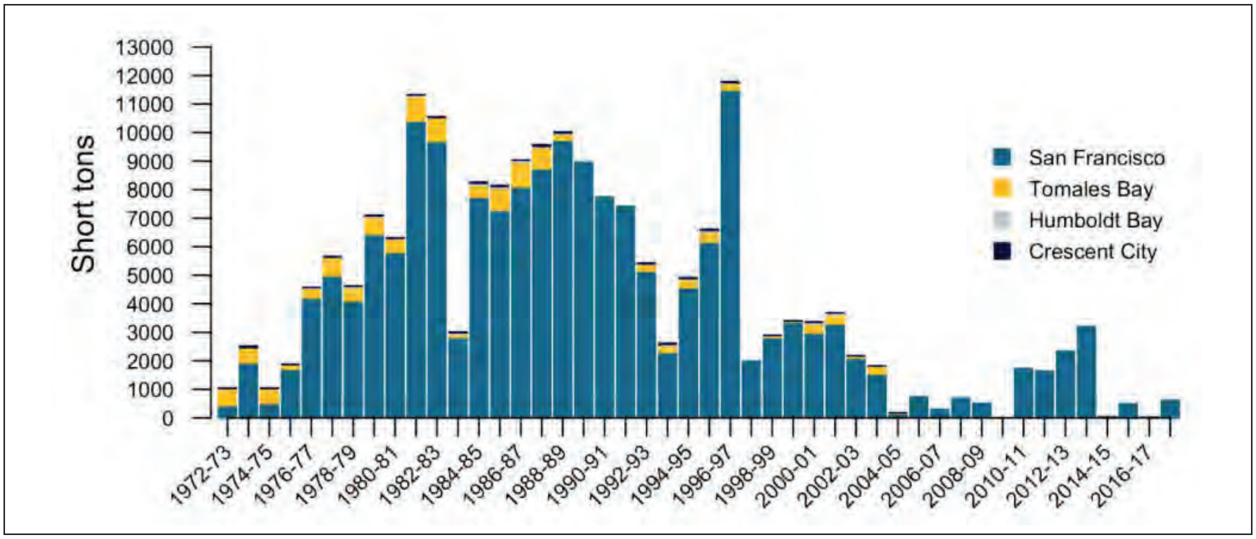

Figure 4-17. Pacific Herring landing in California in short tons (2,000 lb [907 kg]) between 1973 and 2017. The commercial fishery was closed for the 2009–2010 season. The figure does not include landings from the ocean waters fishery in Monterey, California. Figure from CDFW 2019.

Sampling Results

Pacific Herring was the fourth most abundant taxa of fish larvae collected during the sampling from January–December 2022 (**Table 4-2**) and the fifth highest estimated entrainment (**Table 4-3**). A total of 279 thousand Pacific Herring were estimated to be entrained during the year, comprising over 1.6% of the total estimated entrainment of larval fishes. They were the second most abundant taxa at stations SW4 and SW5 (**Table 4-2**). They were collected from at least one of the entrainment stations during the months of February through May (**Figure 4-18**). The peak abundance for this taxon occurred during the March survey at both entrainment stations. Pacific Herring were also in highest abundance at the source water stations during the month of March (**Figure 4-19**). They were collected in highest abundance at the source water stations near the Harbor Entrance and South Bay (SW4 and SW5). They were only present in the March surveys at stations SW4 and SW5.

The length frequency of the 126 Pacific Herring larvae measured from the study had an average NL of 0.33 in. (8.45 mm) and the smallest and longest larvae measured were 0.25 and 0.79 in. (6.24 and 20.15 mm) NL, respectively (**Figure 4-20**). Similar to the other taxa, a large number of the larvae were in the range of the reported length at hatching of approximately 0.22–0.30 in. (5.6–7.5 mm) NL (Moser 1996). These measurements are used to calculate bootstrap estimates of the minimum and maximum lengths used in calculating the period of larval exposure to entrainment for the ETM.

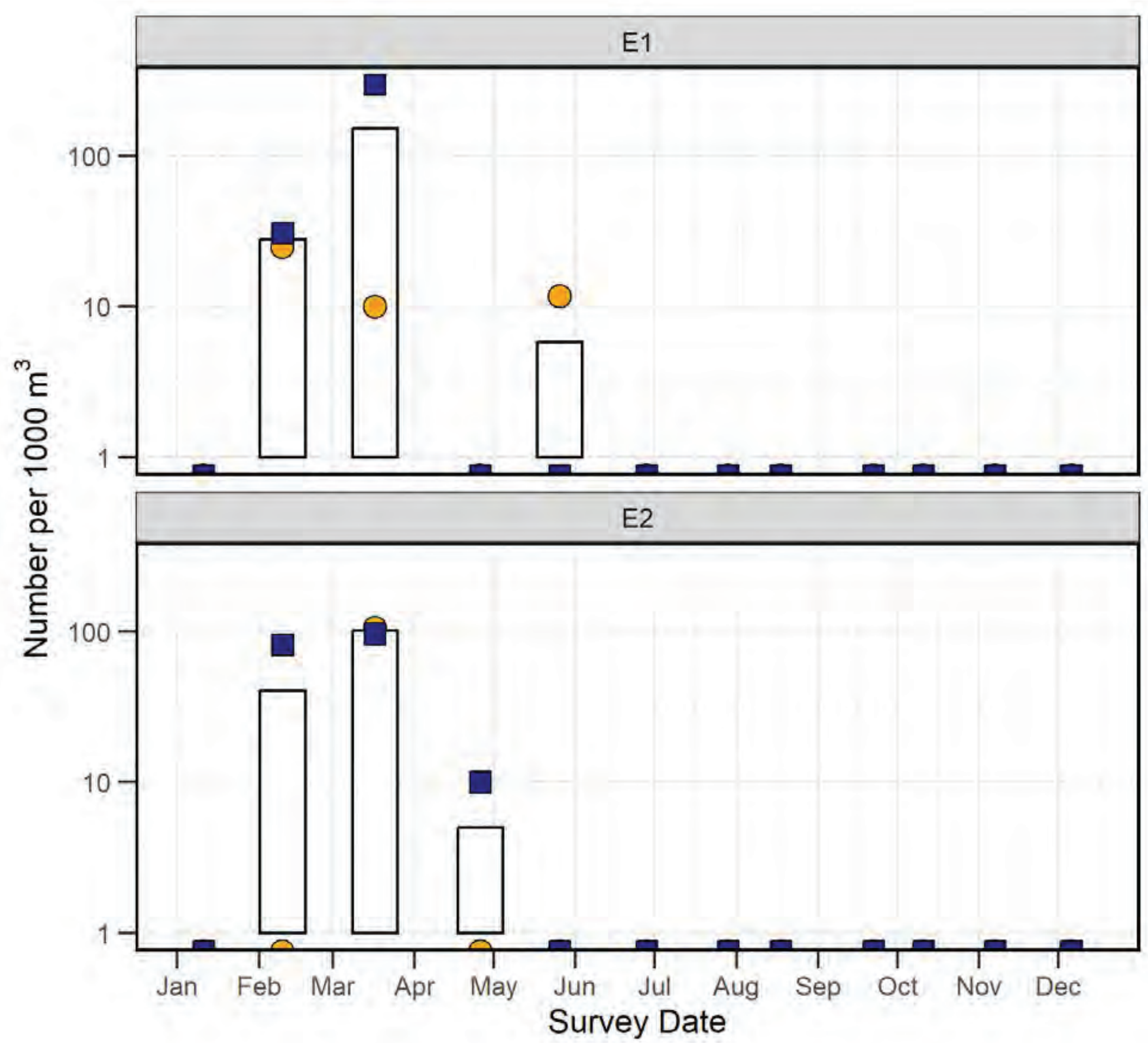

Figure 4-18. Total average concentrations of Pacific Herring larvae (height of bar) collected during monthly surveys at entrainment stations E1 and E2 from January 2022–December 2022. Concentrations from daytime (orange circles) and nighttime (blue squares) are also shown. Dates of the surveys correspond to the centers of the bars. Note use of log-scale due to magnitude of some of the abundances.

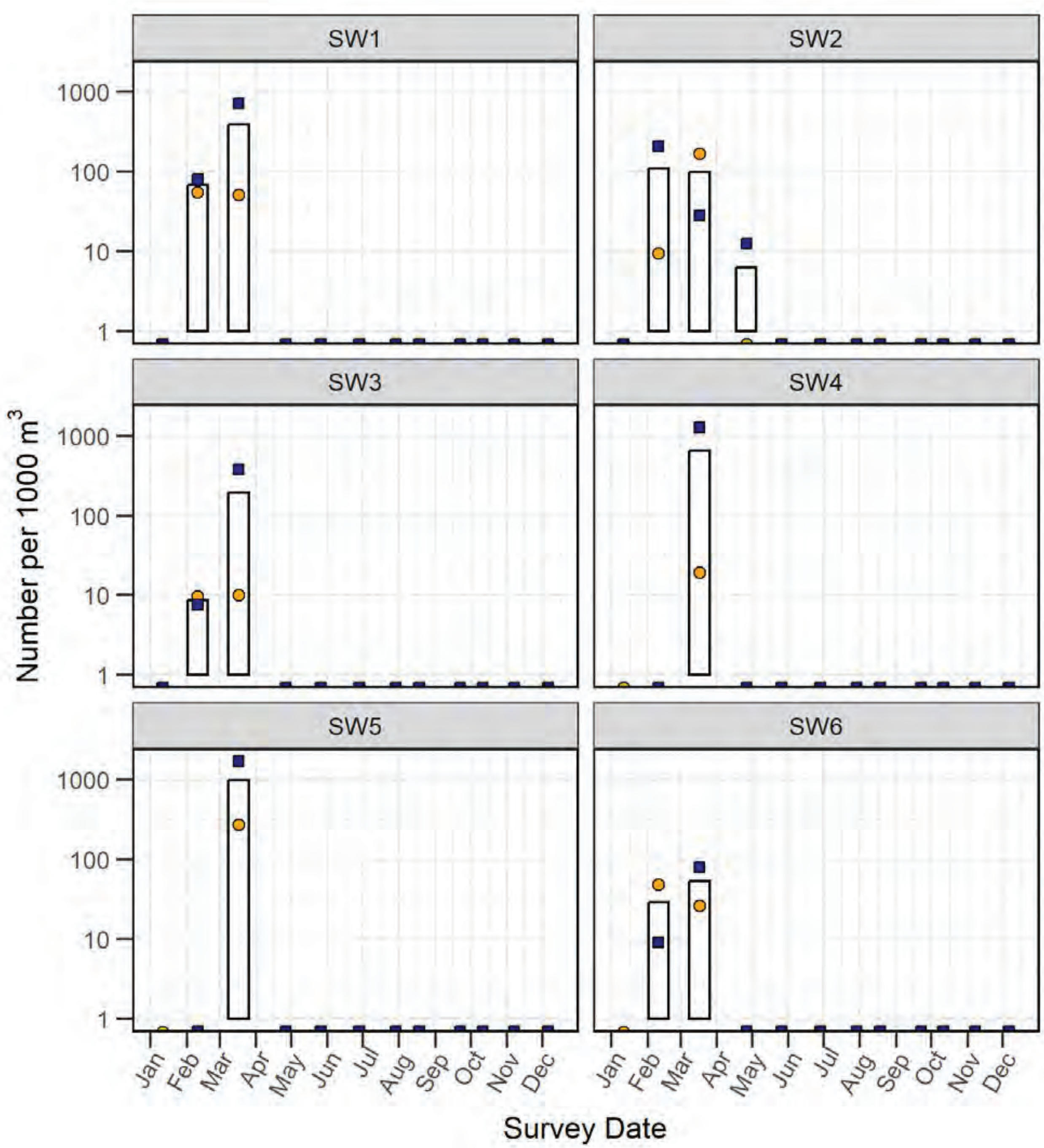

Figure 4-19. Total average concentrations of Pacific Herring larvae (height of bar) collected during monthly surveys at source water stations SW1–SW6 from January 2022–December 2022. Concentrations from daytime (orange circles) and nighttime (blue squares) are also shown. Dates of the surveys correspond to the centers of the bars. Note use of log-scale due to magnitude of some of the abundances.

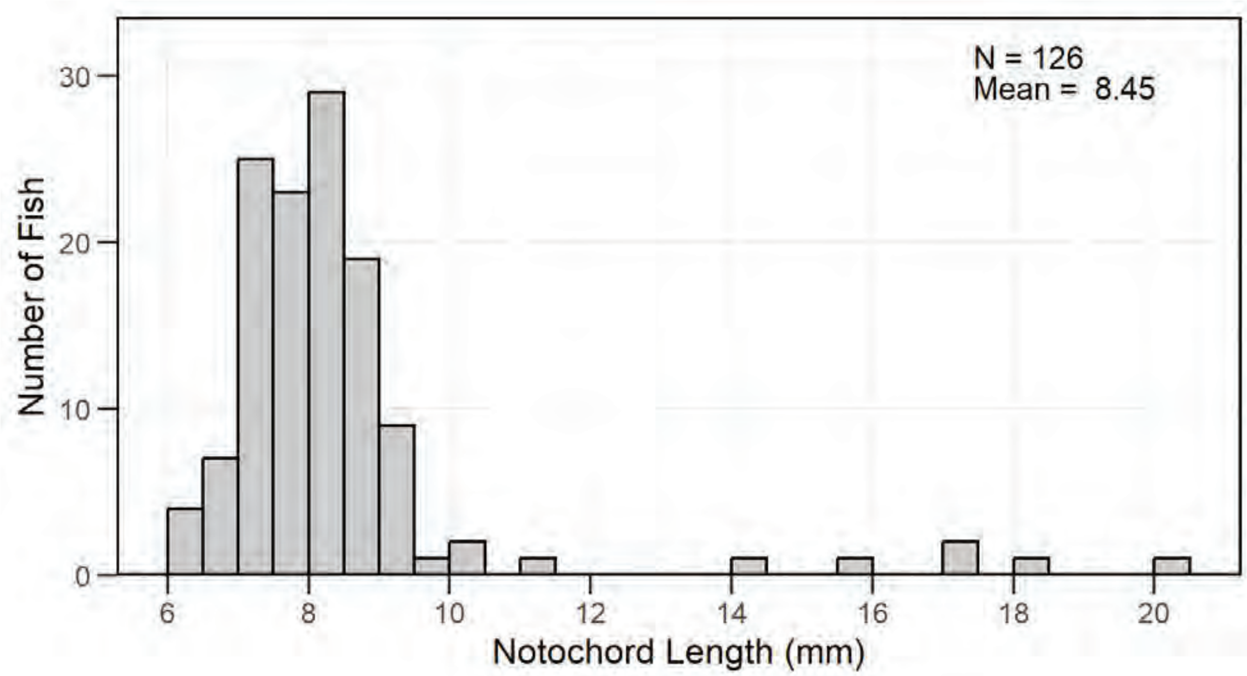

Figure 4-20. Length frequency of Pacific Herring measured from larvae collected from stations E1, E2, SW2, and SW3 from January 2022–December 2022.

4.2.5 **Pacific Tomcod** *Microgadus proximus*

Native distribution of the Pacific Tomcod. Range of colors indicate degree of suitability of habitat which can be interpreted as probabilities of occurrence. Red indicates highest probability of occurrence, yellow indicates lowest. *(Kaschner et. al. 2019)*

(iNaturalist, 2021)

Range**:** Southeastern Bering Sea and eastern Aleutian Islands to Central California

Life History: Size up to 12 in. (305 mm) SL; they exhibit prolonged spawning that extends over several months and occurs during both winter and spring; demersal; adhesive eggs with fecundity estimated to be similar to that of the Atlantic Tomcod *Microgadus tomcod* which ranges from 6,000–80,000 eggs per spawning event.

Habitat: Young recruit in shallow nearshore waters of bays and estuaries. Juveniles range from brackish waters to the open coast and are often found in midwater and near the surface. Adults are more demersal and can be found in depths of 853 ft (260 m) but mostly reside over sand or soft sediments at depths of 82–394 ft (25–120 m).

Fishery: Minor commercial importance. Common recreational sportfish.

The family Gadidae is further broken down into subfamilies, including Gadinae which consists of 22 species divided into 12 genera (Cohen et al. 1990). This subfamily is characterized by soft-rayed fishes with 3 dorsal fins and 2 anal fins (Miller and Lea 1972). Gadids are typically marine fish that reside in deeper waters, however, a few species including the Pacific Tomcod (*Microgadus proximus*) are generally found in more littoral or inshore waters. They are capable of tolerating low salinities and young recruits and juveniles are often found inhabiting estuaries (Hart, 1973). Adult Pacific Tomcod are more demersal and have been found to depths of 853 ft (260 m) but mostly reside over sand or soft sediments at depths of 82–394 ft (25–120 m) (Hart 1973). Some adults have also been found in the shallow channels of places like Humboldt Bay (Love 2011).

While many of the species in this family are of great commercial value, including cod, haddock, and pollock, Pacific Tomcod, are of minor commercial importance due to their small size. However, they are occasionally caught as a recreational sportfish. In Humboldt Bay young recruits and juveniles can be found during all seasons and anglers occasionally catch larger juveniles and some adults via hook and line (Fritzsche and Cavanagh 2007). In a study done by Gleason et al. 2007, that looked at fish diversity and abundance in Humboldt Bay, it was shown that Pacific Tomcod were one of the 67 species identified as appearing in trawls from both North

Bay and Entrance Bay, however, they only ranked <0.1% in overall abundance among the fishes collected. Outside the bay it is reported that these fish are numerous and serve as important prey to a host of predators (Fritzsche and Cavanagh 2007). In a study completed by Richardson and Pearcy (1977), planktonic larvae of Pacific Tomcod were the dominant gadid and fourth most abundant taxon in a coastal assemblage of fish larvae occurring off Yaquina Bay, Oregon. No juvenile or larval Pacific Tomcod were collected during a larval fish study of Humboldt Bay conducted in 1969 (Eldridge and Bryan 1972).

Pacific Tomcod range in color from olive green to a brownish color dorsally with a creamy white ventral side. Adult Pacific Tomcod may be confused with small Pacific Cod (*Gadus macrocephalus*) or Walleye Pollock (*Gadus chalcogrammus*) but can be distinguished from the other two species by their chin barbel length. Pacific Tomcod have a chin barbel with a length that is about one-half the diameter of their eye or shorter, while Pacific Cod have a chin barbel that is rarely shorter than the diameter of their eye, and Walleye Pollock lack a chin barbel (Miller and Lea 1972). The most useful trait to separate Pacific Tomcod larvae from Pacific Cod and Walleye Pollock is by the length and position of the anterior and posterior postanal pigment bars (Matarese et al. 1981). Additionally, depending upon the size of the larvae, other differentiating characteristics that could be used to separate these species include, head, gut, and caudal pigmentation and differences in the number of rays on their superior hypural element (Matarese et al. 1981).

The growth rates and estimated life span of Pacific Tomcod have thus far been undocumented but may be similar to that of the Atlantic Tomcod (*Microgadus tomcod*), which have an average lifespan of 4 years (Salinas and McLaren 1983). Adult Atlantic Tomcod mature at 9 months and are capable of spawning at 11 months (Waldman 2006). Female Atlantic Tomcod range from 6.69–13.4 in. (170–340 mm) in length and produce an average of 20,000 benthic eggs (Matarese et al. 1981). The eggs of Pacific Tomcod are demersal and adhesive with a diameter of 0.12 in. (3 mm) and the larvae at hatching are ~0.11 in. (2.7 mm) NL (Dunn and Matarese 1987). The length of the larvae at transformation is >1.8 in. (46 mm) standard length (SL). Summary data in Dunn and Matarese (1987) on early life history of northeast Pacific Gadid fishes indicates that the larval development of Pacific Tomcod and Pacific Cod are similar. Data from laboratory studies on the development of Pacific Cod were used to calculate an estimated daily growth rate of 0.163 mm per d for larvae from hatch through 30 d (Tomoda and Dan 2014). This estimate is used in calculating larval duration in Pacific Tomcod for the ETM.

Sampling Results

Pacific Tomcod was the sixth most abundant taxa of fish larvae collected during the sampling from January-December 2022 (**Table 4-2**) and the fourth most abundant in the entrainment sampling (**Table 4-3**). A total of 285 thousand Pacific Tomcod were estimated to be entrained during the year, comprising 1.6% of the total estimated entrainment of larval fishes. They were the fourth most abundant taxa at stations E1 and SW3 (**Table 4-2**). They were collected from at least one of the entrainment stations during the months of January through April and also in June (**Figure 4-21**). The peak abundance for this taxon occurred during the April survey at both entrainment stations, however, there was an additional peak in abundance at the E1 station during the month of January. Pacific Tomcod were collected in highest abundance at the source

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water stations just upcoast from the Harbor Entrance along the North Sand spit (SW4) and a little further North near the main channel (SW3) (**Figure 4-22**). These areas are dominated by sand, making them the preferred habitat for this species. They were collected in only the April survey at source water stations SW1, SW2, and SW6, which are areas predominantly dominated by mudflats.

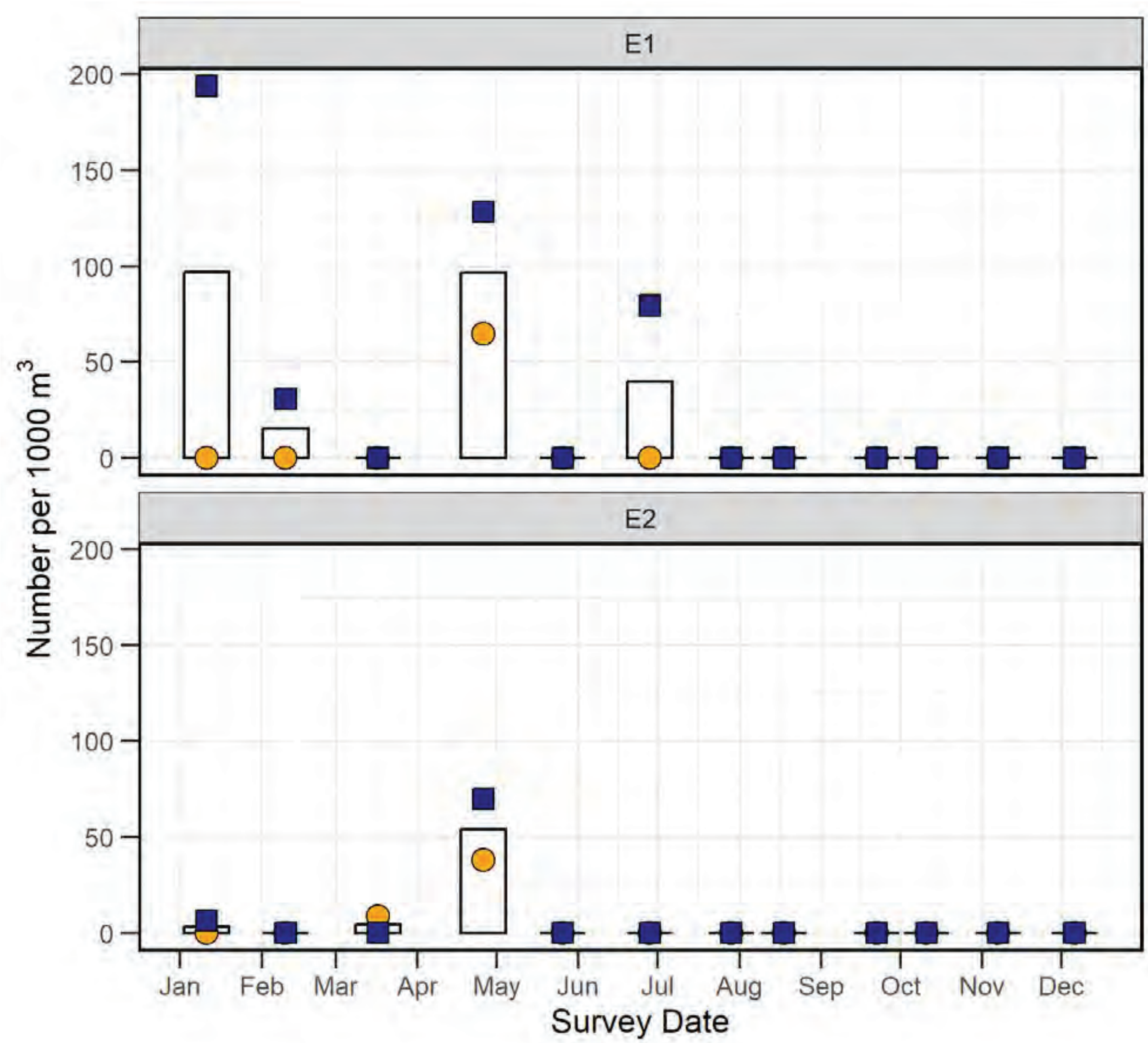

Figure 4-21. Total average concentrations of Pacific Tomcod larvae (height of bar) collected during monthly surveys at entrainment stations E1 and E2 from January 2022–December 2022. Concentrations from daytime (orange circles) and nighttime (blue squares) are also shown. Dates of the surveys correspond to the centers of the bars.

The length frequency of the 112 Pacific Tomcod larvae measured from the study had an average NL of 0.125 in. (3.17 mm) and the smallest and longest larvae measured were 0.08 and 0.16 in. (2.09 and 3.95 mm) NL, respectively (**Figure 4-23**). Similar to the other taxa several of the measured larvae were in the range of the estimated hatch length from Atlantic Tomcod of 2.7

mm (0.11 in.) NL from Dunn and Matarese (1987). These measurements are used to calculate bootstrap estimates of the minimum and maximum lengths used in calculating the period of larval exposure to entrainment for the ETM.

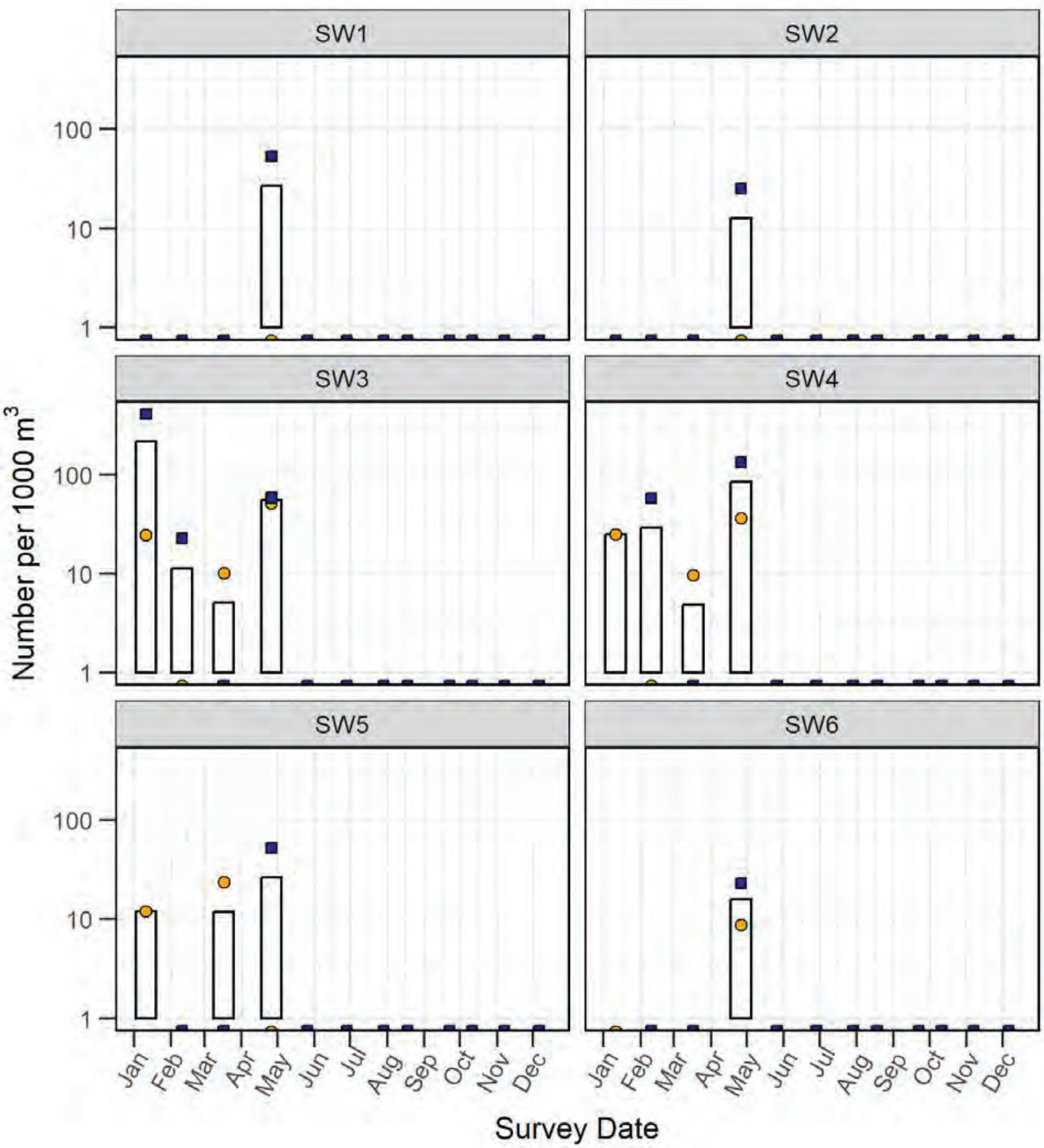

Figure 4-22. Total average concentrations of Pacific Tomcod larvae (height of bar) collected during monthly surveys at source water stations SW1–SW6 from January 2022–December 2022. Concentrations from daytime (orange circles) and nighttime (blue squares) are also shown. Dates of the surveys correspond to the centers of the bars. Note use of log-scale due to magnitude of some of the abundances.

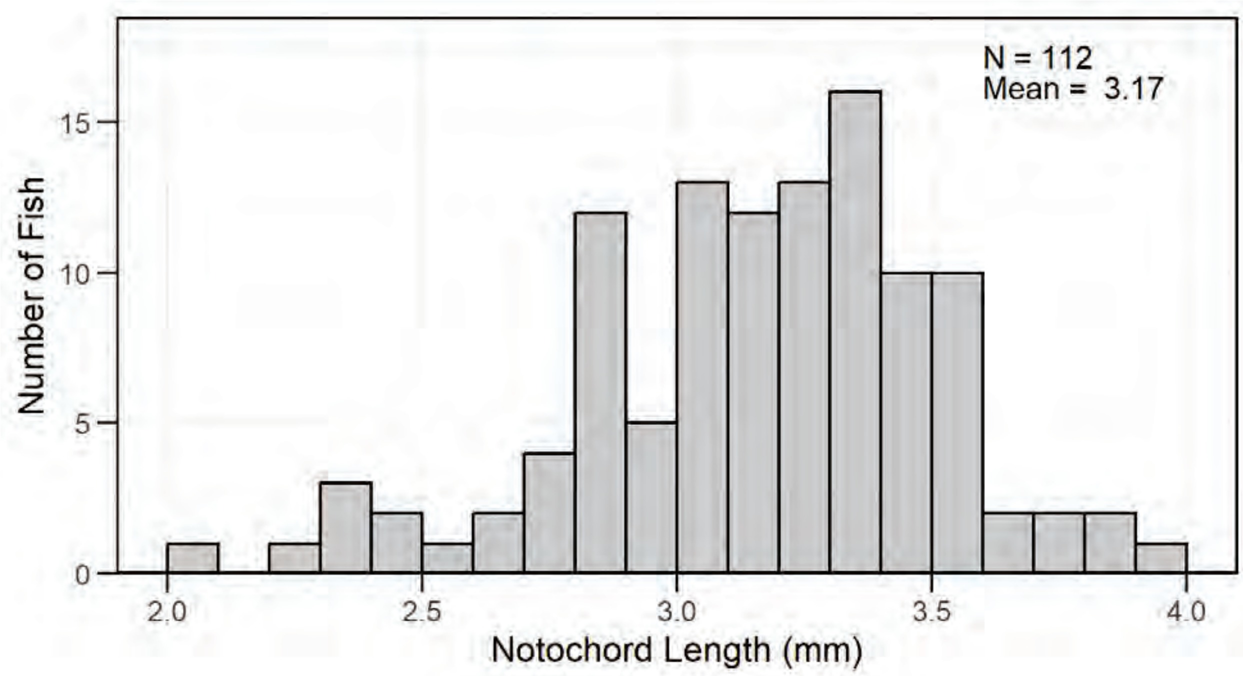

Figure 4-23. Length frequency of Pacific Tomcod measured from larvae collected from stations E1, E2, SW2, and SW3 from January 2022–December 2022.

4.2.6 **Surf Smelt** *Hypomesus pretiosus*

Native distribution of Surf Smelt. Range of colors indicate degree of suitability of habitat which can be interpreted as probabilities of occurrence. Red indicates highest probability of occurrence, yellow indicates lowest. From Fishbase.org *(Kaschner et. al. 2019)*

(David Ayers, USGS)

Range: From southeast Alaska to southern California

Life History: Size up to 12 in. (305 mm); age at maturity from 1– 2 yr; Life span ≥5 yr; spawning occurs in the surf along open coast coarse sand beaches from April to September; demersal; adhesive eggs with fecundity from 1,320-36,000 eggs per season.

Habitat: Nearshore species, commonly found in estuaries. Schools of juveniles and adults are common in kelp and eelgrass.

Fishery: Commercial and recreational fisheries

Surf Smelt, like the Whitebait Smelt discussed previously, belong to the family Osmeridae. The small, soft-rayed fishes with an adipose fin that can be found in marine, estuarine, and freshwater habitats (Hart 1973). Surf Smelt are another one of the six species of osmerids that are native to California's coastal and estuarine waters (Sweetnam et al. 2001). Surf Smelt was the fifth most abundant species collected during a study in 2000-2001 on the fishes of Humboldt Bay (Gleason et al. 2007). Surf Smelt was the second most abundant juvenile fish collected during a study of marine resources during 1969 in Humboldt Bay by Eldridge and Bryan (1972).

Surf Smelt are a silvery, streamlined fish, with a small mouth and short lateral line (Love 2011). They are sexually dimorphic with males having a more brownish back compared to the brighter green back in the females, both have a silver band running along their sides (Schaefer 1936). Surf Smelt are distinguished from other California osmerids by having a head length more than 4 times the eye diameter and 2.5 times the longest anal fin soft ray (Fitch and Lavenberg 1975; Miller and Lea 1972). They look similar to Night Smelt but can be further differentiated by the size of their mouth: in Surf Smelt, the mouth does not reach past the pupil of the eye; in Night Smelt the mouth extends at least to the back edge of the pupil (Love and Passarelli 2020).

Surf Smelt can live up to five years, reaching maturity between one and two years (Love 2011). Spawning generally occurs between April to September along coarse sand and fine gravel beaches (Hart and McHugh 1944, Levy 1985). Females produce between 2,500-37,000 eggs per season, in more than one batch (Hart and McHugh 1944, Love, 2011). Females spawn demersal semi-adhesive eggs with a shell diameter of 0.004 in. (1.1 mm) (Moser 1996). Unlike other demersal fish eggs, which are adhesive all around, Surf Smelt eggs are unique and form an extremely adhesive peduncle that attaches to the beach substrate (Penttila 1978). Eggs hatch in 9-56 days depending on water temperature (Love 2011). Estimated lengths for the larvae at various developmental stages are hatching length at 0.12–0.20 in. (3–5 mm), flexion length at 0.51–0.60 in. (13–15 mm), and transformation length at 1.57 in. (40 mm) (Hearne 1983, Matarese et a1. 1989, Saruwatari and Okiyama 1988, Moser, 1996). Penttilla (1978) determined that recruitment to the spawning population may occur for age 1, which would be equivalent to Surf Smelt measuring approximately 3.9–4.7 in. (100–120 mm) SL. Length frequency analyses of Surf Smelt sampled from the California recreational fishery indicated that age 2 individuals in the 6.7 in. (170 mm) FL range comprised the bulk of the sampled catch.

Sampling Results

Surf Smelt was the fifth most abundant taxa of fish larvae collected during the sampling from January–December 2022 (**Table 4-2**) and the sixth most abundant in the entrainment sampling (**Table 4-3**). A total of 205 thousand Surf Smelt were estimated to be entrained during the year, comprising approximately 1.2% of the total estimated entrainment of larval fishes. They were often within the top seven of the most abundant taxa at the different stations (**Table 4-2**). They were collected from at least one of the entrainment stations during the months of May through July, and in September, November, and December (**Figure 4-24**). The peak abundance for this taxon occurred during the June survey at both entrainment stations. Surf Smelt were collected in highest abundance at the source water stations at the Entrance Bay (SW4), South Bay (SW5), and Arcata Bay (SW6) (**Figure 4-25**). They appeared to be most abundant at source water stations during the month of June, however, at Station SW2 they were most abundant in August.

The length frequency of the 31 Surf Smelt larvae measured from the study had an average NL of 0.56 in. (14.31 mm) and the smallest and longest larvae measured were 0.15 and 0.98 in. (3.90 and 24.96 mm) NL, respectively (**Figure 4-26**). The small number of measurements and the large variation in NL make it difficult to calculate the period of larval exposure to entrainment for the ETM.

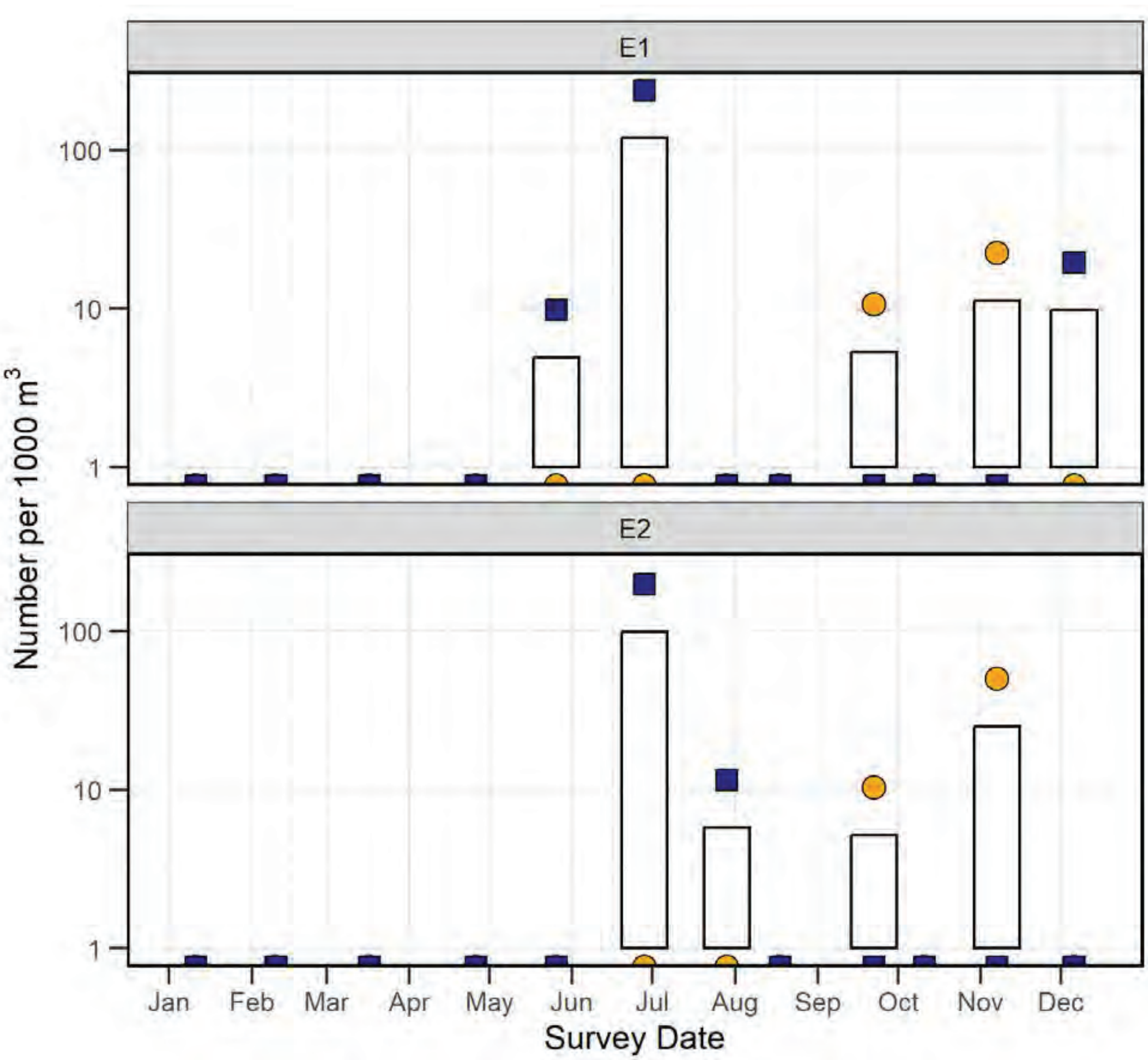

Figure 4-24. Total average concentrations of Surf Smelt larvae (height of bar) collected during monthly surveys at entrainment stations E1 and E2 from January 2022–December 2022. Concentrations from daytime (orange circles) and nighttime (blue squares) are also shown. Dates of the surveys correspond to the centers of the bars. Note use of log-scale due to magnitude of some of the abundances.

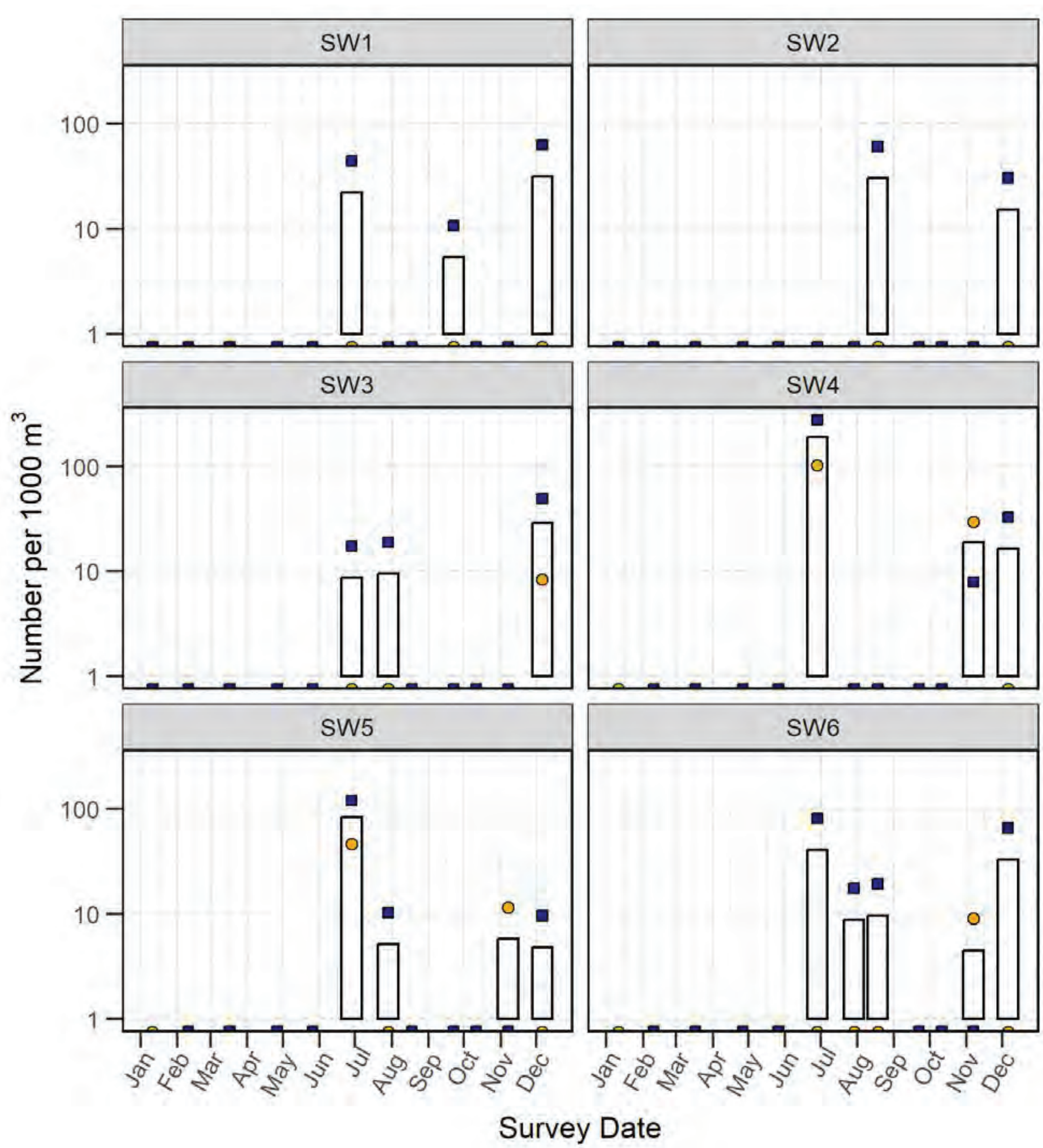

Figure 4-25. Total average concentrations of Surf Smelt larvae (height of bar) collected during monthly surveys at source water stations SW1–SW6 from January 2022–December 2022. Concentrations from daytime (orange circles) and nighttime (blue squares) are also shown. Dates of the surveys correspond to the centers of the bars. Note use of log-scale due to magnitude of some of the abundances.

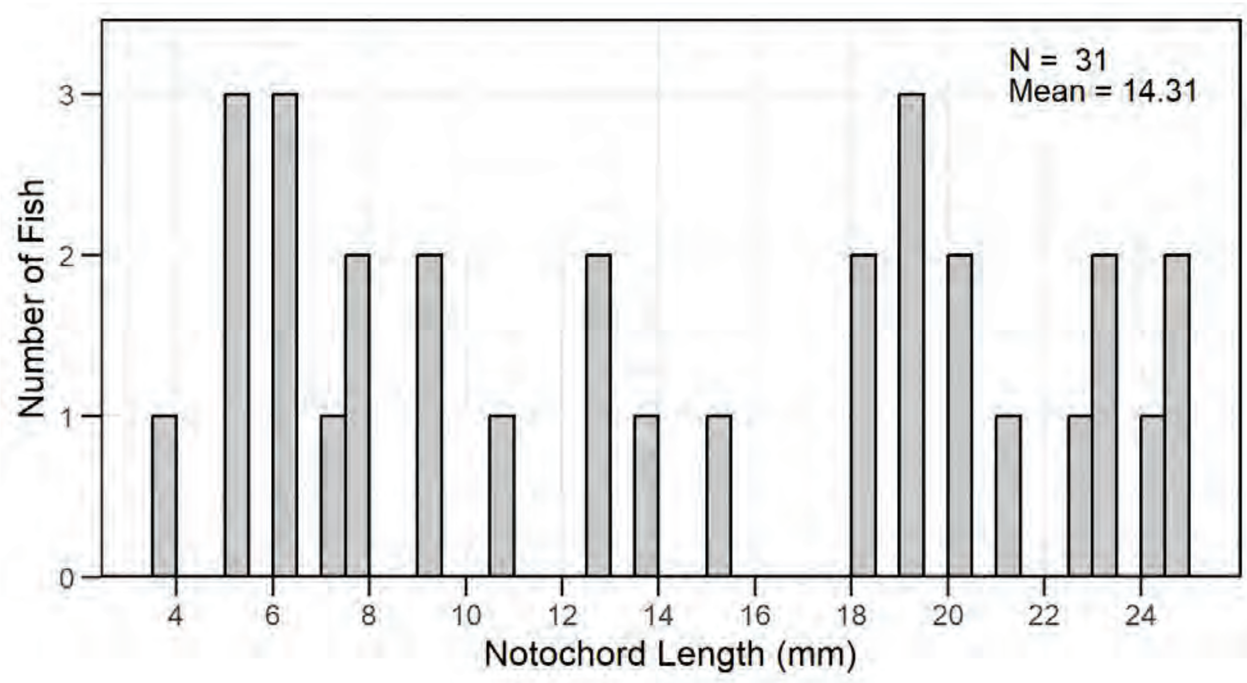

Figure 4-26. Length frequency of Surf Smelt measured from larvae collected from stations E1, E2, SW2, and SW3 from January 2022–December 2022.

4.2.7 **Pacific Staghorn Sculpin** *Leptocottus armatus*

Native distribution of Pacific Staghorn Sculpin. Range of colors indicate degree of suitability of habitat which can be interpreted as probabilities of occurrence. Red indicates highest probability of occurrence, yellow indicates lowest. From Fishbase.org *(Kaschner et. al. 2019)*

(Photo credit: Rene Reyes))

Range: From southeastern Bering Sea to northern Baja California.

Life History: Size up to 19 in. (482.6 mm); age at maturity 1 yr; Life span ≥10 yr; spawning takes place from October through April, peaking in January and February. Females spawn demersal adhesive eggs, once per season, with fecundity from 2,000-11,000 eggs.

Habitat: Nearshore species, commonly found in bays and estuaries; most frequently on sandy or muddy bottoms. Can seasonally be found in brackish and freshwater, including lower portions of coastal rivers and streams.

Fishery: Recreational; frequently caught by shore anglers fishing in bays but considered a nuisance fish and not often retained. Commercial; bycatch in trawl fishery, small bait-fish market.

The Pacific Staghorn Sculpin belongs to the family Cottidae, a large group (more than 300 species) of bottom-dwelling fishes. This estuarine fish ranges from the Pribilof Islands and Port Moller in the Bering Sea to Bahia San Quintin in Baja California and can often be found in tidepools (Love 2011). In the southern half of their range they commonly occur in freshwater (Moyle 1976). Pacific Staghorn Sculpin are abundant in San Francisco, San Pablo, and Tomales bays, Moss Landing Harbor and the Elkhorn Slough (Jones 1962). Pacific Staghorn Sculpin were also found to be the seventh most abundant species collected during a study in 2000–2001 on the fishes of Humboldt Bay (Gleason et al. 2007) and the fifth most abundant taxon of larval fish collected during a study of ichthyoplankton during 1969, also in Humboldt Bay, by Eldridge and Bryan (1972).

Pacific Staghorn Sculpin have a tan, brown, or grayish coloring above and white or yellow below. They have a large flat head, with small eyes. They can be identified by the large upper preopercular spine and by the large, dark spot on the posterior part of their spiny dorsal fin (Miller and Lea 1972, Morrow 1980). The Pacific Staghorn Sculpin is classified as a nondependent marine fish, meaning that although commonly found in estuarine environments, it does not require this habitat type to complete its life cycle (Moyle and Cech 1988). They are usually found in shallow subtidal waters but may be found as deep as 300 ft (91 m). They commonly burrow into sandy mud bottoms of bays and estuaries leaving only their head and eyes exposed. The prey of Pacific Staghorn Sculpin includes amphipods, nereid worms, and small anchovy (Jones 1962).

Pacific Staghorn Sculpin can live up to 10 years and typically mature at age one (Love 2011). Spawning takes place from October through April, with a peak in January and February. Spawning locations tend to be shallow coastal bays, inlets, sounds, and sloughs with optimal salinity measurements between 27 to 28.3 ppt (Jones 1962). Their preferred substrate varies from mud and sand bottoms to firmer rocky areas. The females spawn only once a season, producing between 2,000 to 11,000 spherical eggs, which are deposited in clusters on substrate. After spawning, the adults leave the shallow spawning areas for deeper offshore waters (Tasto 1975). Eggs hatch in about 10 days and the larvae (averaging 0.2 in. [4.5 mm] NL in length) swim to the surface, becoming planktonic (Jones 1962). It has been suggested (Wang 1986) that the larvae may remain on the bottom for a short period of time before they ascend to the surface. It takes approximately eight weeks from the time of hatching until larvae metamorphose to juveniles, at a length of 0.6 –0.8 in. (15–20 mm) TL (Matarese et al. 1989). Jones (1962) reports an estimated growth rate of 0.01 in./day (0.25 mm/day) (reported as R.W. Morris personal communication in Jones 1962). It has been reported that juveniles move up estuaries and into freshwater and remain there for about three months before moving to a more saline environment (Moyle 1976, Love 1996). Juveniles probably become demersal after reaching 0.4–0.6 in. (10–15 mm) in length (Wang 1986).

Sampling Results

Pacific Staghorn Sculpin was the eight most abundant taxa of fish larvae collected during the sampling from January–December 2022 (**Table 4-2**) and the eighth most abundant in the entrainment sampling (**Table 4-3**). A total of 143 thousand Pacific Staghorn Sculpin were estimated to be entrained during the year, comprising less than 1% of the total estimated entrainment of larval fishes. They were often within the top eight of the most abundant taxa at the different stations (**Table 4-2**). They were collected from at least one of the entrainment stations during the months of January through March, September, and November through December (**Figure 4-27**). The peak abundance for this taxon occurred during the January survey at both entrainment stations. Pacific Staghorn Sculpin were collected in highest abundance at the source water stations during January and February with the highest abundances occurring at stations SW1 and SW5 (**Figure 4-28**).

The length frequency of the 77 Pacific Staghorn Sculpin larvae measured from the study had an average NL 0f 0.23 in. (5.91 mm) and the smallest and longest larvae measured were 0.16 and 0.44 in. (4.01 and 11.08 mm) NL, respectively (**Figure 4-29**). Many of the larvae were smaller than the reported hatch length of 0.2 in. [4.5 mm]. These measurements are used to calculate bootstrap estimates of the minimum and maximum lengths used in calculating the period of larval exposure to entrainment for the ETM.

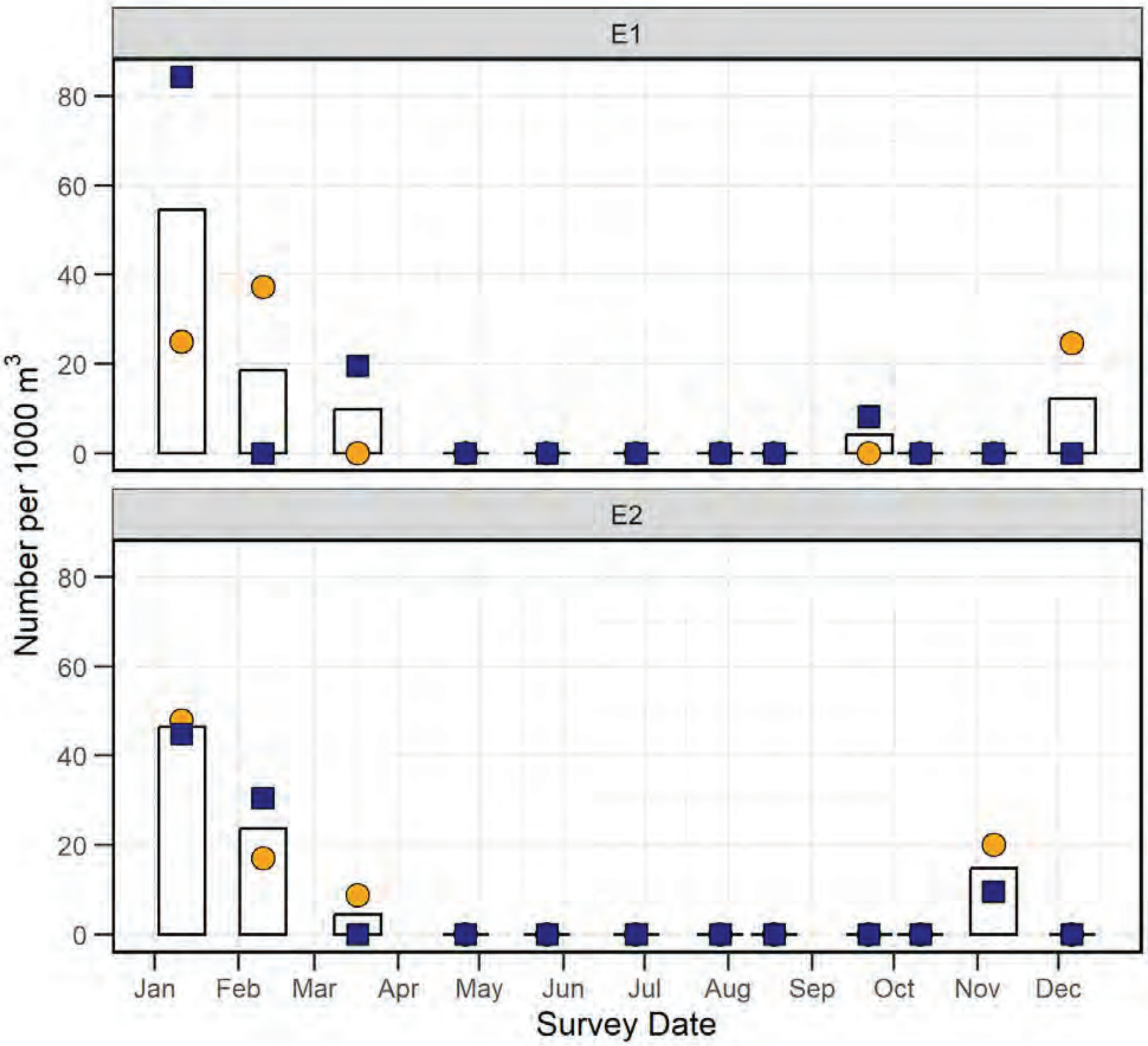

Figure 4-27. Total average concentrations of Pacific Staghorn Sculpin larvae (height of bar) collected during monthly surveys at entrainment stations E1 and E2 from January 2022–December 2022. Concentrations from daytime (orange circles) and nighttime (blue squares) are also shown. Dates of the surveys correspond to the centers of the bars.

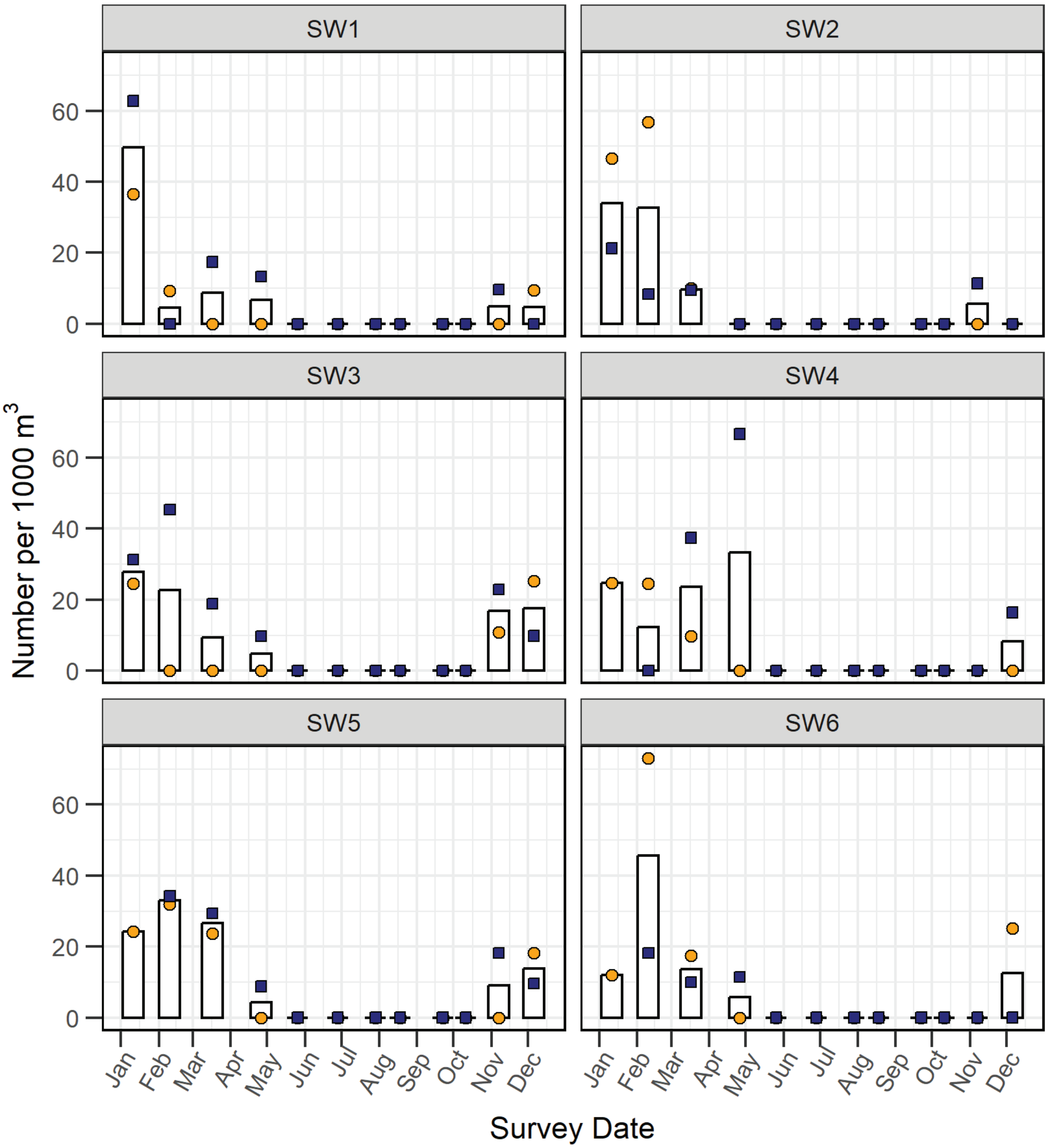

Figure 4-28. Total average concentrations of Pacific Staghorn Sculpin larvae (height of bar) collected during monthly surveys at source water stations SW1–SW6 from January 2022–December 2022. Concentrations from daytime (orange circles) and nighttime (blue squares) are also shown. Dates of the surveys correspond to the centers of the bars.

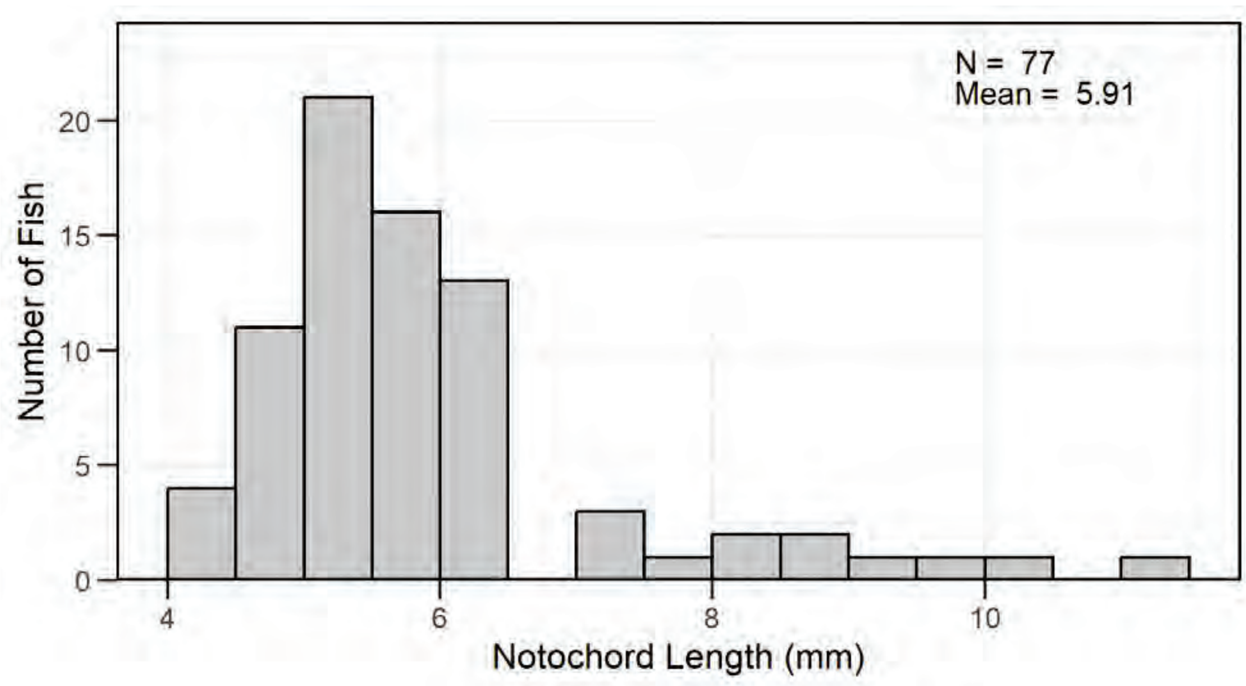

Figure 4-29. Length frequency of Pacific Staghorn Sculpin measured from larvae collected from stations E1, E2, SW2, and SW3 from January 2022–December 2022.

4.2.8 Longfin Smelt *Spirinchus thaleichthys*

Native distribution of LFS. Range of colors indicate degree of suitability of habitat which can be interpreted as probabilities of occurrence. Red indicates highest probability of occurrence, yellow indicates lowest. From Fishbase.org *(Kaschner et. al. 2019)*

(Photo credit: Bill Stagnaro)

Range: From Prince William Sound, Alaska to Monterey Bay, California.

Life History: Size 4.9–5.5 in. (124–140 mm) SL; age at maturity 2 yrs; Life span ≥3 yrs; Spawning occurs primarily from January through March, after which most adults die. Each female can lay between 5,000 and 24,000, adhesive eggs.

Habitat: They spend their adult life in bays, estuaries, and nearshore coastal areas, and migrate into freshwater rivers to spawn.

Fishery: None. LFS are listed as a Threatened Species under the California Endangered Species Act (CESA).

Longfin Smelt (LFS) is one of the seven recognized species of the family Osmeridae that occur in California (Moyle 2002). They are a euryhaline, planktivorous silver fish with a pinkish or olive iridescent hue with distinctive long pectoral fins hence their common name. Adult LFS occur in freshwater, brackish waters and seawater from Alaska to Monterey Bay (Moyle 2002). The San Francisco Bay and Sacramento-San Joaquin Delta (SF Bay Estuary) is currently the southernmost spawning location for this species and supports the largest population of LFS in California. LFS are pelagic and anadromous, although some subpopulations live their entire lifecycle in freshwater lakes and streams. Although populations are present in Humboldt Bay, nearly all information available on LFS comes from either the SF Bay Estuary or Lake Washington populations (Baxter et. al. 1999, Bennett et al. 2002, Chigbu and Sibley 1994, Moulton 1974, Nobriga and Rosenfield 2016, Stevens and Miller 1983).

A more recent study on the distribution of LFS in areas north of SF Bay Estuary included larval sampling of 16 sites from Tomales Bay north to the Smith River (Brennan et al. 2022). Sampling was conducted during the winter months of 2019 and 2020 in areas of the sites that had salinities of 2–12 psu. Due to heavy rainfall in 2019, freshwater flows into estuarine areas including Humboldt Bay were much higher in 2019 than in 2020. As a result, LFS larval abundances across all of the sampling sites were much higher in 2020, which was likely due to high flows in 2019 flushing many of the larvae out of the sampling areas. In Humboldt Bay, slightly more LFS larvae were collected during 2020 (61 vs. 65), but the sampling in 2020 collected LFS larvae at many more sites, including sites further upstream. During both years, the only locations where LFS larvae were collected in Humboldt Bay was in Eureka Slough. No LFS larvae were collected in the Mad River Slough or South Bay. LFS larvae were collected at several sampling locations in the Eel River with most of the larvae collected in 2020. LFS larvae were only collected at one location in the Mad River in 2020, which was near the mouth of the river.

Although, specific locations of LFS spawning events vary with a multitude of conditions including substrate type, flow, temperature, and salinity (Rosenfield 2010), shallow brackish tidal marshes and sloughs are identified as important spawning and recruitment areas (Lewis et al. 2020). Spawning occurs from November through May peaking around March (CDFW 2009). Most fish die after spawning but some females have been found to live another year. Females lay 1,900 to 18,000 adhesive eggs on sandy or grassy substrate that hatch after ~40 days (CDFW 2009). The average fecundity for an average length female (~4 inches [101.6 mm]) is approximately 5,000 eggs (Figure 3 in CDFW 2009). Data on laboratory studies from Yanagitsuru et al. (2021a) found hatching success for LFS eggs averaged 59%, which would result in the hatching of 2,950 larvae from the 5,000 eggs for each average length female. Data in Yanagitsuru et al. (2021a) was used to calculate an average length at hatching of 0.22 in. (5.6 mm), which is the same as an estimate from data in Lewis et al. (2020). Data from Lewis et al. (2020) were also used to estimate the daily growth for LFS as 0.0067 $in.^{-d}$ (0.17 mm^{-d}).

Newly hatched LFS larvae have a salinity tolerance of 2–6 psu and move downstream into more saline water and after a few weeks can tolerate salinities around 8 psu (Baxter et al. 1999). This is consistent with sampling in the SF Bay Estuary that showed the density of LFS larvae was negatively affected in areas with salinities less than 2 psu and greater than 12 psu (Grimaldo et al. 2017). Grimaldo et al. (2017) indicate that the collections in areas with salinities up to 12 psu drew into question previous results from Hobbs et al. (2010) that survival of small larvae (<0.39 in. [10 mm] TL) was limited in salinities greater than 5 psu. This was based on results from investigations on the chemical signatures of otoliths from adult and sub-adult LFS that used strontium isotope ratios ($^{87}Sr/^{86}Sr$) of waters across the estuarine salinity gradient to reconstruct the larval salinity history of LFS from 4 year-classes (1999, 2000, 2003 and 2006) in the SF Bay Estuary. The results from Hobbs et al. (2010) suggest that LFS larvae that occur in locations with high salinities are unlikely to survive to adulthood. It is likely that these larvae are undergoing physiological stresses due to osmotic pressures. This is supported by more recent laboratory studies on salinity tolerances of early LFS larvae which showed highest survival and growth at salinities of 5 and 10 psu, while salinities of 20 psu presented osmoregulatory problems for the larvae and levels of 32 psu resulted in almost 100% mortality (Yanagitsuru et al. 2021a and Yanagitsuru et al. 2021b). After around 90 days the larvae mature into the juvenile stage and can tolerate normal ocean salinities. Therefore, although the sources for the LFS larvae are not in the vicinity of the intakes, it is likely that daily tidal flows could transport larvae for these species into the area of the intakes. Larvae transported into the vicinity of the intake may only be able to survive salinities in this area during periods when extreme freshwater inflows into the bay result in reduced salinities tolerated by the larvae.

Sampling Results

Longfin Smelt were not collected in high abundance during the sampling from January–December 2022 (**Table 4-2** and **Table 4-3**). A total of approximately 28,000 LFS was estimated to be entrained during the year, comprising approximately 0.2% of the total estimated entrainment of larval fishes. They were only collected at the entrainment stations during surveys done in January and February, with the peak abundance for this taxon occurring in January (**Figure 4-30**). Longfin Smelt were only collected in source water stations during the January survey and the highest abundance was found in SW5, the South Bay Station (**Figure 4-31**).

The salinity data for the periods that the samples at the entrainment stations were collected was approximately 30 PSU during the January survey and close to 33 PSU during the February survey (Appendix B). Based on a study described by Yanagitsuru et al. (2021a and 2021b), LFS larvae would not be able to survive at these salinities.

The average NL of the nine LFS larvae collected at the two entrainment stations and source water stations SW2 and SW3 was 0.33 in. (8.45 mm). The NLs ranged from 0.28 to 0.51 in. (7.19 to 12.87 mm) NL.

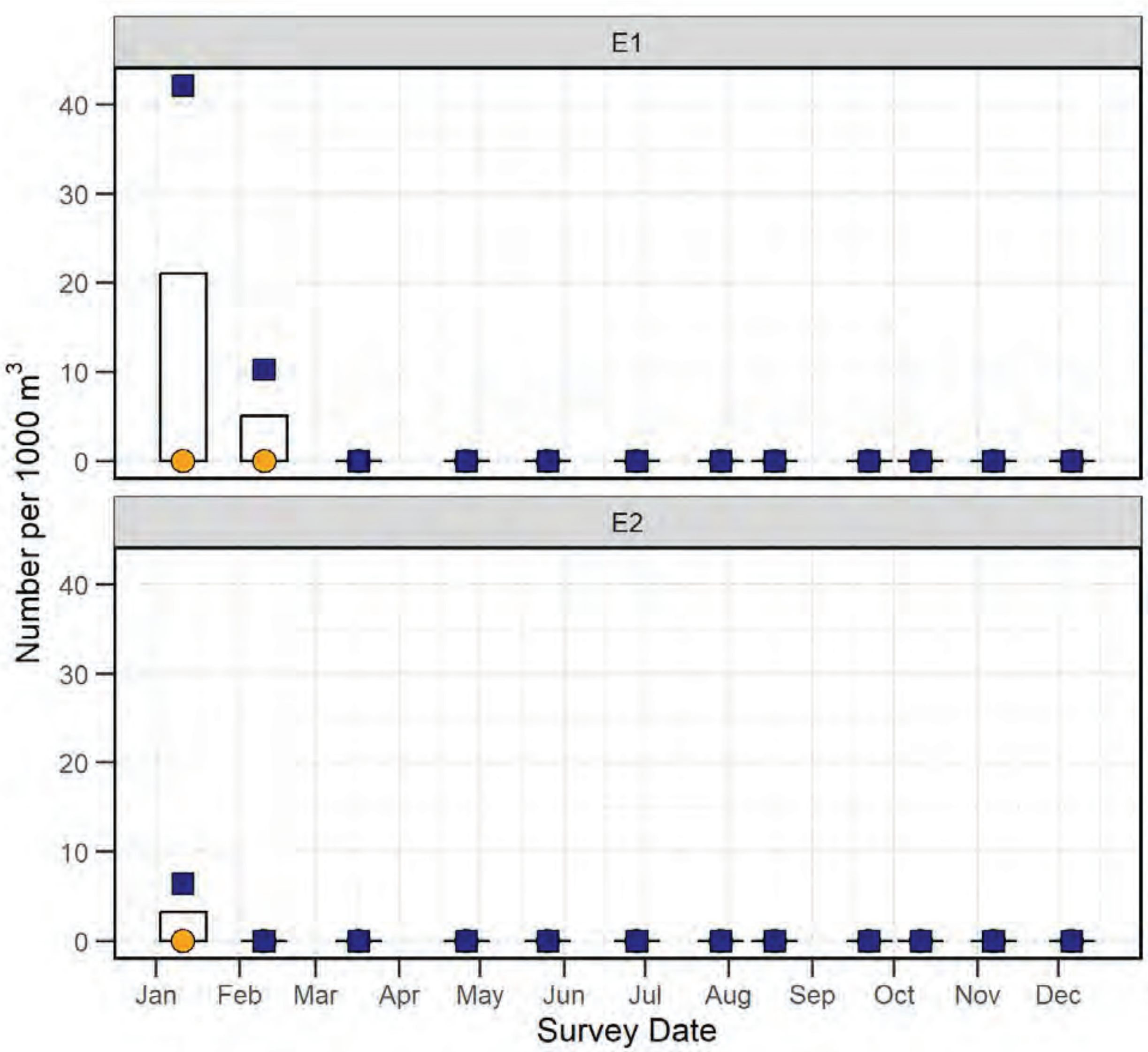

Figure 4-30. Total average concentrations of Longfin Smelt larvae (height of bar) collected during monthly surveys at entrainment stations E1 and E2 from January 2022–December 2022. Concentrations from daytime (orange circles) and nighttime (blue squares) are also shown. Dates of the surveys correspond to the centers of the bars.

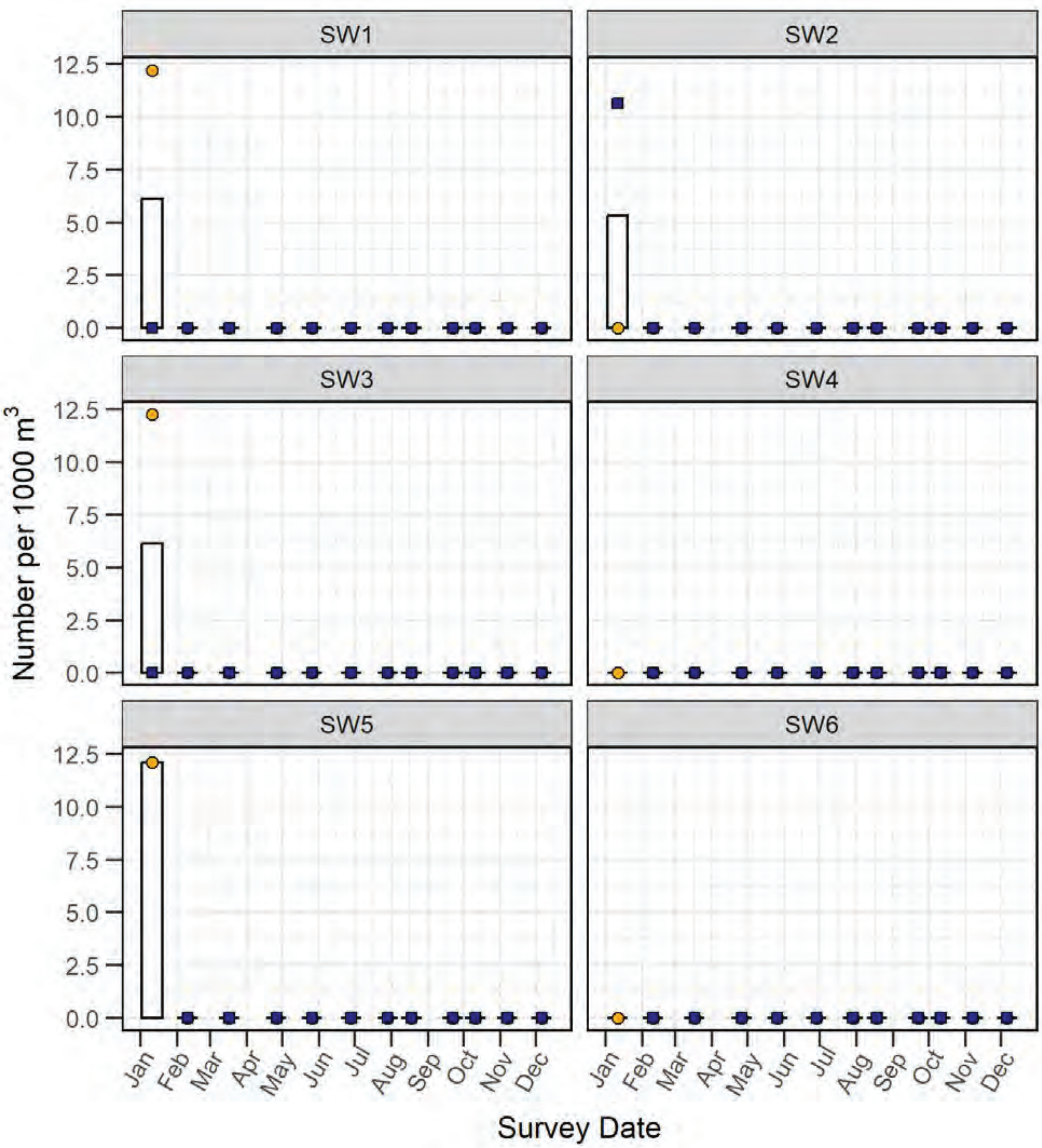

Figure 4-31. Total average concentrations of Longfin Smelt larvae (height of bar) collected during monthly surveys at source water stations SW1–SW6 from January 2022–December 2022. Concentrations from daytime (orange circles) and nighttime (blue squares) are also shown. Dates of the surveys correspond to the centers of the bars.

4.3 Source Water Verification

Results of the Bray-Curtis similarities from the 189 samples and 60 different taxa on fish larvae collected during the 12 surveys were reduced down to the paired similarities between stations with distances that could be estimated as a straight line with a focus on the stations along the north sand spit. Therefore, the paired similarities did not include stations SW1, SW5, and SW6 (**Figure 3-1**). The average Bray-Curtis similarities for the different sampling pairs across all the sampling survey, stations, and cycles resulted in up to 24 similarities per station pair (**Table 4-4**). Correlations for the Bray-Curtis similarity and distance between stations was calculated between sample pairs for data that excluded samples with large differences in tidal heights and conditions at the two locations, but the strongest correlation was detected when using the entire set of data. The correlation among the station pairs for all the samples along the north sand spit was -0.93.

Table 4-4. Average Bray-Curtis similarities and distances (m) between stations pairs for samples collected from January – December 2022 in Humboldt Bay along the north sand spit. Correlation between Bray-Curtis similarity and distance also shown.

Station Pair	Average BC Similarity	Distance (m)	N	Correlation
SW2-SW4	11.96	9691	23	
E2-SW4	27.05	6360	23	
SW2-SW3	26.22	5840	24	
E1-SW4	29.73	5507	23	
E1-SW2	27.24	4202	24	
SW3-SW4	38.28	3856	23	
E2-SW2	41.33	3425	24	
E2-SW3	41.29	2597	24	
E1-SW3	51.19	1705	24	N Sand Spit
E1-E2	41.91	898	24	-0.93

The data for the paired stations in **Table 4-4** are presented in **Figure 4-32** to show the relationship between station pair separation and Bray-Curtis similarity. A mixing model (Model M3 in **Table 3-1**) that is assumed to best represent mixing patterns in Humboldt Bay was calculated for this study. An estimate of flushing time, known as the e-folding time, can be derived from solving the differential equation in the mixing model. The e-folding time within the M3 mixing model also implies an e-folding distance, which represents the distance from the bay mouth that the mixing model predicts flushing will not occur. The Bray-Curtis similarity data provide an independent estimate of that length scale. The similarity results and estimate of the e-folding distance (shown in red) points to a mixing length along the main channel that is greater than the distance between the entrance bay and the proposed seawater intakes of approximately 4.7 mi (7.5 km). This estimate is consistent with the estimates based on physical data collected during the study and the results from Brown and Caldwell (2014) and Claasen (2003), which indicate that particles within the tidal flow would be displaced between 4.3 mi (7 km) and 8.7 mi

(14 km) every tidal cycle. As shown in **Figure 4-32**, the stations with the lowest similarity, SW2 and SW4, are the only station pair outside of this distance. If the results had pointed to a mixing length that was much shorter than the length of the main channel, then it would not be possible to rule out that isolated populations exist near the proposed intake location that are not mixed away by ocean waters within a few tidal cycles. The results indicate that the closed source water model used in the Initial ETM Assessment (Tenera 2021) is not realistic (Model M1 in **Table 3-1**). The results shown in **Figure 4-32** are supported by the biological data which shows a mix of both ocean and bay fishes with the relative abundances at the stations generally reflective of the taxa associated with the habitats in proximity to those stations. These differences are not static as would be expected in a closed system represented by Model M1 as the results in **Figure 4-32** also indicate that the mixing results in a gradient of taxa differences along the north sand spit. The results also indicate that the mixing along the north sand spit is not strong enough to provide complete turnover during each tidal exchange, which is considered as a possibility in Model 2 in **Table 3-1** (i.e., the full tidal prism volume model) in the Initial ETM Assessment. Therefore, the most realistic characterization of impacts is provided by the model in Equation 6 that accounts for the differences in tidal flushing for the different regions of the bay (Model M3 in **Table 3-1**). Those results are reproduced and highlighted in **Table 3-1** alongside the results for the unrealistic, most conservative (closed bay volume) and probably optimistic (full tidal prism volume) results.

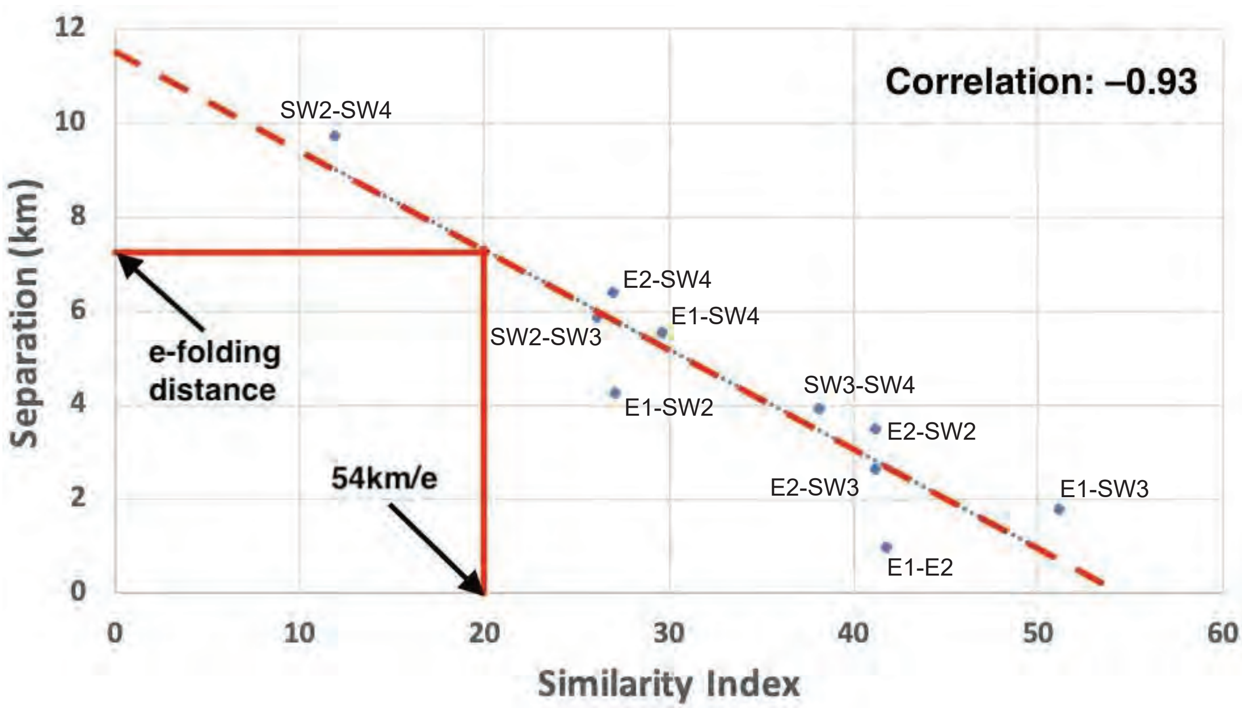

Figure 4-32. Plot showing relationship between distance (km) between station pairs and Bray-Curtis similarity based on data in Table 4-4. The estimate of the e-folding distance is shown by the red solid lines.

5.0 Impact Assessment

The results from the ETM analyses for each taxon are provided in this section and APF estimates for the taxa analyzed using the ETM. The data for Longfin Smelt (LFS) were not analyzed using the ETM because very few larvae were collected, and these larvae were present in only the surveys in January and February. Surveys are used as replicates in the ETM and therefore low replication results in high error in the estimation of P_M. Generally, at least three replicates should be used in any statistically valid parameter estimation. Therefore, the impact assessment for LFS is based solely on the estimated entrainment for the species.

5.1 Estimates of Period of Exposure to Entrainment

The method for deriving the number of days the larvae would be exposed to entrainment is described in Section 3.1.7 Larval Age Estimation and the data used to derive the number of days the larvae would be exposed to entrainment are presented in Section 4.2.

The estimated number of days larvae would be exposed to entrainment for each taxon analyzed in the ETM were calculated using the data on the lengths of the larvae presented in Section 4.2 using the average values from the 1000 bootstrap samples calculated for each taxon as described in Section 3.1.6. The average values from the 1000 bootstrap samples for the seven taxa show that the estimated hatch lengths from the data are within the range of reported hatch lengths from Moser (1996) and other sources reported in Section 4.2 for all of the taxa except Surf Smelt (**Table 5-1**).

Table 5-1. Average estimates from 1000 bootstrap samples of larval lengths for the seven fish taxa analyzed using the ETM. All of the measurements are in mm. The calculated hatch lengths and larval durations are calculated using the methods described in Section 3.1.6. The sources of the estimated growth rates for each taxon are described in the taxa profiles in Section 4.2.

Taxa	Mean	Max	Min	q1	q5	q10	q25	q50	q75	q90	q95	q99	Calculated Hatch Length (mm)	Reported Hatch Length (mm)	Analysis Hatch (mm)	Estimated Growth Rate (mm/d)	Duration (d)
Arrow Goby	3.86	9.28	2.48	2.59	2.75	2.85	3.05	3.44	4.17	5.45	6.48	7.97	3.02	2 - 3	3.02	0.20	17.49
Bay Goby	3.05	4.44	2.10	2.16	2.35	2.50	2.76	2.97	3.22	3.83	4.00	4.32	2.57	3	2.57	0.22	6.53
White Bait Smelt	6.24	13.64	4.16	4.20	4.44	4.75	5.18	5.83	6.81	8.06	9.47	11.93	5.01	5.5	5.01	0.17	26.23
Pacific Herring	8.38	20.15	6.30	6.38	6.68	6.98	7.42	7.97	8.55	9.23	11.87	17.31	7.17	5.6 - 7.5	7.17	0.50	9.39
Pacific Tomcod	3.12	3.90	2.17	2.24	2.29	2.52	2.90	3.18	3.38	3.54	3.63	3.83	2.71	2.7	2.71	0.16	5.66
Surf Smelt	13.67	24.95	4.20	4.68	5.76	6.19	7.73	12.29	19.50	23.13	23.72	24.90	8.48	3 - 5	4.68	0.17	87.18
Pac. Stag. Sculpin	5.88	10.88	4.03	4.08	4.48	4.72	5.12	5.55	6.10	7.71	8.95	10.48	4.81	4 - 5	4.81	0.25	16.56

There were only a limited number of Surf Smelt larvae from the two entrainment stations and the two nearby source water stations. The calculated hatch NL of 0.33 in. (8.5 mm) was much larger than the reported hatch NL of 0.12–0.20 in. (3–5 mm), therefore, the length at the 1st quantile was used as the hatch length. Over a quarter of the Surf Smelt larvae were large enough to have very low probabilities of entrainment through the 0.04 in. (1.0 mm) slot openings based on the Monte Carlo simulation of the results of the allometric regression of NL and head capsule dimensions presented in Section 6.0 (**Figure 6-2**c and **Table 6-1**). Even using the estimated length at the 75^{th} quartile as the maximum length with the adjusted hatch length in the calculation of the larval duration resulted in an estimate of over 87 d which is clearly incorrect and exceeds the expected period of approximately 30 days for the maximum turnover of water within the bay (Swanson 2015). The most likely explanation for the estimated hatch length for Surf Smelt being so high compared to the reported hatch length range is that there were only a limited number of Surf Smelt larvae from the two entrainment stations and the two nearby source water stations. A low number of measured larval fish for Surf Smelt would introduce error into the bootstrap technique, so the estimated values may be wrong. Therefore, the duration for Surf Smelt used in this study is 30 days.

5.1 ETM Assessments

This section presents and discusses the results of the ETM for each of the taxa.

5.1.1 Arrow Goby

The ETM analysis of the data for Arrow Goby using a period of larval exposure of 17.5 d results in an estimate of entrainment mortality to the source water population of approximately 0.376% for the two intakes if operated at full capacity the entire year (**Table 5-2**). The difference between the estimates of P_M for the two intakes partially reflects the higher intake volume at the RMT II intake (Station E1; $P_M = 0.301\%$), but also the lower entrainment estimates at Station E2 ($P_M = 0.075\%$), especially during the June survey when the largest proportion of the source water population was present. The *PE* estimates for that survey received a weight (f_i) of 0.55 in the ETM calculations. The highest concentrations of any of the larvae collected during the study occurred during the June survey at Station E1 for Arrow Goby (10,673 per 1,000 m^3). This resulted in the high entrainment estimate for that survey, but high concentrations at the source water stations during that survey resulted in an estimate of *PE* that was only 40% higher than the estimate for the July survey.

Table 5-2. ETM results for Arrow Goby showing survey estimates of numbers of larvae for the total Humboldt Bay source water and the estimated entrainment at the two intake locations, E1 and E2. The estimated daily entrainment for the two intakes were based on daily intake volumes for the RMT II (Station E1) and RTD (Station E2) intakes of 7.92x10^6 gal (29,980 m^3) and 3.96x10^6 gal (14,990 m^3) per day, respectively.

Survey	Total Source Water (1000s)	Station E1 (1000s)	Station E2 (1000s)	f_i	***PE*** Estimate Station E1	***PE*** Estimate Station E2	Survey ETM Estimate Station E1	Survey ETM Estimate Station E2
Jan	114.8	0.00	0.00	0.0002	0.000000	0.000000	0.000247	0.000247
Feb	58.7	0.00	0.00	0.0001	0.000000	0.000000	0.000126	0.000126
Mar	5,006.9	1.47	1.12	0.0108	0.000105	0.000080	0.010739	0.010744
Apr	6,520.3	0.59	0.36	0.0140	0.000044	0.000027	0.014000	0.014005
May	48,586.0	0.70	0.85	0.1044	0.000008	0.000010	0.104390	0.104387
June	257,755.8	319.98	31.14	0.5539	0.000252	0.000024	0.551447	0.553643
July	31,700.0	27.26	0.97	0.0681	0.000177	0.000006	0.067909	0.068111
Aug	108,821.8	17.86	25.83	0.2338	0.000076	0.000110	0.233533	0.233395
Sept	3,306.7	0.00	0.21	0.0071	0.000000	0.000038	0.007106	0.007101
*Oct	2,391.1	0.62	0.40	0.0051	0.000083	0.000053	0.005131	0.005133
Nov	800.1	0.18	0.43	0.0017	0.000079	0.000189	0.001717	0.001714
Dec	301.3	0.15	0.00	0.0006	0.000156	0.000000	0.000646	0.000647
	Sums of Survey Estimates				Average ***PEs***		P_M Estimates	
	465,363.5	368.81	61.31		0.000082	0.000045	0.003010	0.000747
							0.3010%	0.0747%
							Total P_M =	0.3757%

5.1.2 **Bay Goby**

The ETM analysis of the data for Bay Goby using a period of larval exposure of 6.5 d results in an estimate of entrainment mortality to the source water population of approximately 0.117% (**Table 5-3**). This is the P_M due to entrainment for both intakes if operated at full capacity the entire year. The P_M estimates for Bay Goby at the RMT II intake, represented by Station E1, and at the RTD intake, represented by Station E2 are 0.076% and 0.040%, respectively. The difference between the estimates of P_M for the two intakes reflects the higher intake volume at the RMT II intake (Station E1). The estimate of the proportion of the source water population exposed to entrainment (f_i) during the year shows that the highest source water abundances and highest entrainment occurred during the surveys from August through October and also in December.

Table 5-3. ETM results for Bay Goby showing survey estimates of numbers of larvae for the total Humboldt Bay source water and the estimated entrainment at the two intake locations, E1 and E2. The estimated daily entrainment for the two intakes were based on daily intake volumes for the RMT II (Station E1) and RTD (Station E2) intakes of 7.92x10^6 gal (29,980 m^3) and 3.96x10^6 gal (14,990 m^3) per day, respectively.

Survey	Total Source Water (1000s)	Station E1 (1000s)	Station E2 (1000s)	f_i	***PE*** Estimate Station E1	***PE*** Estimate Station E2	Survey ETM Estimate Station E1	Survey ETM Estimate Station E2
Jan	4,902.0	0.38	0.22	0.0433	0.000045	0.000026	0.043329	0.043335
Feb	484.7	-	-	0.0043	0.000000	0.000000	0.004285	0.004285
Mar	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
Apr	1,972.2	1.39	0.60	0.0174	0.000328	0.000141	0.017400	0.017421
May	1,814.2	1.02	0.00	0.0160	0.000307	0.000000	0.016008	0.016041
June	7,057.5	-	0.74	0.0624	0.000000	0.000042	0.062401	0.062383
July	6,153.6	2.44	0.61	0.0544	0.000116	0.000029	0.054368	0.054399
Aug	45,518.9	14.64	3.39	0.4025	0.000114	0.000026	0.402170	0.402399
Sept	13,326.5	4.61	4.55	0.1178	0.000150	0.000148	0.117715	0.117716
Oct	12,045.3	6.35	0.51	0.1065	0.000174	0.000014	0.106381	0.106493
Nov	7,996.2	-	4.12	0.0707	0.000000	0.000295	0.070701	0.070565
Dec	11,828.3	4.55	1.08	0.1046	0.000151	0.000036	0.104480	0.104559
	Sums of Survey Estimates				Average ***PEs***		***P_M*** Estimates	
	113,099.3	35.37	15.82		0.000115	0.000063	0.000762	0.000404
							0.0762%	0.0404%
							Total ***P_M*** =	0.1166%

5.1.3 Whitebait Smelt

The ETM analysis of the data for Whitebait Smelt using a period of larval exposure of 26.2 d results in an estimate of entrainment mortality to the source water population of approximately 0.046% (**Table 5-4**). This is the P_M due to entrainment for both intakes if operated at full capacity the entire year. The P_M estimates for Whitebait Smelt at the RMT II intake, represented by Station E1, and at the RTD intake, represented by Station E2 are 0.032% and 0.014%, respectively. The difference between the estimates of P_M for the two intakes reflects the higher intake volume at the RMT II intake (Station E1). The estimate of the proportion of the source water population exposed to entrainment (f_i) during the year shows that the highest source water abundances and highest entrainment occurred during the June survey.

Table 5-4. ETM results for Whitebait Smelt showing survey estimates of numbers of larvae for the total Humboldt Bay source water and the estimated entrainment at the two intake locations, E1 and E2. The estimated daily entrainment for the two intakes were based on daily intake volumes for the RMT II (Station E1) and RTD (Station E2) intakes of 7.92×10^6 gal (29,980 m^3) and 3.96×10^6 gal (14,990 m^3) per day, respectively.

Survey	Total Source Water (1000s)	Station E1 (1000s)	Station E2 (1000s)	f_i	***PE*** Estimate Station E1	***PE*** Estimate Station E2	Survey ETM Estimate Station E1	Survey ETM Estimate Station E2
Jan	7,042.7	1.14	0.17	0.0430	0.000013	0.000002	0.042973	0.042986
Feb	2,534.8	0.15	0.08	0.0155	0.000005	0.000003	0.015470	0.015471
Mar	3,730.2	0.44	0.08	0.0228	0.000009	0.000002	0.022763	0.022768
Apr	12,164.6	4.60	2.29	0.0743	0.000043	0.000021	0.074168	0.074210
May	23,302.6	7.48	0.71	0.1422	0.000024	0.000002	0.142148	0.142228
June	105,139.2	10.73	7.39	0.6418	0.000007	0.000005	0.641638	0.641675
July	7,836.0	0.78	0.09	0.0478	0.000007	0.000001	0.047821	0.047829
Aug	2,034.9	0.15	-	0.0124	0.000005	0.000000	0.012419	0.012421
Sept	45.5	-	0.07	0.0003	0.000000	0.000773	0.000277	0.000272
Oct	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
Nov	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
Dec	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
	Sums of Survey Estimates				Average ***PEs***		P_M Estimates	
	163,830.6	25.48	10.88		0.000009	0.000067	0.000323	0.000142
							0.0323%	0.0142%
							Total PM =	0.0464%

5.1.4 Pacific Herring

The ETM analysis of the data for Pacific Herring using a period of larval exposure of 9.4 d results in an estimate of entrainment mortality to the source water population of approximately 0.031% (**Table 5-5**). This is the P_M due to entrainment for both intakes if operated at full capacity the entire year. The P_M estimates for Pacific Herring at the RMT II intake, represented by Station E1, and at the RTD intake, represented by Station E2 are 0.021% and 0.010%, respectively. The difference between the estimates of P_M for the two intakes is likely due to the difference in volume between the two intakes. The estimate of the proportion of the source water population exposed to entrainment (f_i) during the year shows that over 95% of the Pacific Herring larvae occurred during the March survey.

Table 5-5. ETM results for Pacific Herring showing survey estimates of numbers of larvae for the total Humboldt Bay source water and the estimated entrainment at the two intake locations, E1 and E2. The estimated daily entrainment for the two intakes were based on daily intake volumes for the RMT II (Station E1) and RTD (Station E2) intakes of 7.92×10^6 gal (29,980 m^3) and 3.96×10^6 gal (14,990 m^3) per day, respectively.

Survey	Total Source Water (1000s)	Station E1 (1000s)	Station E2 (1000s)	f_i	*PE* Estimate Station E1	*PE* Estimate Station E2	Survey ETM Estimate Station E1	Survey ETM Estimate Station E2
Jan	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
Feb	3,028.9	0.83	0.61	0.0422	0.000150	0.000110	0.042122	0.042138
Mar	68,564.8	4.56	1.51	0.9548	0.000016	0.000005	0.954704	0.954801
Apr	108.5	-	0.07	0.0015	0.000000	0.000506	0.001511	0.001504
May	104.8	0.17	-	0.0015	0.000472	0.000000	0.001452	0.001459
June	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
July	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
Aug	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
Sept	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
Oct	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
Nov	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
Dec	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
	Sums of Survey Estimates				Average *PEs*		P_M Estimates	
	71,807.0	5.56	2.19		0.000053	0.000052	0.000210	0.000098
							0.0210%	0.0098%
							Total PM =	0.0308%

5.1.5 Pacific Tomcod

The ETM analysis of the data for Pacific Tomcod using a period of larval exposure of 5.66 d results in an estimate of entrainment mortality to the source water population of approximately 0.084% (**Table 5-6**). This is the P_M due to entrainment for both intakes if operated at full capacity the entire year. The P_M estimates for Pacific Tomcod at the RMT II intake, represented by Station E1, and at the RTD intake, represented by Station E2 are 0.075% and 0.009%, respectively. The difference between the estimates of P_M for the two intakes partially reflects the difference in volume between the two intakes but is also due to the much lower entrainment at Station E2 (7,450 vs 920), which far exceeds the difference in the volumes. The difference in entrainment estimates for the two intakes is especially apparent in the estimates for the January, February, and June surveys. The estimate of the proportion of the source water population exposed to entrainment (f_i) during the year shows that the largest proportions of the larvae occurred during the January and April surveys.

Table 5-6. ETM results for Pacific Tomcod showing survey estimates of numbers of larvae for the total Humboldt Bay source water and the estimated entrainment at the two intake locations, E1 and E2. The estimated daily entrainment for the two intakes were based on daily intake volumes for the RMT II (Station E1) and RTD (Station E2) intakes of 7.92x10^6 gal (29,980 m^3) and 3.96x10^6 gal (14,990 m^3) per day, respectively.

Survey	Total Source Water (1000s)	Station E1 (1000s)	Station E2 (1000s)	f_i	*PE* Estimate Station E1	*PE* Estimate Station E2	Survey ETM Estimate Station E1	Survey ETM Estimate Station E2
Jan	7,158.6	2.91	0.05	0.3763	0.000145	0.000002	0.376012	0.376316
Feb	1,899.2	0.46	-	0.0998	0.000062	0.000000	0.099804	0.099839
Mar	663.6	-	0.07	0.0349	0.000000	0.000037	0.034883	0.034876
Apr	8,586.7	2.89	0.81	0.4514	0.000106	0.000029	0.451127	0.451322
May	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
June	714.5	1.19	-	0.0376	0.000660	0.000000	0.037420	0.037560
July	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
Aug	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
Sept	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
Oct	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
Nov	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
Dec	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
	Sums of Survey Estimates				Average *PEs*		P_M Estimates	
	19,022.5	7.45	0.92		0.000081	0.000006	0.000754	0.000088
							0.0754%	0.0088%
							Total PM =	0.0842%

5.1.6 Surf Smelt

The ETM analysis of the data for Surf Smelt using a period of larval exposure of 30 d results in an estimate of entrainment mortality to the source water population of approximately 0.078% (**Table 5-7**). This is the P_M due to entrainment for both intakes if operated at full capacity the entire year. The duration of 30 d was used because of the small number of Surf Smelt larvae collected and the large variation in lengths made calculation of a duration difficult to apply using the methods employed for the other taxa. The P_M estimates for Surf Smelt at the RMT II intake, represented by Station E1, and at the RTD intake, represented by Station E2 are 0.053% and 0.025%, respectively. The difference between the estimates of P_M for the two intakes reflects the difference in volume . The estimate of the proportion of the source water population exposed to entrainment (f_i) during the year shows that the largest proportion of the larvae occurred during the June survey ($f_i = 0.75$).

Table 5-7. ETM results for Surf Smelt showing survey estimates of numbers of larvae for the total Humboldt Bay source water and the estimated entrainment at the two intake locations, E1 and E2. The estimated daily entrainment for the two intakes were based on daily intake volumes for the RMT II (Station E1) and RTD (Station E2) intakes of 7.92x106 gal (29,980 m3) and 3.96x106 gal (14,990 m3) per day, respectively.

Survey	Total Source Water (1000s)	Station E1 (1000s)	Station E2 (1000s)	f_i	*PE* Estimate Station E1	*PE* Estimate Station E2	Survey ETM Estimate Station E1	Survey ETM Estimate Station E2
Jan	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
Feb	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
Mar	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
Apr	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
May	87.9	0.15	-	0.0043	0.000183	0.000000	0.004308	0.004332
June	15,239.6	3.58	1.49	0.7510	0.000017	0.000007	0.750581	0.750808
July	437.4	-	0.09	0.0216	0.000000	0.000038	0.021555	0.021531
Aug	385.9	-	-	0.0190	0.000000	0.000000	0.019018	0.019018
Sept	197.3	0.16	0.08	0.0097	0.000147	0.000071	0.009680	0.009702
Oct	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
Nov	1,554.9	0.34	0.38	0.0766	0.000016	0.000018	0.076585	0.076581
Dec	2,390.1	0.29	-	0.1178	0.000012	0.000000	0.117736	0.117780
	Sums of Survey Estimates				Average ***PEs***		***P_M*** Estimates	
	20,293.3	4.51	2.03		0.000031	0.000011	0.000535	0.000248
							0.0535%	0.0248%
							Total PM =	0.0783%

5.1.7 Pacific Staghorn Sculpin

The ETM analysis of the data for Pacific Staghorn Sculpin using a period of larval exposure of 16.6 d results in an estimate of entrainment mortality to the source water population of approximately 0.096% (**Table 5-8**). This is the P_M due to entrainment for both intakes if operated at full capacity the entire year. The P_M estimates for Surf Smelt at the RMT II intake, represented by Station E1, and at the RTD intake, represented by Station E2 are 0.064% and 0.032%, respectively. The difference between the estimates of P_M for the two intakes reflects the difference in their volumes. The estimate of the proportion of the source water population exposed to entrainment (f_i) during the year shows that the largest proportion of the larvae occurred during the January and February surveys (f_i = 0.3194 and 0.2180 respectively).

It is likely that the estimates of P_M for the two intakes are conservative since the head capsule dimensions for larvae at the length of the 95th quantile (0.35 in. [8.9 mm]) in **Table 5-1** are close to, and may exceed, the 0.04 in. (1.0 mm) width of the slot openings on the intakes as shown in **Figure 5-1**. The analysis on the efficiency of the WWS modules in Section 6.0 indicate that the probability of entrainment at the length of the 95th quantile is reduced to 63% (**Table 6-1**).

Table 5-8. ETM results for Pacific Staghorn Sculpin showing survey estimates of numbers of larvae for the total Humboldt Bay source water and the estimated entrainment at the two intake locations, E1 and E2. The estimated daily entrainment for the two intakes were based on daily intake volumes for the RMT II (Station E1) and RTD (Station E2) intakes of 7.92x10^6 gal (29,980 m^3) and 3.96x10^6 gal (14,990 m^3) per day, respectively.

Survey	Total Source Water (1000s)	Station E1 (1000s)	Station E2 (1000s)	f_i	*PE* Estimate Station E1	*PE* Estimate Station E2	Survey ETM Estimate Station E1	Survey ETM Estimate Station E2
Jan	4,662.3	1.64	0.69	0.3194	0.000065	0.000028	0.319089	0.319288
Feb	3,182.2	0.56	0.36	0.2180	0.000039	0.000025	0.217885	0.217936
Mar	2,507.2	0.29	0.07	0.1718	0.000018	0.000004	0.171728	0.171768
Apr	1,953.3	-	-	0.1338	0.000000	0.000000	0.133832	0.133832
May	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
June	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
July	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
Aug	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
Sept	73.3	0.12	-	0.0050	0.000305	0.000000	0.004997	0.005022
Oct	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
Nov	770.7	-	0.22	0.0528	0.000000	0.000086	0.052802	0.052726
Dec	1,446.5	0.37	-	0.0991	0.000044	0.000000	0.099032	0.099104
	Sums of Survey Estimates				Average *PEs*		P_M Estimates	
	14,595.5	2.98	1.34		0.000039	0.000012	0.000636	0.000324
							0.0636%	0.0324%
							Total PM =	0.0960%

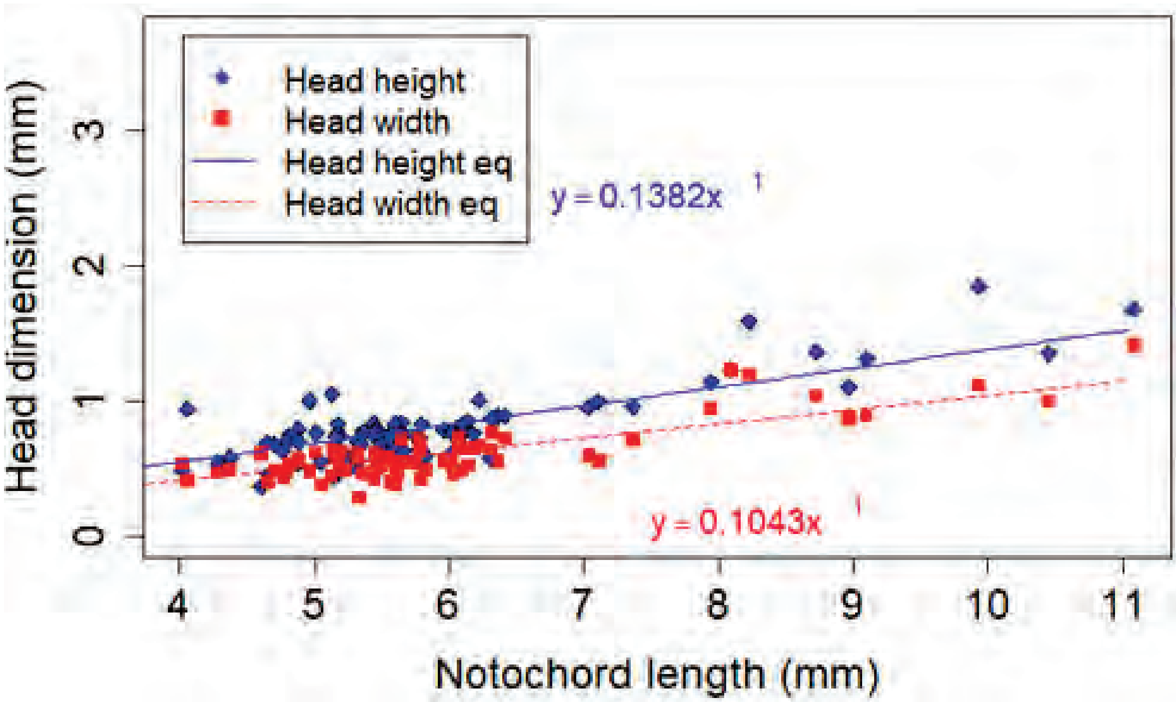

Figure 5-1. Plot of head capsule height and width against notochord length for Pacific Staghorn Sculpin. The allometric regression equations for the measurements are shown on the graph.

5.1.8 ETM Summary

The ETM estimates of P_M for the seven taxa presented in the previous sections are presented in **Table 5-9**. The average P_M from the estimates for the combined volume for the two intakes (0.118%) was similar in value to the results from the volumetric results for Model M3 in the Initial ETM Assessment (**Table 3-1**). The results from the Initial ETM Assessment ranged from 0.062% to 0.104% depending on the larval durations used in the analysis.

The highest ETM estimate of P_M from this study was 0.376% for Arrow Goby (**Table 5-9**). This is because, compared to other taxa, Arrow Goby were in high abundance at the entrainment stations compared to the source water stations (**Table 4-2**). Therefore, the intakes would be predicted to entrain a higher proportion of the population of Arrow Goby in the bay than the other taxa analyzed. Arrow Goby live on mudflats, which are one of the predominant habitat types in Arcata Bay. In the habitat areas shown in **Figure 2-2**, mudflats would occur in the areas designated as macroalgae, eelgrass, and intertidal. These areas comprise most of Arcata Bay and also occur on Tuluwat Island and in areas along the Main Channel. The prevalence of mudflat habitat near the location of the intakes explains the high P_M for Arrow Goby compared to the other species. Arrow Goby may spawn multiple times per year (Brothers 1975) and this may explain why they were collected during all 12 surveys at both the intake and source water stations (**Table 5-2**). This high number of surveys means the ETM estimate for Arrow Goby is likely to be less error prone than taxa collected from fewer surveys. They occurred in highest abundance at the stations in Arcata Bay (Stations SW1, SW2, and SW6 **Figure 4-8**) and also at the two entrainment stations (**Figure 4-7**), which are located in or near Arcata Bay (see also

Table 4-2). Source water stations outside of Arcata Bay had lower concentrations of Arrow Goby than the entrainment stations. Furthermore, Arrow Goby had a relatively low larval duration compared with Whitebait and Surf Smelt (**Table 5-1**). Typically, a lower larval duration would result in a lower P_M, but Arrow Goby has a higher P_M than both these taxa.

The Bay Goby has less specific habitat preferences than the Arrow Goby. The sampling results show that the number of Bay Goby throughout Humboldt Bay are much more evenly distributed than Arrow Goby, which were more abundant at the Arcata Bay and intake stations. Because of this, the P_M for Bay Goby is 0.117% (**Table 5-9**), which is less than Arrow Goby and closer the volumetric estimates calculated in the Initial ETM Assessment. For example, the estimate in the Initial ETM Assessment for Pacific Herring was 0.075% (**Table 3-1**). The results for these two taxa are comparable because Pacific Herring has a similar larval duration (6.8 days) to the duration used for Bay Goby (6.5 days) in these studies (**Table 5-1**). Arrow Goby, Bay Goby, and Pacific Herring all produce demersal eggs that are negatively buoyant and/ or remain close to the substrate. Unlike gobies, which are presumed to use their burrows to harbor fertilized demersal eggs, Pacific Herring attach fertilized eggs to submerged vegetation such as algae and seagrass where they remain unattended during development. Pacific Herring eggs are also found attached to submerged hard habitat including rocks, pier pilings, and other structures. Once hatched, larval Pacific Herring remain in the plankton for up to 70 days and are generally surface-oriented. Pelagic durations of gobies are less well understood. Based on the results of this study, it appears that Arrow Goby larvae are more discretely distributed in Humboldt Bay relative to Bay Goby, which appears to have a distribution pattern more similar to species like Pacific Herring.

The NL measurements for most of the taxa occurred within a very narrow range compared to previous entrainment studies (e.g., Tenera 2005, Tenera 2011). Many of these studies were conducted at power plants with large volume intakes where the frequency and scope of the sampling was justifiably more extensive than the sampling for this study due to the potential for greater impacts. The volumes of the intakes at some of the power plants are two orders of magnitude greater than the volumes for the Humboldt Bay intakes, and as a result, some of the power plant studies included biweekly and sometimes weekly sampling at the intakes with four or more samples per day. Therefore, due to the narrow range of measurements in this study, no attempt was made to adjust the ETM estimates based on the potential for reduced entrainment impacts to larger larvae as a consequence of the WWS modules.

Estimates of APF for each of the taxa analyzed are shown in **Table 5-9**. The ETM estimates were based on the approximate surface area of Humboldt Bay at MSL which is consistent with the estimates of the volumes at MSL for the different areas of the bay used in the ETM analyses. The average estimate of APF from the seven taxa was 17.9 acres (7.2 hectares). On previous projects where APF has been used (MBC and Tenera 2005), the amount of habitat area required as compensation for the effects of entrainment has been based on the average APF from the taxa analyzed for the study. The APF is a conservative estimate of the area required to compensate for entrainment losses because, as discussed above, the actual spawning habitat for the species being analyzed is much more limited than the entire bay. This is evident in the sampling results for Arrow Goby, but in fact none of the seven taxa occur throughout the bay in all habitats. The APF is conservative and is based on the entire source water because it is meant to compensate for entrainment losses to a much broader range of planktonic organisms than just the ichthyoplankton sampled in the study.

Table 5-9. Summary of ETM results for taxa analyzed from sampling in Humboldt Bay from January–December 2022 with ETM estimates of P_M for the RMT II (Station E1) and RTD (Station E2) intakes. Area Production Foregone (APF) estimates were calculated based on an estimate of the surface area of Humboldt Bay at MSL of 15,098 acres (6,110 hectares).

	P_M Estimates (%)			APF Estimates (acres [hectares])		
Taxa	RMT II Intake (Station E1)	RTD Intake (Station E2)	Total	RMT II Intake	RTD Intake	Total
Arrow Goby	0.3010	0.0747	0.3757	45.4 (18.4)	11.3 (4.6)	56.7 (23.0)
Bay Goby	0.0762	0.0404	0.1166	11.5 (4.7)	6.1 (2.5)	17.6 (7.1)
Whitebait Smelt	0.0323	0.0142	0.0464	4.9 (2.0)	2.1 (0.9)	7.0 (2.8)
Pacific Herring	0.0210	0.0098	0.0308	3.2 (1.3)	1.5 (0.6)	4.7 (1.9)
Pacific Tomcod	0.0754	0.0088	0.0842	11.4 (4.6)	1.3 (0.5)	12.7 (5.1)
Surf Smelt	0.0535	0.0248	0.0783	8.1 (3.3)	3.7 (1.5)	11.8 (4.8)
Pacific Staghorn Sculpin	0.0636	0.0324	0.0960	9.6 (3.9)	4.9 (2.0)	14.5 (5.9)
Average	0.0890	0.0293	0.1183	13.4 (5.4)	4.4 (1.8)	17.9 (7.2)

5.2 Longfin Smelt Assessment

The total estimated entrainment totals for the study year of 2022 from **Table 4-3** for LFS for the two intakes was 28,013 (SE = 22,086). A total of six LFS larvae were collected from Station E1 (RMT II Intake) which equated to an estimated annual entrainment of 26,380 (Std. Err. = 22,026) larvae, and one larva was collected from Station E2 (RTD Intake) which equates to an estimated annual entrainment of 1,633 (SE = 1,633) larvae. The estimates are based on the study year period calculated using the survey intervals in **Table 4-1**.

In Appendix N of the Final Environmental Impact Report (FEIR) for this project,[15] an approach was presented for estimating the number of female adult LFS required to produce the estimated entrainment of LFS larvae. The method for extrapolating the larval losses to adult females is termed fecundity hindcasting (FH) (Steinbeck et al. 2007). Fecundity hindcasting can be more broadly categorized as adult equivalent modeling which has historically been used in intake assessments at large power plants (Steinbeck et al. 2007). The approach used in this study is explained in the following paragraphs.

The average NL of the LFS larvae collected during the sampling at the two entrainment stations and the two closest source water stations (SW2 and SW3) was 0.33 in. (8.5 mm). Using the life

[15] Appendix N - Tenera Humboldt Bay Piling Removal Restoration for Longfin Smelt and other Marine Resources. In Final Environmental Impact Report Samoa Peninsula Land-based Aquaculture Project, County of Humboldt, Planning and Building Department, June 30, 2022, Samoa Peninsula Land-based Aquaculture Project, SCH#: 2021040532. Prepared by GHD, Eureka, CA

history information on hatch length and larval growth for LFS in Section 4.2.8, the estimated age of the entrained larvae was 17.7 d. The calculations in Appendix N were based on an estimated larval growth rate of 0.005 in. per d (0.14 mm per d) from CDFW (2009). More recent information presented in Section 4.2.8 from Lewis et al. (2020) indicate a larval growth rate of 0.0067 in. per d (0.17 mm per d), which was used to estimate the duration for this analysis.

The approach in Appendix N of the FEIR used the following life history information for LFS: 1) an average fecundity of 5,000 eggs for an average sized female (Figure 3 in CDFW 2009); 2) an estimated hatching success rate for LFS eggs of 59% (Yanagitsuru et al. 2021b); and 3) an estimated daily survival rate for the larvae of 0.862. The estimate of daily survival in this report was based directly on an estimate of mortality of approximately 90% of early-stage larvae through day 20 from Tigan et al. (2019) that was cited in Yanagitsuru et al. (2021b). The daily survival over the 20 days was calculated as 0.891 and the estimated survival over 17.7 days was 0.130 ($0.891^{17.7}$ = Survival of 13.0 % and Mortality of 87.0%). These life history parameters were used to estimate that 383 17.7-day old larvae would result from the spawning of an average size female LFS. Therefore, the estimated take of 28,013 17.7-day LFS larvae is equivalent to the take of 73 average size, reproductive age, female LFS.

Similar to the APF that provides estimates of habitat that could be used in determining the amount of habitat required to compensate for entrainment losses, the FH estimate calculated in Section 5.2 of 73 average size female LFS from the LFS entrainment estimate can be used to determine appropriate compensation for the take of LFS. Based on the conservative estimate of the required spawning area for a female LFS of 43 ft^2 (4 m^2) used in the Project FEIR, a mitigation area of 3,139 ft^2 (292 m^2) of LFS spawning, rearing, and nursery habitat would compensate for the entrainment losses from the intake when operated at full capacity.

This estimate does not account for the limited tolerances of the small LFS collected during the study to salinities greater than 10–12 psu (see Baxter 1999, Grimaldo et al. 2017, Yanagitsuru et al. 2021a cited in Section 4.2.8). The information presented in Section 4.2.8 indicates that the LFS larvae collected during the sampling would not survive the salinities levels that are close to seawater (~32 psu) which normally occur in the area of the intake. The salinity levels during the sampling indicate that the LFS collected at the two entrainment stations during the study were likely dead or in severe physiological stress at the time of collection.

6.0 Impact Assessment Discussion

This section includes a discussion of the results presented in sections 4 and 5. It also includes projections on the effectiveness of entrainment reductions using the proposed WWS modules and a conclusion that integrates the material.

6.1 Discussion

This study provides estimates of the potential effects to planktonic marine organisms resulting from the predicted entrainment of larvae during the operation of two intakes located off the Samoa Peninsula in Humboldt Bay (**Figure 1-1**). The proposed intake design capacities are 5,500 gallons per minute (gpm) (20.8 m^3 per minute) for the RMT II intake and 2,750 gpm (10.4 m^3 per minute) for the RTD intake for a total capacity of 8,250 gpm (31.2 m^3 per minute) or 11.88 million gallons per day (mgd) (44,970 m^3 per day). The total daily capacities for the RMT II and RTD intakes are 7.92 and 3.96 mgd (29,980 and 14,990 m^3), respectively. The ETM approach used in this study to estimate the effects of the intakes is the standard approach approved by California resource agencies for estimating the effects of entrainment. The ETM has been used on intake projects ranging from desalination plants with intake volumes similar to this project to large power plants with intake volumes of 2,500 mgd (9.5 million m^3) (Steinbeck et al. 2016). An Initial ETM Assessment that provided estimates for the initial permitting stages of the project used a simplified approach to the ETM that assumed that the concentration of larvae at the intake and in the source water are approximately equal. This allowed the ratio of the volumes of the intakes to the source water to be used as the estimates of *PE* for the analysis, an approach that was also used in the original formulation of the ETM (Boreman et al. 1978, 1981).

The ETM estimates of P_M from the Initial ETM Assessment were calculated using three source water models (**Table 3-1**). The results for the source water model based on the estimated tidal exchange ratios for the different areas of Humboldt Bay varied from 0.062% to 0.104% depending on the periods of larval exposure to entrainment used in the calculations. The average ETM estimate of P_M for the taxa analyzed from the sampling conducted during January–December 2022 for this study was 0.118% which was higher than the estimates in the Initial ETM Assessment (**Table 5-9**), but for all of the taxa except for Arrow Goby were within the range of the estimates (0.062 – 0.104%) from the earlier report. These results verify the usefulness of the volumetric ETM model in the initial permitting efforts. As discussed in Steinbeck et al. (2016), the use of the volumetric model is especially applicable in locations, such as open coastal habitats, where the source water areas are relatively homogeneous. Therefore, it is encouraging to see that the model may be applicable even in source water areas with varied habitats such as Humboldt Bay. As expected, the model is more applicable for species such as Bay Goby ($P_M = 0.117$) and Pacific Staghorn Sculpin ($P_M = 0.096$) that are associated with a broader range of habitats than Arrow Goby (($P_M = 0.376$), which is more generally associated with mudflat habitats. The intakes are located in an area of the bay with large areas of mudflat habitats, which helps explain the higher estimate of P_M for Arrow Goby.

Although ETM estimates of P_M are typically used on projects in California to provide a basis for calculating mitigation (Raimondi 2011), the P_M also provides important information that should be used in the initial determination of whether the losses might be significant to the population and whether mitigation should be required for a project. The estimate of P_M provides the same type of information used by resource scientists in managing fisheries. Estimates of P_M are similar to estimates of the effects of fishing mortality on a population and, in this context, can be interpreted relative to other sources of mortality, except, in the case of P_M, the mortality due to entrainment is occurring to the population of larvae in the source water, and not an adult population that may include reproductive adults. In fact, one of the primary goals of fishery management is to have a good estimate of the proportional mortality due to fishing for individual fish stocks. This is often difficult due to the costs of obtaining good estimates of the stock of fish. The *PE* estimates of daily entrainment mortality in the ETM can also be compared directly to estimates of natural daily mortality This allows resource managers to determine if entrainment represent a large incremental increase in mortality compared to natural mortality rates. If estimates of instantaneous natural mortality (Ricker 1975) or natural variation in abundances for the larvae and adult populations are available, then these estimates provide additional context for interpreting the effects of P_M. ETM estimates of P_M that are sufficiently small compared to natural mortality or natural variation in larval population size provide evidence that the effects of entrainment are negligible and therefore compensation for entrainment losses is not necessary. All of the ETM estimates of P_M represent percentage losses to larval populations due to entrainment of less than 0.4% for all the taxa with an average loss of only 0.118%. Average annual larval fish abundances off the coast of California were shown to vary by as much as four orders of magnitude among years in a study by McClatchie et al. (2018). This large variation is likely due to differences in larval production and mortality among years due to changes in ocean conditions. Therefore, an additional source of mortality that averages only 0.118% is unlikely to have any significant effect on biological populations in the bay.

In considering impacts on source water populations of fishes it is also important to recognize that not all populations of fishes in Humboldt Bay will be susceptible to impacts from the intakes caused by entrainment or impingement. The intake design utilizes small slot openings (0.04 in. [1.0 mm]) and has a large enough surface area that velocities at the screen face are reduced to levels that should eliminate any effects of impingement. As a result, there are many fishes in Humboldt Bay that should not be affected by the intake. These groups include sharks and rays that either have large egg cases or give birth to small but fully formed juveniles that would not be subject to entrainment. Similar to sharks and rays, surfperches give birth to fully formed juveniles that are too large to be subject to entrainment. In the study of the fishes of Humboldt Bay by Gleason et al. (2007), sharks, rays and surfperch made up almost 16% of the total fishes collected including Shiner Surfperch that had the second highest abundance of the 67 species collected.

The only adjustment to the ETM analyses to account for the small size of the slot openings on the screens involved limiting the data used in the calculations to larvae less than approximately one inch (25 mm) NL. At power plants with intake screens that use larger square mesh with openings of 0.375 in. (9.5 mm), a larval NL of 1.2 in. (30 mm) is used as the upper limit of the larvae used in ETM assessments. Most fish larvae larger than approximately one inch (25 mm) NL are able to swim and avoid entrainment. Therefore, this was the upper NL limit of the larvae

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used in this assessment, because the two Humboldt Bay intakes are planned to use small slot openings of 0.04 in. (1.0 mm) and have very low velocities at the screen surface. The limits on the size of the larvae included in the analyses are difficult to implement in the field, so during the processing of the samples, larvae larger than one inch (25 mm) NL were identified as not entrainable and were not included in any of the data summaries or analyses in this report. Of the 1,044 larvae measured as part of the sample processing, only six larvae, all Surf Smelt, were larger than one inch (25 mm) NL. Only the larvae with NL less than one inch (25 mm) were included in the calculations of the larval periods of entrainment exposure. As discussed in the results for Pacific Staghorn Sculpin, the dimensions of the larvae at the length of the 95th quantile (0.35 in. [8.9 mm]) used in calculating the larval period of exposure are close to the 0.04 in. (1.0 mm) width of the slot openings on the intakes (**Table 5-1**). Therefore, the ETM estimates of P_M for this species are conservative since some percentage of the larger larvae for this species would not pass through the intakes. The estimates of the reductions due to the WWS for each of the seven taxa are presented in the next section.

The same allometric regression model used in the analysis of head capsule height and width shown in **Figure 5-1** for Pacific Staghorn Sculpin larvae measured during the study was also used for the other species analyzed using the ETM. These analyses were used to estimate the proportion of the larvae at different lengths that would be entrained through the small WWS slot openings (0.04 in. [1.0 mm]) planned to be used at the two intakes. The analyses of the projected efficiency of the WWS for the fish taxa analyzed for the study are provided in the next section.

6.1.1 Estimated Wedgewire Screen Efficiency

The potential for WWS systems, such as the modules proposed for the two Humboldt Bay intakes, to reduce the effects of entrainment of larval fishes has been investigated using field (Ehrler and Raifsnider 2000, Weisberg et al. 1987) and laboratory (EPRI 2003, Amaral 2005) studies. Ehrler and Raifsnider (2000) undertook a field evaluation of WWS technology on the Delaware River which indicated an approximate 50% reduction in total annual entrainment of striped bass larvae with the use of 0.04 in. (1.0 mm) WWS. Field studies by Weisberg et al. (1987) using WWS with slot sizes of 0.04, 0.08, and 0.12 in. (1, 2, and 3 mm) detected statistically significant reductions for Bay Anchovy (*Anchoa mitchilli*) larvae longer than 0.43 in. (11 mm) and Naked Goby (*Gobiosoma bosci*) larvae longer than 0.28 in. (7 mm). Amaral (2005) used laboratory flume studies to estimate the combined entrainment and impingement reductions due to cylindrical WWS modules with three slot sizes (0.02, 0.04, and 0.08 in. [0.5, 1.0, and 2.0 mm]) and compared these to the results with an unscreened intake. Larvae from eight species of fish were used to estimate entrainment and impingement of species across a range of life histories and swimming capabilities (Striped Bass [*Morone saxatilis*], Winter Flounder [*Pleuronectes americanus*], Yellow Perch [*Perca flavescens*], Rainbow Smelt [*Osmerus mordax*], Common Carp [*Cyprinus carpio*], White Sucker [*Catostomus commersoni*], Alewife [*Alosa pseudoharengus*], and Bluegill [*Lepomis macrochirus*]). Testing at different channel and through-screen velocities showed significant reductions in combined impingement and entrainment at all screen conditions (slot size and through-screen velocity) relative to the un-screened alternative.

The results from studies by Amaral (2005) and Weisberg et al. (1987) concluded that the exclusion efficiency of WWS is highly dependent on the interaction between the length of the organisms exposed to entrainment and the WWS slot size. The length and overall morphology of the organisms exposed to entrainment may vary between WWS locations and times of the year because of differences in the species of larval fish present throughout the year and between locations.

Although previous studies on the effectiveness of WWS at reducing entrainment have focused on fish length (Weisberg et al. 1987, Amaral 2005), there has also been a general recognition that larval morphology, and not just length, is important in estimating the effectiveness of different screen openings at reducing entrainment (Schneeburger and Jude 1981, EPRI 2005). Normandeau (2009) used a metric called "greatest body depth" (GBD) to model WWS entrainment benefits, where GBD is defined as either the thickness of the head or the deepest part of the body. While the body depth of fish larvae has been measured and used in estimating the potential effectiveness of different screen openings at reducing entrainment (Schneeburger and Jude 1981, Normandeau 2009), Bell (1973) also pointed out that larvae are prevented from passing through a screen based on the dimensions of the head capsule, which in larval fishes is the only part of the body that is not easily compressed.

A recent review on the effectiveness of cylindrical screening systems at reducing entrainment of fishes by Coutant (2020) presents several examples and reasons why the reductions by the systems exceed the expected levels based on screen size and larval dimensions. Coutant (2020) discusses the design of cylindrical intake screen systems and the features that help reduce entrainment. These features include the cylindrical shape of the intakes, their alignment relative to existing tidal or river currents, and their low through-screen velocities. In a summary of lab studies on entrainment by cylindrical WWS, similar to the design proposed for the Humboldt Bay intakes, Coutant (2020) concludes that the contribution of screen-size opening, and through-screen velocity was a minor factor in the reduction in entrainment. The major factor was the cylindrical design of the intake and its orientation parallel to ambient current which creates a bow wave and the resulting flow dynamics help move larvae and other objects away from the screen surface where they may be subject to entrainment. The increased turbulence probably decreased the likelihood that larvae would be oriented exactly parallel to the screen slots where they could be more easily entrained. Although not as large a factor as the cylindrical design of the screen, sweeping currents along the screen surface that far exceed through-screen velocities also made entrainment unlikely. Therefore, entrainment loss estimates solely on larval size are likely to be highly conservative especially due to the proposed placement of the intake screens in an area of Humboldt Bay where they will be subject to strong sweeping velocities on ebb and flood tides.

Unfortunately, most of the taxa used in the analysis of screen efficiency in Tenera (2011) did not occur in large enough abundance during the Humboldt Bay study to allow for comparison except for gobies. Most of the data used in Tenera (2011) were from locations in central and southern California which is outside of the range where species of smelt and Pacific Tomcod found in Humboldt Bay are abundant. Therefore, the comparison with the data from this study is limited to gobies.

A pilot study on the efficiency of WWS modules at reducing entrainment for California coastal fishes was conducted for a planned desalination project to be placed offshore of Santa Cruz, California (Tenera 2010). A series of tests were conducted using a small WWS module using a slot width of 0.08 in. (2 mm) with a through-screen velocity of 0.3 fps. Although not statistically significant due to highly variable results, a reduction of nearly 20% in total entrainment of all fish larvae was calculated between samples collected through the WWS module relative to an unscreened intake. The two intakes were placed below a pier and therefore did not benefit from the hydrodynamic flushing described by Coutant (2020) that would also benefit the WWS modules used for the Humboldt intakes due to the presence of strong tidal currents at the intake locations.

The same allometric regression model used in the analysis of notochord length and head capsule dimensions in Tenera (2011) was used in the regressions using the NL and head capsule measurements from the data collected during this study that are shown in **Figure 6-1** and **Figure 6-2**. The same plot and regressions for the Pacific Staghorn Sculpin head capsule dimensions are shown in **Figure 5-1**. The regression parameters were used to estimate the probabilities of entrainment and are presented in **Table 6-1**. The entrainment probabilities were calculated out to a length of 25 mm over the range of NL measurements available for each of the seven taxa.

The probabilities across the size range of entrainable larvae for a taxon can be used to assess the effects on population mortality when using a particular WWS slot width for reducing the entrainment of larvae. Two simple assumptions to calculate the reduction of mortality are: 1) linear growth over time; and 2) constant exponential natural mortality. These assumptions are reasonable because the period of time that the larvae are vulnerable to being entrained is likely to be very short. The period of time may only be a few days for fishes that are only subject to entrainment over a narrow size range, but for other fishes the period of time would likely never extend beyond one or two months. By assuming linear growth, length becomes directly proportional to age. As a larval cohort progresses through consecutive length classes it follows an exponential decrease in numbers over time due to natural mortality. Under these assumptions, each length (or age) would produce the same number of fishes at a length when they are not subject to entrainment. A first approximation of the reduction in entrainment for each screen mesh dimension can be made by averaging the length-specific entrainment probabilities. The inverse of this proportion ($1 - p$; where p is the average length-specific entrainment probability) determines the reduction of mortality due to the screen for the total cohort of larvae that would survive to the length or age when they are no longer subject to entrainment. The average reduction in mortality would need to be adjusted for the composition and size structure of the fish larvae for a specific location and sample year, but otherwise it provides an estimate of the population-level mortality identical to an adult equivalent model using constant growth and survival rates extrapolated to the length or age that the fish are no longer subject to entrainment (estimated to be 0.79–0.98 in. [20–25 mm] NL for this analysis). Fishes larger than this NL have swimming abilities that allow them to potentially avoid entrainment, especially at the reduced intake velocities that will occur at the Humboldt Bay intakes.

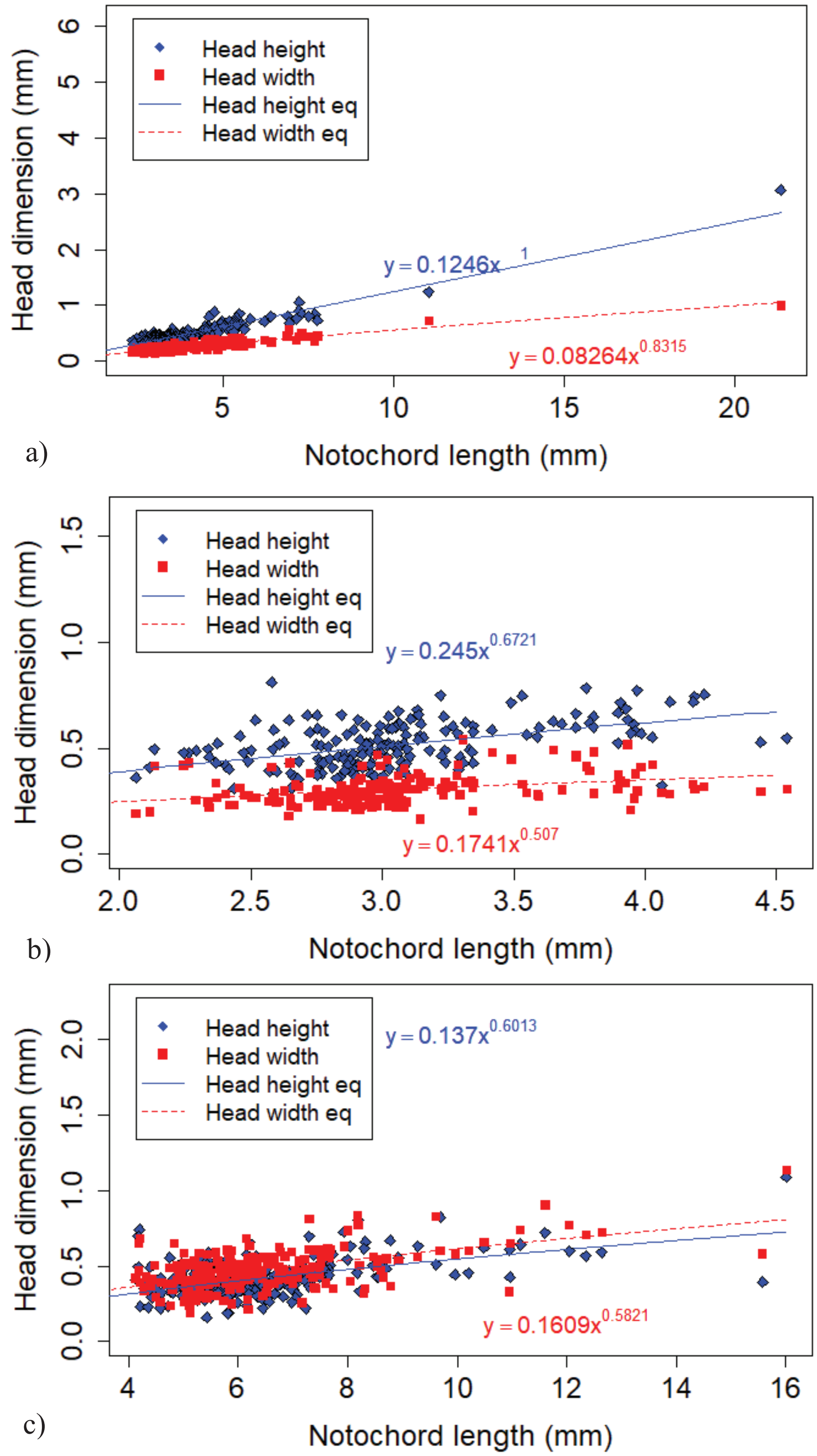

Figure 6-1. Plots of head capsule height and width against notochord length for a) Arrow Goby, b) Bay Goby, and c) Whitebait Smelt. The allometric regression equations are shown on the graphs.

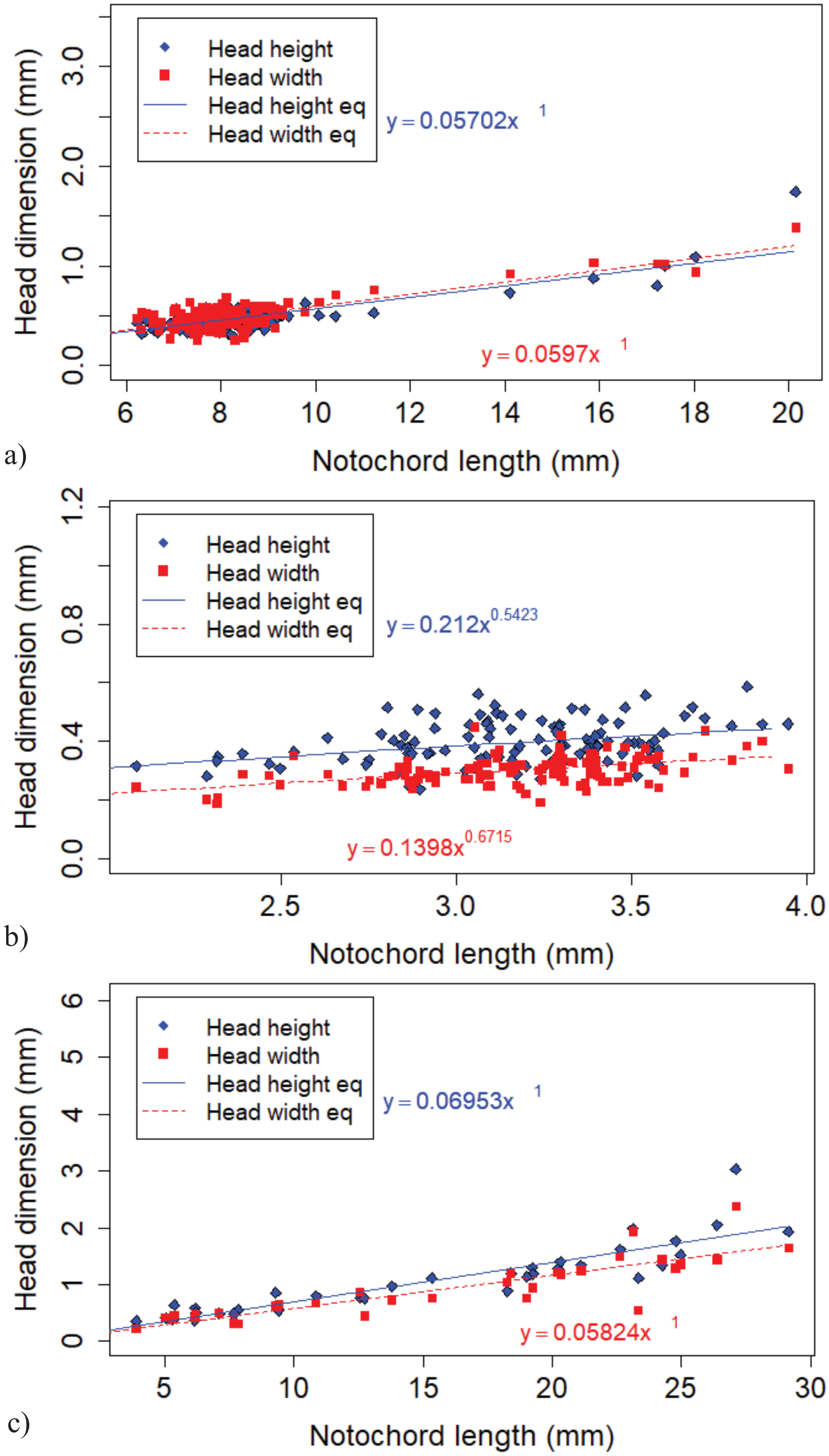

Figure 6-2. Plots of head capsule height and width against notochord length for a) Pacific Herring, b) Pacific Tomcod, and c) Surf Smelt. The allometric regression equations are shown on the graphs.

Table 6-1. Estimated probabilities of entrainment for fish larvae analyzed for the Humboldt Bay entrainment study at mm NL intervals from estimated hatch NL through 25 mm for a wedgewire slot size of 0.04 in. (1 mm) using estimates of variability around the allometric regressions shown in **Figure 5-1**, **Figure 6-1**, and **Figure 6-2**. Average proportion entrained of fishes from hatch length to 25 mm, and subsequent mortality reduction (the inverse of average proportion entrained) are also shown.

NL Length (mm)	Arrow Goby	Bay Goby	Whitebait Smelt	Pacific Herring	Pacific Tomcod	Surf Smelt	Pacific Staghorn Sculpin
3	1.0000	1.0000			1.0000		
4	1.0000	1.0000			1.0000	1.0000	1.0000
5	1.0000	1.0000	1.0000		0.9999	0.9997	0.9996
6	1.0000	0.9999	1.0000	1.0000	0.9985	0.9967	0.9888
7	1.0000	0.9994	1.0000	1.0000	0.9918	0.9866	0.9320
8	1.0000	0.9975	1.0000	1.0000	0.9757	0.9658	0.8017
9	1.0000	0.9933	1.0000	1.0000	0.9492	0.9320	0.6334
10	1.0000	0.9854	0.9998	1.0000	0.9095	0.8823	0.4387
11	1.0000	0.9718	0.9995	0.9988	0.8666	0.8333	0.3002
12	1.0000	0.9576	0.9976	0.9916	0.8186	0.7769	0.2025
13	1.0000	0.9364	0.9936	0.9662	0.7672	0.7217	0.1316
14	1.0000	0.9160	0.9861	0.9149	0.7176	0.6757	0.0848
15	0.9999	0.8891	0.9730	0.8257	0.6676	0.6239	0.0571
16	0.9984	0.8662	0.9540	0.7107	0.6213	0.5757	0.0363
17	0.9837	0.8365	0.9299	0.5843	0.5803	0.5321	0.0241
18	0.9109	0.8110	0.8990	0.4575	0.5376	0.4952	0.0154
19	0.7588	0.7854	0.8644	0.3432	0.5007	0.4602	0.0112
20	0.5140	0.7574	0.8282	0.2439	0.4655	0.4247	0.0072
21	0.2911	0.7298	0.7835	0.1732	0.4325	0.3985	0.0048
22	0.1313	0.7051	0.7393	0.1236	0.4080	0.3731	0.0034
23	0.0486	0.6773	0.6949	0.0804	0.3955	0.3443	0.0025
24	0.0164	0.6559	0.6494	0.0548	0.3755	0.3236	0.0019
25	0.0047	0.6337	0.6006	0.0363	0.3610	0.3030	0.0012
Average	0.7357	0.8377	0.7872	0.5210	0.6808	0.6094	0.2783
Mortality Reduction	0.2643	0.1623	0.2128	0.4790	0.3192	0.3906	0.7217

The problems of calculating the probabilities of entrainment with the limited range of larvae collected during the sampling in Humboldt Bay is shown by comparing the results presented in the Initial ETM Assessment for goby larvae from Tenera (2011) with the results from this study. The probabilities calculated using the data from the allometric regressions presented in the Initial ETM Assessment for goby larvae indicate that no larvae with a NL larger than 0.52 in. (13 mm) would be entrained through a screen with a slot opening of 0.04 in. (1.0 mm) (Table 5-3 in Tenera [2021]). This was due to a pronounced increase in the allometric growth of goby larvae that starts at a NL of approximately 0.28 in. (7 mm). Unfortunately, all the Arrow Goby and Bay

Goby collected during the present study were too small to exhibit this increase in growth rate. Therefore, while the results for Arrow Goby and Bay Goby indicate that larvae are still susceptible to entrainment at a NL of 0.98 in. (25 mm) (**Table 6-1**), it is more likely that the larvae are too large at this NL to be entrained based on the results from the Initial ETM Assessment.

Even with the limitations on the analysis of WWS efficiency due to the small size range of larvae collected which results in conservative estimates, the results in **Table 6-1** indicate large reductions in mortality for Pacific Herring and Pacific Staghorn Sculpin. It is also important to recognize that these probabilities are based on the conservative assumption that larvae close to the screen are orientated so that the only factor limiting entrainment is the head capsule dimension. Therefore, the probabilities in **Table 6-1** represent extremely conservative estimates of the potential effectiveness of WWS. The average reduction from the seven taxa is 38% which is almost twice the reduction in entrainment measured in testing of WWS modules associated with the study in Santa Cruz previously mentioned. Similar to the estimates in **Table 6-1**, the estimated reduction from the Santa Cruz study did not incorporate any of the hydrodynamic benefits of the WWS modules discussed by Coutant (2020).

In reality, observations show that properly designed WWS intake systems, similar to the system proposed for Humboldt Bay, likely far exceed the theoretical entrainment performance estimated based on head capsule dimensions. Video cameras installed on a WWS intake system for a pilot desalination project in southern California showed that small, entrainable, early post larval fishes were able to swim away from the screen if they drifted too close or made screen contact even when the intake system was operating, thereby avoiding entrainment or impingement (Tenera 2014b) (**Figure 6-3**). The intake system for this project was designed with a maximum through-slot velocity of 0.33 ft/sec (10 cm/sec), which is higher than the low design approach velocity of 0.2 ft/sec (6 cm/sec) of the proposed project screens. Therefore, the actual effectiveness of the screens proposed for the Humboldt Bay project assessed here should exceed the estimates based solely on head capsule dimensions.

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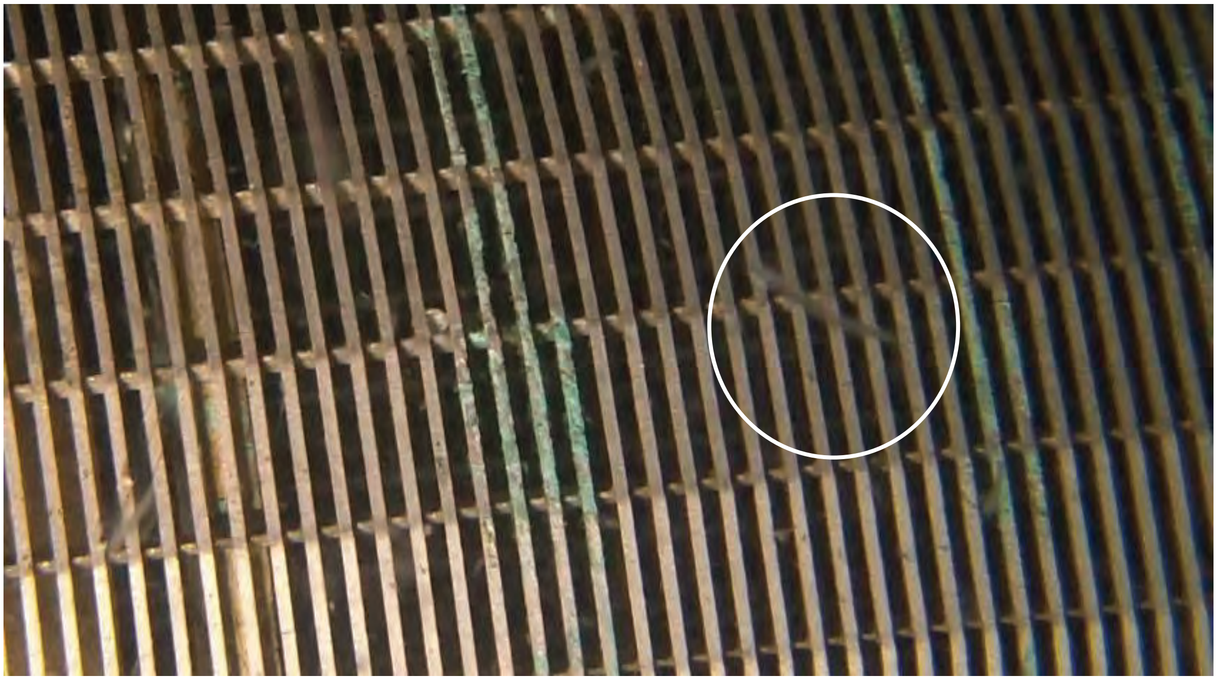

Figure 6-3. Video frame grab of the 2 mm screen taken in January 2012 during wedgewire screen efficiency study for the West Basin Water District with the pump operating (Tenera 2014b). Frame shows the early post-larval fish swimming along horizontal to the screen.

6.2 Conclusions

The results of the ETM assessment indicate an average loss of 0.118% of the source water population due to entrainment and a highest loss by taxa of less than 0.4% (**Table 5-9**). This is the ETM estimate of P_M, which represents the loss caused by entrainment to the population subject to entrainment. The average loss is similar to the results for the taxa analyzed in the Initial ETM Assessment using the same source water model used for the ETM analyses in this report. Those estimates of P_M varied from 0.062% to 0.104% depending on the periods of larval exposure to entrainment used in the calculations (**Table 3-1**). The comparison of the results verifies the usefulness of the volumetric ETM model in initial permitting efforts. With natural variation in the abundance of larval fish populations in the nearshore waters off California among years of up to four orders of magnitude (McClatchie et al. 2018), an additional source of mortality due to entrainment by the two Humboldt Bay intakes that averages only 0.118% would not be expected to have any effect on the health of the fish populations in the bay.

It is important to remember that this estimated level of mortality is extremely conservative because it does not consider the design of the intake system with WWS modules with 0.04 in. (1.0 mm) slot openings. The small slot opening excludes larger fish larvae and invertebrate larvae such as crab megalops. The WWS modules are also designed to maintain a through-slot velocity at the intake surface of 0.2 fps (6 cm/s), which is NMFS criteria for protection of salmonids (NMFS 2011). Tenera has conducted studies that show that many larger fish larvae are able to swim against such currents as shown in **Figure 6-3**. Also, research by Coutant (2020) discusses the design of cylindrical intake screen systems and the features that help reduce entrainment for cylindrical WWS modules beyond the features of the slot opening and low velocity. These features include the cylindrical shape of the intakes and their alignment relative to existing tidal or river currents that creates a bow wave and resulting flow dynamics that help move larvae and other objects away from the screen surface where they may be subject to entrainment. Coutant concludes that the increased turbulence decreases the likelihood that larvae would be oriented exactly parallel to the screen slots where they could be more easily entrained. The design of the intakes, under normal operations, also eliminates any effects of impingement, and effects on fishes (e.g., sharks and perches) and other organisms that do not have life stages subject to entrainment.

The factors discussed by Coutant (2000) are not considered in the calculation of the potential effectiveness of WWS modules with 0.04 in. (1.0 mm) slot openings at reducing entrainment discussed in earlier in this section. This analysis was limited by the size range of the larvae collected during the study, but even with those limitations, the average reduction in mortality resulting from the addition of the WWS technology was as high as 72% for Pacific Staghorn Sculpin and 48% for Pacific Herring across the size range of larvae subject to entrainment for the seven taxa analyzed (**Table 6-1**). It is also important to recognize that these probabilities are based on the conservative assumption that larvae near the screen would be orientated such that the only factor limiting entrainment is the head capsule dimension. The average reduction in entrainment mortality just due to the WWS was 38%, which would reduce the average ETM estimate of P_M of 0.118% in **Table 5-9** to 0.073%. The bow wave created by the WWS module and the low approach velocity that allows many larvae to avoid the screen are not considered in these ETM estimates.

All of these factors indicate that the effects of the ETM assessment indicating an average entrainment loss of only 0.118% (**Table 5-9**) for the seven taxa is conservative since the model assumes that the estimated concentration of larvae at the station are entrained. None of the other factors discussed above that would result in further reductions in entrainment have been included in the calculations of estimated entrainment mortality presented here. The factors contributing to the conservative nature of the average ETM estimate of P_M of 0.118% (**Table 5-9**) include the following:

- The effectiveness of the WWS modules with 0.04 in. (1.0 mm) slot openings at reducing entrainment, which is estimated to average 38% for the seven taxa analyzed;
- The estimated effectiveness is based on the head capsule dimensions of the larvae which assumes that larvae near the screen would be orientated such that the only factor limiting entrainment are the head capsule dimensions;
- The effect of a reduction in entrainment would reduce the maximum length of the larvae entrained and would reduce the larval durations for the taxa used in the calculation of the ETM estimate of P_M for each taxon; and
- The effectiveness of the design of the shape and orientation of the WWS screen modules at reducing entrainment described by Coutant (2020). These design features have the potential to greatly reduce entrainment especially during periods with strong flood and ebb tidal currents.

The APF estimate to compensate for the entrainment losses is estimated at 17.9 acres (7.2 hectares) (**Table 5-9**). The conservative assumptions used in the ETM estimates listed above indicate that the APF estimate based on the average ETM estimate of P_M of 0.118% is also conservative and should fully compensate for the small estimated losses to source water populations. As described in Appendix E of the Final Substitute Documentation for the 2015 California Desalination Amendment to the Ocean Plan,[16] the average ETM and APF estimates from a study can be used to estimate not only the effects of entrainment on the taxa analyzed, but also all of the planktonic organisms subject to entrainment in the source water. Most of these other organisms would likely be more uniformly distributed throughout the source water, because unlike many fishes, there are no specific habitats associated with the reproduction of phytoplankton and most zooplankton. Therefore, the volumetric model would be appropriate for estimating impacts to these components of the plankton community. The fact that the average estimated entrainment mortality is slightly higher than the estimated volumetric loss provides some assurance that the APF estimate of 17.9 acres (7.2 hectares) would fully compensate for not only the estimated losses to the seven taxa, but all entrained organisms and any effects on salmonids and other species of concern due to reductions in prey.

An initial estimate of APF was provided for the District in Appendix N of the Draft EIR[17] for the project that was based on the results of the Initial ETM Assessment prepared by Tenera (2021) (Appendix P of the Draft EIR). The APF estimate of 10.4 acres (4.2 hectares) in Appendix N was based on a source water area of 10,000 acres (4,047 hectares) and was intended to be used as an example of how APF was calculated. The source water area based on the data in Swanson (2015) that was used in the APF calculations in the Initial ETM Assessment and in this report was 15,104 acres (6,112 hectares). Therefore, the corrected APF from the Initial ETM Assessment would be 15.7 acres (6.3 hectares), which, as expected, is very close to the APF estimate of 17.9 acres (7.2 hectares) in this report. Using the same 4:1 ratio proposed in Appendix N, an area of piling removal equivalent to 4.5 acres (1.8 hectares) would fully compensate for the losses to marine resources resulting from entrainment at the two intakes.

An implicit assumption in the application of APF as a form of compensatory mitigation is that the entrainment losses calculated by an ETM (i.e. P_M) directly relate to population losses. This assumption may be invalid, because density-dependent factors are almost certain to affect, and may entirely decouple, the relationship between larval population size in Humboldt Bay and subsequent adult spawning stock size. Density-dependent processes are factors that determine population size that are correlated with the 'density' of the population. A classic example is habitat availability; for example, if a species of fish requires kelp habitat as an adult and there is relatively small amounts of kelp habitat and many larval rockfish ready to develop into the adult

[16] Final Staff Report Including the Final Substitute Environmental Documentation for California State Water Resources Control Board Resolution 2015-0033: Amendment to the Statewide Water Quality Control Plan for the Ocean Waters of California Addressing Desalination Facility Intakes, Brine Discharges, and to Incorporate other Nonsubstantive Changes. Adopted May 6, 2015.

[17] Appendix N of Draft EIR Prepared by GHD for the County of Humboldt Planning Department. Humboldt Bay Piling Removal Restoration for Longfin Smelt and other Marine Resources. December 13, 2021. Prepared by Tenera Environmental Inc., San Luis Obispo, CA Tenera Document SLO2021-019.

stage, the number of adult rockfish the following year will be limited by the availability of kelp habitat, not the number of larval rockfish. Therefore, if some proportion of those larval rockfish are entrained into an intake before they can develop into adults and inhabit a local kelp forest, the entrainment proportion will have no bearing on the number of adults that occur in the kelp forest. However, it is state policy that the estimate of proportional mortality from an ETM be used to estimate an APF acreage prior to permit issuance. This calculation of APF ignores any consideration of density-dependent processes. On this basis, ETM and APF are highly conservative entrainment impact assessment approaches.

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Appendix A

Sample Data and Information

This appendix presents tables of the numbers and taxonomic identification of all the organisms collected during the sampling for the Humboldt Bay Intake Assessment study conducted from January through December 2022. Information on each sample includes the sample date of each survey, the sample number, sample volume in m^3, and the split multiplier that identifies what fraction of the original sample the count recorded for each taxa represent. The adjusted count in the table is the estimated count for the entire sample volume after adjusting for the sample split. The concentration in numbers per 1,000 m^3 for the entire sample volume is also presented.

Survey: HuB001 Start Date: 01/11/2022

Cycle: 1	Sample: 1	Station: SW1		
Split Multiplier: 1	Volume: 81.92			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
<u>Entrainable Larval Fishes</u>				
Leptocottus armatus	Pacific staghorn sculpin	3	3	36.62
Lepidogobius lepidus	bay goby	1	1	12.21
Spirinchus thaleichthys	longfin smelt	1	1	12.21
<u>Fish Eggs</u>				
non-engraulidae eggs	non-engraulidae eggs	12	12	146.52

Cycle: 1	Sample: 2	Station: SW2		
Split Multiplier: 1	Volume: 128.87			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
<u>Entrainable Larval Fishes</u>				
Leptocottus armatus	Pacific staghorn sculpin	6	6	46.56
Allosmerus elongatus	whitebait smelt	2	2	15.52
Lepidogobius lepidus	bay goby	1	1	7.76
Oligocottus/Clinocottus spp.	sculpins	1	1	7.76
<u>Fish Fragments</u>				
Leptocottus armatus	Pacific staghorn sculpin	1	1	7.76
<u>Fish Eggs</u>				
non-engraulidae eggs	non-engraulidae eggs	9	9	69.84

Cycle: 1	Sample: 3	Station: E2		
Split Multiplier: 1	Volume: 104.52			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
<u>Entrainable Larval Fishes</u>				
Leptocottus armatus	Pacific staghorn sculpin	5	5	47.84
Sebastes spp. V_	KGB rockfish larval complex	2	2	19.13
Allosmerus elongatus	whitebait smelt	1	1	9.57
Lepidogobius lepidus	bay goby	1	1	9.57
<u>Fish Eggs</u>				
non-engraulidae eggs	non-engraulidae eggs	6	6	57.40

Cycle: 1	Sample: 4	Station: E1		
Split Multiplier: 1	Volume: 80.03			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
<u>Entrainable Larval Fishes</u>				
Leptocottus armatus	Pacific staghorn sculpin	2	2	24.99
<u>Fish Eggs</u>				
non-engraulidae eggs	non-engraulidae eggs	9	9	112.45

(continued)

Survey: HuB001 (continued) Start Date: 01/11/2022

Cycle: 1	Sample: 5	Station: SW3		
Split Multiplier: 1	Volume: 81.68			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Leptocottus armatus	Pacific staghorn sculpin	2	2	24.48
Microgadus proximus	Pacific tomcod	2	2	24.48
Allosmerus elongatus	whitebait smelt	1	1	12.24
Lepidogobius lepidus	bay goby	1	1	12.24
Spirinchus thaleichthys	longfin smelt	1	1	12.24
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	6	6	73.45

Cycle: 1	Sample: 6	Station: SW5		
Split Multiplier: 1	Volume: 82.54			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	13	13	157.51
Allosmerus elongatus	whitebait smelt	4	4	48.46
Leptocottus armatus	Pacific staghorn sculpin	2	2	24.23
Microgadus proximus	Pacific tomcod	1	1	12.12
Spirinchus thaleichthys	longfin smelt	1	1	12.12
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	2	2	24.23

Cycle: 1	Sample: 7	Station: SW4		
Split Multiplier: 1	Volume: 80.61			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	7	7	86.83
Leptocottus armatus	Pacific staghorn sculpin	2	2	24.81
Microgadus proximus	Pacific tomcod	2	2	24.81
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	9	9	111.64

Cycle: 1	Sample: 8	Station: SW6		
Split Multiplier: 1	Volume: 83.91			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	1	1	11.92
Leptocottus armatus	Pacific staghorn sculpin	1	1	11.92
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	2	2	23.83

(continued)

Survey: HuB001 (continued) Start Date: 01/11/2022

Cycle: 2	Sample: 9	Station: SW1		
Split Multiplier: 1	Volume: 79.61			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Leptocottus armatus	Pacific staghorn sculpin	5	5	62.80
Artedius spp.	sculpins	2	2	25.12
larvae, yolksac	yolksac larvae	1	1	12.56
Liparis spp.	snailfishes	1	1	12.56
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	7	7	87.92

Cycle: 2	Sample: 10	Station: SW2		
Split Multiplier: 1	Volume: 93.89			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Leptocottus armatus	Pacific staghorn sculpin	2	2	21.30
Allosmerus elongatus	whitebait smelt	1	1	10.65
Sebastes spp. V_	KGB rockfish larval complex	1	1	10.65
Spirinchus thaleichthys	longfin smelt	1	1	10.65
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	5	5	53.25

Cycle: 2	Sample: 11	Station: E2		
Split Multiplier: 1	Volume: 156.01			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Leptocottus armatus	Pacific staghorn sculpin	7	7	44.87
Lepidogobius lepidus	bay goby	3	3	19.23
Allosmerus elongatus	whitebait smelt	2	2	12.82
Microgadus proximus	Pacific tomcod	1	1	6.41
Sebastes spp. V_	KGB rockfish larval complex	1	1	6.41
Spirinchus thaleichthys	longfin smelt	1	1	6.41
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	16	16	102.56

(continued)

Survey: HuB001 (continued)

Start Date: 01/11/2022

Cycle: 2	Sample: 12	Station: E1		
Split Multiplier: 1	Volume: 118.68			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
<u>Entrainable Larval Fishes</u>				
Microgadus proximus	Pacific tomcod	23	23	193.80
Leptocottus armatus	Pacific staghorn sculpin	10	10	84.26
Allosmerus elongatus	whitebait smelt	9	9	75.83
Spirinchus thaleichthys	longfin smelt	5	5	42.13
Lepidogobius lepidus	bay goby	3	3	25.28
Osmeridae	smelts	1	1	8.43
<u>Fish Fragments</u>				
larval fish fragment	larval fish fragments	1	1	8.43
<u>Fish Eggs</u>				
non-engraulidae eggs	non-engraulidae eggs	6	6	50.56

Cycle: 2	Sample: 13	Station: SW3		
Split Multiplier: 1	Volume: 95.92			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
<u>Entrainable Larval Fishes</u>				
Microgadus proximus	Pacific tomcod	39	39	406.57
Allosmerus elongatus	whitebait smelt	6	6	62.55
Lepidogobius lepidus	bay goby	5	5	52.12
Leptocottus armatus	Pacific staghorn sculpin	3	3	31.27
larvae, yolksac	yolksac larvae	2	2	20.85
Bathymasteridae	ronquils	1	1	10.42
Oligocottus/Clinocottus spp.	sculpins	1	1	10.42
<u>Fish Fragments</u>				
larval fish fragment	larval fish fragments	1	1	10.42
<u>Fish Eggs</u>				
non-engraulidae eggs	non-engraulidae eggs	5	5	52.12

Survey: HuB002 | Start Date: 02/10/2022

Cycle: 1	Sample: 1	Station: SW1		
Split Multiplier: 1	Volume: 107.88			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clupea pallasii	Pacific herring	6	6	55.62
Ammodytes hexapterus	Pacific sand lance	2	2	18.54
Leptocottus armatus	Pacific staghorn sculpin	1	1	9.27
Oligocottus/Clinocottus spp.	sculpins	1	1	9.27
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	27	27	250.27

Cycle: 1	Sample: 2	Station: SW2		
Split Multiplier: 1	Volume: 105.54			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Leptocottus armatus	Pacific staghorn sculpin	6	6	56.85
Lepidogobius lepidus	bay goby	2	2	18.95
Ammodytes hexapterus	Pacific sand lance	1	1	9.47
Clupea pallasii	Pacific herring	1	1	9.47
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	76	76	720.09

Cycle: 1	Sample: 3	Station: E2		
Split Multiplier: 1	Volume: 118.12			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Ammodytes hexapterus	Pacific sand lance	4	4	33.86
Leptocottus armatus	Pacific staghorn sculpin	2	2	16.93
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	24	24	203.18

Cycle: 1	Sample: 4	Station: E1		
Split Multiplier: 1	Volume: 80.61			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Ammodytes hexapterus	Pacific sand lance	3	3	37.22
Leptocottus armatus	Pacific staghorn sculpin	3	3	37.22
Clupea pallasii	Pacific herring	2	2	24.81
Oligocottus/Clinocottus spp.	sculpins	1	1	12.41
Pholidae	gunnels	1	1	12.41
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	14	14	173.68

(continued)

Survey: HuB002 (continued) Start Date: 02/10/2022

Cycle: 1	Sample: 5	Station: SW3		
Split Multiplier: 1	Volume: 102.33			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Ammodytes hexapterus	Pacific sand lance	3	3	29.32
Lepidogobius lepidus	bay goby	2	2	19.55
Oligocottus/Clinocottus spp.	sculpins	2	2	19.55
Allosmerus elongatus	whitebait smelt	1	1	9.77
Clupea pallasii	Pacific herring	1	1	9.77
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	33	33	322.50

Cycle: 1	Sample: 6	Station: SW4		
Split Multiplier: 1	Volume: 81.46			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Ammodytes hexapterus	Pacific sand lance	9	9	110.48
Allosmerus elongatus	whitebait smelt	5	5	61.38
Leptocottus armatus	Pacific staghorn sculpin	2	2	24.55
Artedius spp.	sculpins	1	1	12.28
larvae, yolksac	yolksac larvae	1	1	12.28
Sebastes spp. V	blue rockfish larval complex	1	1	12.28
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	16	16	196.40

Cycle: 1	Sample: 7	Station: SW5		
Split Multiplier: 1	Volume: 94.08			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Leptocottus armatus	Pacific staghorn sculpin	3	3	31.89
Ammodytes hexapterus	Pacific sand lance	1	1	10.63
Artedius spp.	sculpins	1	1	10.63
Lepidogobius lepidus	bay goby	1	1	10.63
Parophrys vetulus	English sole	1	1	10.63
Pholidae	gunnels	1	1	10.63
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	30	30	318.87

(continued)

Survey: HuB002 (continued) Start Date: 02/10/2022

Cycle: 1	Sample: 8	Station: SW6		
Split Multiplier: 1	Volume: 82.05			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Leptocottus armatus	Pacific staghorn sculpin	6	6	73.13
Clupea pallasii	Pacific herring	4	4	48.75
Allosmerus elongatus	whitebait smelt	1	1	12.19
Clevelandia ios	arrow goby	1	1	12.19
larvae, yolksac	yolksac larvae	1	1	12.19
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	6	6	73.13

Cycle: 2	Sample: 9	Station: SW1		
Split Multiplier: 1	Volume: 125.69			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clupea pallasii	Pacific herring	10	10	79.56
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	12	12	95.47

Cycle: 2	Sample: 10	Station: SW2		
Split Multiplier: 1	Volume: 119.45			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clupea pallasii	Pacific herring	25	25	209.29
Allosmerus elongatus	whitebait smelt	1	1	8.37
Ammodytes hexapterus	Pacific sand lance	1	1	8.37
Leptocottus armatus	Pacific staghorn sculpin	1	1	8.37
Oligocottus/Clinocottus spp.	sculpins	1	1	8.37
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	8	8	66.97

(continued)

Survey: HuB002 (continued) Start Date: 02/10/2022

Cycle: 2	Sample: 11	Station: E2		
Split Multiplier: 1	Volume: 98.40			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clupea pallasii	Pacific herring	8	8	81.30
Leptocottus armatus	Pacific staghorn sculpin	3	3	30.49
Oligocottus/Clinocottus spp.	sculpins	3	3	30.49
Ammodytes hexapterus	Pacific sand lance	2	2	20.33
Allosmerus elongatus	whitebait smelt	1	1	10.16
Artedius spp.	sculpins	1	1	10.16
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	4	4	40.65

Cycle: 2	Sample: 12	Station: E1		
Split Multiplier: 1	Volume: 97.74			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Ammodytes hexapterus	Pacific sand lance	7	7	71.62
Clupea pallasii	Pacific herring	3	3	30.70
Microgadus proximus	Pacific tomcod	3	3	30.70
Parophrys vetulus	English sole	2	2	20.46
Allosmerus elongatus	whitebait smelt	1	1	10.23
larvae, yolksac	yolksac larvae	1	1	10.23
Liparis spp.	snailfishes	1	1	10.23
Oligocottus/Clinocottus spp.	sculpins	1	1	10.23
Spirinchus thaleichthys	longfin smelt	1	1	10.23
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	8	8	81.85

Cycle: 2	Sample: 13	Station: SW3		
Split Multiplier: 1	Volume: 132.22			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Ammodytes hexapterus	Pacific sand lance	9	9	68.07
Leptocottus armatus	Pacific staghorn sculpin	6	6	45.38
Microgadus proximus	Pacific tomcod	3	3	22.69
Artedius spp.	sculpins	1	1	7.56
Citharichthys stigmaeus	speckled sanddab	1	1	7.56
Clupea pallasii	Pacific herring	1	1	7.56
larval fish - damaged	damaged larval fishes	1	1	7.56
Parophrys vetulus	English sole	1	1	7.56
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	7	7	52.94

(continued)

Survey: HuB002 (continued) | Start Date: 02/10/2022

Cycle: 2	Sample: 14	Station: SW4		
Split Multiplier: 1	Volume: 103.85			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Atherinops affinis	topsmelt	10	10	96.29
Microgadus proximus	Pacific tomcod	6	6	57.77
Ammodytes hexapterus	Pacific sand lance	1	1	9.63
Artedius spp.	sculpins	1	1	9.63
Lipolagus ochotensis	popeye blacksmelt	1	1	9.63
Tarletonbeania crenularis	blue lanternfish	1	1	9.63
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	7	7	67.40

Cycle: 2	Sample: 15	Station: SW5		
Split Multiplier: 1	Volume: 87.71			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	5	5	57.00
Ammodytes hexapterus	Pacific sand lance	4	4	45.60
Leptocottus armatus	Pacific staghorn sculpin	3	3	34.20
Lipolagus ochotensis	popeye blacksmelt	3	3	34.20
Liparis spp.	snailfishes	2	2	22.80
Actinopterygii	ray-finned fishes	1	1	11.40
Citharichthys stigmaeus	speckled sanddab	1	1	11.40
larvae, yolksac	yolksac larvae	1	1	11.40
Oligocottus/Clinocottus spp.	sculpins	1	1	11.40
Ruscarius creaseri	roughcheek sculpin	1	1	11.40
Scorpaenichthys marmoratus	cabezon	1	1	11.40
Spirinchus starksi	night smelt	1	1	11.40
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	8	8	91.21

Cycle: 2	Sample: 16	Station: SW6		
Split Multiplier: 1	Volume: 110.01			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	2	2	18.18
Leptocottus armatus	Pacific staghorn sculpin	2	2	18.18
Actinopterygii	ray-finned fishes	1	1	9.09
Ammodytes hexapterus	Pacific sand lance	1	1	9.09
Clupea pallasii	Pacific herring	1	1	9.09
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	10	10	90.90

Survey: HuB003 | Start Date: 03/17/2022

Cycle: 1	Sample: 1	Station: SW1		
Split Multiplier: 1	Volume: 117.54			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
<u>Entrainable Larval Fishes</u>				
Clupea pallasii	Pacific herring	6	6	51.05
Clevelandia ios	arrow goby	4	4	34.03
Ammodytes hexapterus	Pacific sand lance	2	2	17.02
<u>Fish Fragments</u>				
larval fish fragment	larval fish fragments	3	3	25.52
<u>Fish Eggs</u>				
non-engraulidae eggs	non-engraulidae eggs	23	23	195.68

Cycle: 1	Sample: 2	Station: SW2		
Split Multiplier: 1	Volume: 100.11			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
<u>Entrainable Larval Fishes</u>				
Clupea pallasii	Pacific herring	17	17	169.81
Clevelandia ios	arrow goby	6	6	59.93
Ammodytes hexapterus	Pacific sand lance	3	3	29.97
Allosmerus elongatus	whitebait smelt	2	2	19.98
Oligocottus/Clinocottus spp.	sculpins	2	2	19.98
Sebastes spp. V	blue rockfish larval complex	2	2	19.98
Bathymasteridae	ronquils	1	1	9.99
Gillichthys mirabilis	longjaw mudsucker	1	1	9.99
Leptocottus armatus	Pacific staghorn sculpin	1	1	9.99
Liparis spp.	snailfishes	1	1	9.99
<u>Fish Fragments</u>				
larval fish fragment	larval fish fragments	10	10	99.89
<u>Fish Eggs</u>				
non-engraulidae eggs	non-engraulidae eggs	14	14	139.84

(continued)

Survey: HuB003 (continued) Start Date: 03/17/2022

Cycle: 1	Sample: 3	Station: E2		
Split Multiplier: 1	Volume: 114.44			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clupea pallasii	Pacific herring	12	12	104.86
Oligocottus/Clinocottus spp.	sculpins	4	4	34.95
Sebastes spp. V_	KGB rockfish larval complex	3	3	26.22
Liparis spp.	snailfishes	2	2	17.48
Ammodytes hexapterus	Pacific sand lance	1	1	8.74
larvae, yolksac	yolksac larvae	1	1	8.74
Leptocottus armatus	Pacific staghorn sculpin	1	1	8.74
Microgadus proximus	Pacific tomcod	1	1	8.74
Stenobrachius leucopsarus	northern lampfish	1	1	8.74
Stichaeidae	pricklebacks	1	1	8.74
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	27	27	235.94

Cycle: 1	Sample: 4	Station: E1		
Split Multiplier: 1	Volume: 100.72			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Sebastes spp. V	blue rockfish larval complex	2	2	19.86
Bathymasteridae	ronquils	1	1	9.93
Clupea pallasii	Pacific herring	1	1	9.93
Liparis spp.	snailfishes	1	1	9.93
Stenobrachius leucopsarus	northern lampfish	1	1	9.93
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	19	19	188.64

Cycle: 1	Sample: 5	Station: SW3		
Split Multiplier: 1	Volume: 98.51			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Artedius spp.	sculpins	2	2	20.30
Sebastes spp. V	blue rockfish larval complex	2	2	20.30
Stenobrachius leucopsarus	northern lampfish	2	2	20.30
Clupea pallasii	Pacific herring	1	1	10.15
larvae, yolksac	yolksac larvae	1	1	10.15
Lyopsetta exilis	slender sole	1	1	10.15
Microgadus proximus	Pacific tomcod	1	1	10.15
Scorpaenichthys marmoratus	cabezon	1	1	10.15
Tarletonbeania crenularis	blue lanternfish	1	1	10.15
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	6	6	60.91

(continued)

Survey: HuB003 (continued) Start Date: 03/17/2022

Cycle: 1	Sample: 6	Station: SW4		
Split Multiplier: 1	Volume: 102.72			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
larvae, yolksac	yolksac larvae	3	3	29.20
Artedius spp.	sculpins	2	2	19.47
Clupea pallasii	Pacific herring	2	2	19.47
Leptocottus armatus	Pacific staghorn sculpin	1	1	9.73
Microgadus proximus	Pacific tomcod	1	1	9.73
Sebastes spp. V	blue rockfish larval complex	1	1	9.73
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	22	22	214.17

Cycle: 1	Sample: 7	Station: SW5		
Split Multiplier: 1	Volume: 84.24			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clupea pallasii	Pacific herring	23	23	273.04
Allosmerus elongatus	whitebait smelt	2	2	23.74
Cottus asper	prickly sculpin	2	2	23.74
Leptocottus armatus	Pacific staghorn sculpin	2	2	23.74
Microgadus proximus	Pacific tomcod	2	2	23.74
Sebastes spp. V	blue rockfish larval complex	1	1	11.87
Spirinchus starksi	night smelt	1	1	11.87
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	13	13	154.33
Targeted Invertebrates				
Romal. anten./Metacar. grac. (megalops)	cancer crabs	1	1	11.87

Cycle: 1	Sample: 8	Station: SW6		
Split Multiplier: 1	Volume: 114.43			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clupea pallasii	Pacific herring	3	3	26.22
Leptocottus armatus	Pacific staghorn sculpin	2	2	17.48
Sebastes spp. V_	KGB rockfish larval complex	2	2	17.48
Allosmerus elongatus	whitebait smelt	1	1	8.74
Clevelandia ios	arrow goby	1	1	8.74
larval fish - damaged	damaged larval fishes	1	1	8.74
Oligocottus/Clinocottus spp.	sculpins	1	1	8.74
Fish Fragments				
larval fish fragment	larval fish fragments	1	1	8.74
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	10	10	87.39

(continued)

Survey: HuB003 (continued) Start Date: 03/17/2022

Cycle: 2	Sample: 9	Station: SW5		
Split Multiplier: 1	Volume: 102.21			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clupea pallasii	Pacific herring	174	174	1,702.37
Clevelandia ios	arrow goby	3	3	29.35
Leptocottus armatus	Pacific staghorn sculpin	3	3	29.35
Spirinchus starksi	night smelt	3	3	29.35
Allosmerus elongatus	whitebait smelt	2	2	19.57
Artedius spp.	sculpins	1	1	9.78
Oligocottus snyderi	fluffy sculpin	1	1	9.78
Oligocottus/Clinocottus spp.	sculpins	1	1	9.78
Parophrys vetulus	English sole	1	1	9.78
Sebastes spp. V	blue rockfish larval complex	1	1	9.78
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	9	9	88.05

Cycle: 2	Sample: 10	Station: SW4		
Split Multiplier: 1	Volume: 106.94			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clupea pallasii	Pacific herring	137	137	1,281.12
Allosmerus elongatus	whitebait smelt	11	11	102.86
larvae, yolksac	yolksac larvae	5	5	46.76
Leptocottus armatus	Pacific staghorn sculpin	4	4	37.40
Liparis spp.	snailfishes	3	3	28.05
Oligocottus/Clinocottus spp.	sculpins	2	2	18.70
Cottus asper	prickly sculpin	1	1	9.35
Lyopsetta exilis	slender sole	1	1	9.35
Spirinchus starksi	night smelt	1	1	9.35
Fish Fragments				
larval fish fragment	larval fish fragments	13	13	121.57
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	20	20	187.02

(continued)

Survey: HuB003 (continued) Start Date: 03/17/2022

Cycle: 2	Sample: 11	Station: SW3		
Split Multiplier: 1	Volume: 158.82			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clupea pallasii	Pacific herring	60	60	377.78
Clevelandia ios	arrow goby	8	8	50.37
Allosmerus elongatus	whitebait smelt	3	3	18.89
Artedius spp.	sculpins	3	3	18.89
Leptocottus armatus	Pacific staghorn sculpin	3	3	18.89
Liparis spp.	snailfishes	1	1	6.30
Oligocottus/Clinocottus spp.	sculpins	1	1	6.30
Ruscarius meanyi	Puget Sound sculpin	1	1	6.30
Sebastes spp. V_	KGB rockfish larval complex	1	1	6.30
Fish Fragments				
larval fish fragment	larval fish fragments	6	6	37.78
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	17	17	107.04

Cycle: 2	Sample: 12	Station: E1		
Split Multiplier: 1	Volume: 101.99			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clupea pallasii	Pacific herring	30	30	294.14
Clevelandia ios	arrow goby	10	10	98.05
Allosmerus elongatus	whitebait smelt	3	3	29.41
Leptocottus armatus	Pacific staghorn sculpin	2	2	19.61
Liparis spp.	snailfishes	2	2	19.61
Stenobrachius leucopsarus	northern lampfish	1	1	9.80
Fish Fragments				
larval fish fragment	larval fish fragments	2	2	19.61
Non-Entrainable Fishes				
Ammodytes hexapterus	Pacific sand lance	1	1	9.80
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	12	12	117.66
Targeted Invertebrates				
Romal. anten./Metacar. grac. (megalops)	cancer crabs	1	1	9.80

(continued)

Survey: HuB003 (continued) Start Date: 03/17/2022

Cycle: 2	Sample: 13	Station: E2		
Split Multiplier: 1	Volume: 93.70			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	14	14	149.41
Clupea pallasii	Pacific herring	9	9	96.05
Oligocottus/Clinocottus spp.	sculpins	5	5	53.36
Allosmerus elongatus	whitebait smelt	1	1	10.67
Bathymasteridae	ronquils	1	1	10.67
Cottus asper	prickly sculpin	1	1	10.67
Sebastes spp. V_	KGB rockfish larval complex	1	1	10.67
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	3	3	32.02

Cycle: 2	Sample: 14	Station: SW2		
Split Multiplier: 1	Volume: 105.42			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
larval fish - damaged	damaged larval fishes	11	11	104.34
Clevelandia ios	arrow goby	9	9	85.37
Clupea pallasii	Pacific herring	3	3	28.46
Ammodytes hexapterus	Pacific sand lance	1	1	9.49
Bathylagidae	blacksmelts	1	1	9.49
Leptocottus armatus	Pacific staghorn sculpin	1	1	9.49
Fish Fragments				
larval fish fragment	larval fish fragments	5	5	47.43
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	5	5	47.43

Cycle: 2	Sample: 15	Station: SW1		
Split Multiplier: 1	Volume: 114.46			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clupea pallasii	Pacific herring	83	83	725.13
Clevelandia ios	arrow goby	39	39	340.72
larval fish - damaged	damaged larval fishes	2	2	17.47
Leptocottus armatus	Pacific staghorn sculpin	2	2	17.47
Cottus asper	prickly sculpin	1	1	8.74
Liparis spp.	snailfishes	1	1	8.74
Parophrys vetulus	English sole	1	1	8.74
Fish Fragments				
larval fish fragment	larval fish fragments	3	3	26.21
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	19	19	165.99

(continued)

Survey: HuB003 (continued) Start Date: 03/17/2022

Cycle: 2	Sample: 16	Station: SW6		
Split Multiplier: 1	Volume: 100.59			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clupea pallasii	Pacific herring	8	8	79.53
Cottus asper	prickly sculpin	2	2	19.88
Allosmerus elongatus	whitebait smelt	1	1	9.94
Clevelandia ios	arrow goby	1	1	9.94
Leptocottus armatus	Pacific staghorn sculpin	1	1	9.94
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	7	7	69.59

Survey: HuB004 Start Date: 04/26/2022

Cycle: 1	Sample: 1	Station: SW1		
Split Multiplier: 1	Volume: 110.73			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	2	2	18.06
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	2	2	18.06

Cycle: 1	Sample: 2	Station: SW2		
Split Multiplier: 1	Volume: 153.39			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	7	7	45.64
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	3	3	19.56

Cycle: 1	Sample: 3	Station: E2		
Split Multiplier: 1	Volume: 105.50			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	6	6	56.87
Microgadus proximus	Pacific tomcod	4	4	37.91
Clevelandia ios	arrow goby	3	3	28.44
Liparis spp.	snailfishes	1	1	9.48
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	8	8	75.83

Cycle: 1	Sample: 4	Station: E1		
Split Multiplier: 1	Volume: 92.63			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Microgadus proximus	Pacific tomcod	6	6	64.78
Lepidogobius lepidus	bay goby	4	4	43.18
Artedius spp.	sculpins	2	2	21.59
Oligocottus/Clinocottus spp.	sculpins	2	2	21.59
Allosmerus elongatus	whitebait smelt	1	1	10.80
Oligocottus snyderi	fluffy sculpin	1	1	10.80
Sebastes spp. V_	KGB rockfish larval complex	1	1	10.80
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	24	24	259.11

(continued)

Survey: HuB004 (continued) Start Date: 04/26/2022

Cycle: 1	Sample: 5	Station: SW3		
Split Multiplier: 1	Volume: 116.58			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	7	7	60.04
Microgadus proximus	Pacific tomcod	6	6	51.47
Lepidogobius lepidus	bay goby	4	4	34.31
Spirinchus starksi	night smelt	3	3	25.73
Clevelandia ios	arrow goby	2	2	17.16
Liparis spp.	snailfishes	1	1	8.58
Oligocottus snyderi	fluffy sculpin	1	1	8.58
Sebastes spp. V_	KGB rockfish larval complex	1	1	8.58
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	28	28	240.17

Cycle: 1	Sample: 6	Station: SW4		
Split Multiplier: 1	Volume: 82.58			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Spirinchus starksi	night smelt	7	7	84.76
Allosmerus elongatus	whitebait smelt	6	6	72.65
Cottus asper	prickly sculpin	3	3	36.33
Microgadus proximus	Pacific tomcod	3	3	36.33
larval fish – damaged	damaged larval fishes	1	1	12.11
Liparis spp.	snailfishes	1	1	12.11
Non-Entrainable Fishes				
Pholidae	gunnels	1	1	12.11
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	9	9	108.98

Cycle: 1	Sample: 7	Station: SW5		
Split Multiplier: 1	Volume: 80.12			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	2	2	24.96
Artedius spp.	sculpins	2	2	24.96
Cebidichthys violaceus	monkeyface prickleback	1	1	12.48
Lepidogobius lepidus	bay goby	1	1	12.48
Stichaeidae	pricklebacks	1	1	12.48
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	19	19	237.15

(continued)

Survey: HuB004 (continued) | Start Date: 04/26/2022

Cycle: 1	Sample: 8	Station: SW6		
Split Multiplier: 1	Volume: 114.46			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	56	56	489.24
Liparis spp.	snailfishes	2	2	17.47
Artedius spp.	sculpins	1	1	8.74
Microgadus proximus	Pacific tomcod	1	1	8.74
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	7	7	61.16

Cycle: 2	Sample: 9	Station: SW5		
Split Multiplier: 1	Volume: 113.95			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	12	12	105.31
Spirinchus starksi	night smelt	10	10	87.75
Microgadus proximus	Pacific tomcod	6	6	52.65
Cottus asper	prickly sculpin	1	1	8.78
Leptocottus armatus	Pacific staghorn sculpin	1	1	8.78
Liparis spp.	snailfishes	1	1	8.78
Oligocottus snyderi	fluffy sculpin	1	1	8.78
Oligocottus/Clinocottus spp.	sculpins	1	1	8.78
Non-Entrainable Fishes				
Pholidae	gunnels	1	1	8.78
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	14	14	122.86
Targeted Invertebrates				
Cancer productus/Romal. spp. (megalops)	rock crab megalops	6	6	52.65
Metacarcinus magister (megalops)	Dungeness crab megalops	5	5	43.88
Romal. anten./Metacar. grac. (megalops)	cancer crabs	2	2	17.55

(continued)

Survey: HuB004 (continued) Start Date: 04/26/2022

Cycle: 2	Sample: 10	Station: SW4		
Split Multiplier: 1	Volume: 74.98			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Microgadus proximus	Pacific tomcod	10	10	133.37
Allosmerus elongatus	whitebait smelt	6	6	80.02
Spirinchus starksi	night smelt	6	6	80.02
Leptocottus armatus	Pacific staghorn sculpin	5	5	66.68
Artedius harringtoni	scalyhead sculpin	1	1	13.34
Artedius spp.	sculpins	1	1	13.34
Cottus asper	prickly sculpin	1	1	13.34
Isopsetta isolepis	butter sole	1	1	13.34
Parophrys vetulus	English sole	1	1	13.34
Non-Entrainable Fishes				
Pholidae	gunnels	1	1	13.34
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	13	13	173.38
Targeted Invertebrates				
Cancer productus/Romal. spp. (megalops)	rock crab megalops	5	5	66.68
Metacarcinus magister (megalops)	Dungeness crab megalops	2	2	26.67

Cycle: 2	Sample: 11	Station: SW3		
Split Multiplier: 1	Volume: 102.69			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	13	13	126.60
Spirinchus starksi	night smelt	7	7	68.17
Microgadus proximus	Pacific tomcod	6	6	58.43
Cottidae	sculpins	2	2	19.48
Liparis spp.	snailfishes	2	2	19.48
Artedius spp.	sculpins	1	1	9.74
Clevelandia ios	arrow goby	1	1	9.74
Leptocottus armatus	Pacific staghorn sculpin	1	1	9.74
Oligocottus snyderi	fluffy sculpin	1	1	9.74
Pholidae	gunnels	1	1	9.74
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	21	21	204.50
Targeted Invertebrates				
Cancer productus/Romal. spp. (megalops)	rock crab megalops	3	3	29.21

(continued)

Survey: HuB004 (continued) Start Date: 04/26/2022

Cycle: 2	Sample: 12	Station: E1		
Split Multiplier: 1	Volume: 101.29			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	30	30	296.19
Spirinchus starksi	night smelt	15	15	148.09
Microgadus proximus	Pacific tomcod	13	13	128.35
Lepidogobius lepidus	bay goby	5	5	49.36
Clevelandia ios	arrow goby	4	4	39.49
Cottus asper	prickly sculpin	4	4	39.49
Isopsetta isolepis	butter sole	2	2	19.75
Oligocottus/Clinocottus spp.	sculpins	2	2	19.75
Artedius spp.	sculpins	1	1	9.87
Clinocottus embryum	calico sculpin	1	1	9.87
Liparis spp.	snailfishes	1	1	9.87
Ruscarius creaseri	roughcheek sculpin	1	1	9.87
Sebastes spp. V_	KGB rockfish larval complex	1	1	9.87
Stichaeidae	pricklebacks	1	1	9.87
Fish Fragments				
larval fish fragment	larval fish fragments	3	3	29.62
Non-Entrainable Fishes				
Pholidae	gunnels	2	2	19.75
Isopsetta isolepis	butter sole	1	1	9.87
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	13	13	128.35
Targeted Invertebrates				
Cancer productus/Romal. spp. (megalops)	rock crab megalops	2	2	19.75
Metacarcinus magister (megalops)	Dungeness crab megalops	2	2	19.75
Romal. anten./Metacar. grac. (megalops)	cancer crabs	2	2	19.75

(continued)

Survey: HuB004 (continued) | Start Date: 04/26/2022

Cycle: 2	Sample: 13	Station: E2		
Split Multiplier: 1	Volume: 100.28			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	25	25	249.31
Lepidogobius lepidus	bay goby	8	8	79.78
Microgadus proximus	Pacific tomcod	7	7	69.81
Cottus asper	prickly sculpin	4	4	39.89
Liparis spp.	snailfishes	4	4	39.89
Spirinchus starksi	night smelt	4	4	39.89
Clevelandia ios	arrow goby	2	2	19.94
Artedius spp.	sculpins	1	1	9.97
Clupea pallasii	Pacific herring	1	1	9.97
Isopsetta isolepis	butter sole	1	1	9.97
Fish Fragments				
larval fish fragment	larval fish fragments	5	5	49.86
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	20	20	199.45
Targeted Invertebrates				
Metacarcinus magister (megalops)	Dungeness crab megalops	2	2	19.94
Cancer productus/Romal. spp. (megalops)	rock crab megalops	1	1	9.97

Cycle: 2	Sample: 14	Station: SW2		
Split Multiplier: 1	Volume: 79.62			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	42	42	527.49
Allosmerus elongatus	whitebait smelt	3	3	37.68
Isopsetta isolepis	butter sole	2	2	25.12
Lepidogobius lepidus	bay goby	2	2	25.12
Liparis spp.	snailfishes	2	2	25.12
Microgadus proximus	Pacific tomcod	2	2	25.12
Oligocottus/Clinocottus spp.	sculpins	2	2	25.12
Clupea pallasii	Pacific herring	1	1	12.56
Spirinchus starksi	night smelt	1	1	12.56
Fish Fragments				
larval fish fragment	larval fish fragments	8	8	100.47
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	18	18	226.07
Targeted Invertebrates				
Metacarcinus magister (megalops)	Dungeness crab megalops	1	1	12.56

(continued)

Survey: HuB004 (continued) Start Date: 04/26/2022

Cycle: 2	Sample: 15	Station: SW1		
Split Multiplier: 1	Volume: 74.77			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	7	7	93.62
Clevelandia ios	arrow goby	5	5	66.87
Microgadus proximus	Pacific tomcod	4	4	53.50
Liparis spp.	snailfishes	2	2	26.75
Cottus asper	prickly sculpin	1	1	13.37
Lepidogobius lepidus	bay goby	1	1	13.37
Leptocottus armatus	Pacific staghorn sculpin	1	1	13.37
Sebastes spp. V_	KGB rockfish larval complex	1	1	13.37
Spirinchus starksi	night smelt	1	1	13.37
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	97	97	1,297.26

Cycle: 2	Sample: 16	Station: SW6		
Split Multiplier: 1	Volume: 87.31			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	5	5	57.26
Clevelandia ios	arrow goby	3	3	34.36
Lepidogobius lepidus	bay goby	2	2	22.91
Microgadus proximus	Pacific tomcod	2	2	22.91
Oligocottus/Clinocottus spp.	sculpins	2	2	22.91
Spirinchus starksi	night smelt	2	2	22.91
Artedius spp.	sculpins	1	1	11.45
Gillichthys mirabilis	longjaw mudsucker	1	1	11.45
Leptocottus armatus	Pacific staghorn sculpin	1	1	11.45
Parophrys vetulus	English sole	1	1	11.45
Sebastes spp. V_	KGB rockfish larval complex	1	1	11.45
Non-Entrainable Fishes				
Clevelandia ios	arrow goby	1	1	11.45
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	19	19	217.61

Survey: HuB005 Start Date: 05/26/2022

Cycle: 1	Sample: 1	Station: SW1		
Split Multiplier: 2	Volume: 161.37			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	92	184	1,140.21
Lepidogobius lepidus	bay goby	1	2	12.39
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	38	76	470.96

Cycle: 1	Sample: 2	Station: SW2		
Split Multiplier: 4	Volume: 129.70			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	248	992	7,648.54
Acanthogobius flavimanus	yellowfin goby	1	4	30.84
Bathymasteridae	ronquils	1	4	30.84
Gillichthys mirabilis	longjaw mudsucker	1	4	30.84
Platichthys stellatus	starry flounder	1	4	30.84
Rhinogobiops nicholsii	blackeye goby	1	4	30.84
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	23	92	709.34

Cycle: 1	Sample: 3	Station: E2		
Split Multiplier: 1	Volume: 129.34			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	12	12	92.78
Liparis spp.	snailfishes	1	1	7.73
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	68	68	525.73

(continued)

Survey: HuB005 (continued) Start Date: 05/26/2022

Cycle: 1	Sample: 4	Station: E1		
Split Multiplier: 1	Volume: 85.73			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Citharichthys sordidus	Pacific sanddab	7	7	81.65
Lepidogobius lepidus	bay goby	5	5	58.32
Clevelandia ios	arrow goby	4	4	46.66
Clupea pallasii	Pacific herring	1	1	11.66
Pleuronectidae	righteye flounders	1	1	11.66
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	80	80	933.19
Targeted Invertebrates				
Metacarcinus magister (megalops)	Dungeness crab megalops	1	1	11.66

Cycle: 1	Sample: 5	Station: SW3		
Split Multiplier: 1	Volume: 120.19			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Citharichthys sordidus	Pacific sanddab	31	31	257.93
Hippoglossoides elassodon	flathead sole	3	3	24.96
Clevelandia ios	arrow goby	1	1	8.32
Cottus asper	prickly sculpin	1	1	8.32
larval fish - damaged	damaged larval fishes	1	1	8.32
Oligocottus/Clinocottus spp.	sculpins	1	1	8.32
Rhinogobiops nicholsii	blackeye goby	1	1	8.32
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	49	49	407.70
Targeted Invertebrates				
Metacarcinus magister (megalops)	Dungeness crab megalops	2	2	16.64

(continued)

Survey: HuB005 (continued) Start Date: 05/26/2022

Cycle: 1	Sample: 6	Station: SW4		
Split Multiplier: 2	Volume: 96.85			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
<u>Entrainable Larval Fishes</u>				
Citharichthys sordidus	Pacific sanddab	12	24	247.80
Allosmerus elongatus	whitebait smelt	7	14	144.55
Hippoglossoides elassodon	flathead sole	3	6	61.95
Clevelandia ios	arrow goby	1	2	20.65
Oligocottus/Clinocottus spp.	sculpins	1	2	20.65
<u>Fish Eggs</u>				
non-engraulidae eggs	non-engraulidae eggs	18	36	371.69
<u>Targeted Invertebrates</u>				
Cancer productus/Romal. spp. (megalops)	rock crab megalops	3	6	61.95
Metacarcinus magister (megalops)	Dungeness crab megalops	2	4	41.30

Cycle: 1	Sample: 7	Station: SW5		
Split Multiplier: 1	Volume: 101.54			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
<u>Entrainable Larval Fishes</u>				
Citharichthys sordidus	Pacific sanddab	22	22	216.67
Hippoglossoides elassodon	flathead sole	6	6	59.09
Pleuronectoidei	flatfishes	4	4	39.39
Lepidogobius lepidus	bay goby	2	2	19.70
Oligocottus/Clinocottus spp.	sculpins	1	1	9.85
<u>Fish Eggs</u>				
non-engraulidae eggs	non-engraulidae eggs	74	74	728.81
<u>Targeted Invertebrates</u>				
Metacarcinus magister (megalops)	Dungeness crab megalops	1	1	9.85

(continued)

Survey: HuB005 (continued) Start Date: 05/26/2022

Cycle: 1	Sample: 8	Station: SW6		
Split Multiplier: 1	Volume: 107.97			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	14	14	129.67
Lepidogobius lepidus	bay goby	2	2	18.52
Acanthogobius flavimanus	yellowfin goby	1	1	9.26
Allosmerus elongatus	whitebait smelt	1	1	9.26
Gillichthys mirabilis	longjaw mudsucker	1	1	9.26
Rhinogobiops nicholsii	blackeye goby	1	1	9.26
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	182	182	1,685.70

Cycle: 2	Sample: 9	Station: SW5		
Split Multiplier: 1	Volume: 95.99			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Citharichthys sordidus	Pacific sanddab	26	26	270.87
Pleuronectoidei	flatfishes	15	15	156.27
Hippoglossoides elassodon	flathead sole	10	10	104.18
Lepidogobius lepidus	bay goby	2	2	20.84
Allosmerus elongatus	whitebait smelt	1	1	10.42
Clevelandia ios	arrow goby	1	1	10.42
Oligocottus/Clinocottus spp.	sculpins	1	1	10.42
Spirinchus starksi	night smelt	1	1	10.42
Tarletonbeania crenularis	blue lanternfish	1	1	10.42
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	58	58	604.24

Cycle: 2	Sample: 10	Station: SW4		
Split Multiplier: 2	Volume: 88.83			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	21	42	472.80
Citharichthys sordidus	Pacific sanddab	10	20	225.14
Spirinchus starksi	night smelt	9	18	202.63
Hippoglossoides elassodon	flathead sole	8	16	180.11
Chitonotus pugetensis	roughback sculpin	1	2	22.51
Pleuronectoidei	flatfishes	1	2	22.51
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	22	44	495.31
Targeted Invertebrates				
Metacarcinus magister (megalops)	Dungeness crab megalops	1	2	22.51

(continued)

Survey: HuB005 (continued) Start Date: 05/26/2022

Cycle: 2	Sample: 11	Station: SW3		
Split Multiplier: 1	Volume: 123.18			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
<u>Entrainable Larval Fishes</u>				
Allosmerus elongatus	whitebait smelt	40	40	324.72
Citharichthys sordidus	Pacific sanddab	16	16	129.89
Spirinchus starksi	night smelt	13	13	105.53
Hippoglossoides elassodon	flathead sole	7	7	56.83
Pleuronectoidei	flatfishes	6	6	48.71
Cottus asper	prickly sculpin	1	1	8.12
<u>Fish Fragments</u>				
larval fish fragment	larval fish fragments	8	8	64.94
<u>Fish Eggs</u>				
non-engraulidae eggs	non-engraulidae eggs	76	76	616.97
<u>Targeted Invertebrates</u>				
Metacarcinus magister (megalops)	Dungeness crab megalops	177	177	1,436.89
Cancer productus/Romal. spp. (megalops)	rock crab megalops	2	2	16.24

Cycle: 2	Sample: 12	Station: E1		
Split Multiplier: 1	Volume: 102.14			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
<u>Entrainable Larval Fishes</u>				
Allosmerus elongatus	whitebait smelt	51	51	499.30
Spirinchus starksi	night smelt	18	18	176.22
Citharichthys sordidus	Pacific sanddab	5	5	48.95
Hippoglossoides elassodon	flathead sole	5	5	48.95
Artedius spp.	sculpins	3	3	29.37
Hypomesus pretiosus	surf smelt	1	1	9.79
Lepidogobius lepidus	bay goby	1	1	9.79
Rhinogobiops nicholsii	blackeye goby	1	1	9.79
<u>Fish Fragments</u>				
larval fish fragment	larval fish fragments	4	4	39.16
<u>Fish Eggs</u>				
non-engraulidae eggs	non-engraulidae eggs	52	52	509.09
<u>Targeted Invertebrates</u>				
Metacarcinus magister (megalops)	Dungeness crab megalops	90	90	881.11
Cancer productus/Romal. spp. (megalops)	rock crab megalops	2	2	19.58
Romal. anten./Metacar. grac. (megalops)	cancer crabs	1	1	9.79

(continued)

Survey: HuB005 (continued) Start Date: 05/26/2022

Cycle: 2	Sample: 13	Station: E2		
Split Multiplier: 1	Volume: 94.60			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	9	9	95.14
Citharichthys sordidus	Pacific sanddab	3	3	31.71
Clevelandia ios	arrow goby	2	2	21.14
Spirinchus starksi	night smelt	2	2	21.14
Hippoglossoides elassodon	flathead sole	1	1	10.57
Rhinogobiops nicholsii	blackeye goby	1	1	10.57
Fish Fragments				
larval fish fragment	larval fish fragments	2	2	21.14
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	38	38	401.68
Targeted Invertebrates				
Metacarcinus magister (megalops)	Dungeness crab megalops	10	10	105.71
Cancer productus/Romal. spp. (megalops)	rock crab megalops	4	4	42.28

Cycle: 2	Sample: 14	Station: SW2		
Split Multiplier: 1	Volume: 95.17			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	11	11	115.58
Clevelandia ios	arrow goby	10	10	105.07
Allosmerus elongatus	whitebait smelt	2	2	21.01
Citharichthys sordidus	Pacific sanddab	2	2	21.01
Gillichthys mirabilis	longjaw mudsucker	1	1	10.51
Hippoglossoides elassodon	flathead sole	1	1	10.51
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	30	30	315.21
Targeted Invertebrates				
Metacarcinus magister (megalops)	Dungeness crab megalops	3	3	31.52

(continued)

Survey: HuB005 (continued) Start Date: 05/26/2022

Cycle: 2	Sample: 15	Station: SW1		
Split Multiplier: 4	Volume: 85.39			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	13	52	609.00
Citharichthys sordidus	Pacific sanddab	1	4	46.85
Pleuronectoidei	flatfishes	1	4	46.85
Rhinogobiops nicholsii	blackeye goby	1	4	46.85
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	15	60	702.70
Targeted Invertebrates				
Metacarcinus magister (megalops)	Dungeness crab megalops	4	16	187.39

Cycle: 2	Sample: 16	Station: SW6		
Split Multiplier: 1	Volume: 112.01			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	12	12	107.13
Atherinops affinis	topsmelt	1	1	8.93
Pleuronectoidei	flatfishes	1	1	8.93
Rhinogobiops nicholsii	blackeye goby	1	1	8.93
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	44	44	392.82
Targeted Invertebrates				
Cancer productus/Romal. spp. (megalops)	rock crab megalops	1	1	8.93

Survey: HuB006 | Start Date: 06/28/2022

Cycle: 1	Sample: 1	Station: SW1		
Split Multiplier: 1	Volume: 117.95			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
<u>Entrainable Larval Fishes</u>				
Clevelandia ios	arrow goby	24	24	203.48
Lepidogobius lepidus	bay goby	1	1	8.48
Rhinogobiops nicholsii	blackeye goby	1	1	8.48
Syngnathidae	pipefishes	1	1	8.48
<u>Fish Eggs</u>				
non-engraulidae eggs	non-engraulidae eggs	11	11	93.26
Engraulidae (eggs)	anchovy eggs	10	10	84.78

Cycle: 1	Sample: 2	Station: SW2		
Split Multiplier: 4	Volume: 116.98			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
<u>Entrainable Larval Fishes</u>				
Clevelandia ios	arrow goby	55	220	1,880.67
Engraulis mordax	northern anchovy	1	4	34.19
<u>Fish Eggs</u>				
non-engraulidae eggs	non-engraulidae eggs	3	12	102.58

Cycle: 1	Sample: 3	Station: E2		
Split Multiplier: 4	Volume: 90.11			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
<u>Entrainable Larval Fishes</u>				
Clevelandia ios	arrow goby	88	352	3,906.16
Allosmerus elongatus	whitebait smelt	1	4	44.39
Atherinopsis californiensis	jacksmelt	1	4	44.39
<u>Fish Fragments</u>				
larval fish fragment	larval fish fragments	2	8	88.78
<u>Fish Eggs</u>				
non-engraulidae eggs	non-engraulidae eggs	13	52	577.05
Engraulidae (eggs)	anchovy eggs	9	36	399.49

(continued)

Survey: HuB006 (continued) | Start Date: 06/28/2022

Cycle: 1	Sample: 4	Station: E1		
Split Multiplier: 8	Volume: 97.07			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	259	2,072	21,346.19
Cottus asper	prickly sculpin	1	8	82.42
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	34	272	2,802.20
Engraulidae (eggs)	anchovy eggs	1	8	82.42

Cycle: 1	Sample: 5	Station: SW3		
Split Multiplier: 8	Volume: 104.14			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	18	144	1,382.69
Allosmerus elongatus	whitebait smelt	1	8	76.82
Artedius spp.	sculpins	1	8	76.82
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	74	592	5,684.40
Engraulidae (eggs)	anchovy eggs	1	8	76.82

Cycle: 1	Sample: 6	Station: SW4		
Split Multiplier: 4	Volume: 77.61			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	3	12	154.63
Hypomesus pretiosus	surf smelt	2	8	103.08
Clevelandia ios	arrow goby	1	4	51.54
Spirinchus starksi	night smelt	1	4	51.54
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	14	56	721.59
Targeted Invertebrates				
Cancer productus/Romal. spp. (megalops)	rock crab megalops	1	4	51.54

(continued)

Survey: HuB006 (continued) Start Date: 06/28/2022

Cycle: 1	Sample: 7	Station: SW5		
Split Multiplier: 4	Volume: 87.13			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Hippoglossoides elassodon	flathead sole	1	4	45.91
Hypomesus pretiosus	surf smelt	1	4	45.91
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	83	332	3,810.39
Engraulidae (eggs)	anchovy eggs	1	4	45.91

Cycle: 1	Sample: 8	Station: SW6		
Split Multiplier: 1	Volume: 92.15			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	188	188	2,040.14
Lepidogobius lepidus	bay goby	6	6	65.11
Allosmerus elongatus	whitebait smelt	3	3	32.56
Spirinchus starksi	night smelt	1	1	10.85
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	158	158	1,714.59
Engraulidae (eggs)	anchovy eggs	2	2	21.70

Cycle: 2	Sample: 9	Station: SW5		
Split Multiplier: 4	Volume: 99.99			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Hypomesus pretiosus	surf smelt	3	12	120.01
Allosmerus elongatus	whitebait smelt	2	8	80.00
Pleuronectoidei	flatfishes	2	8	80.00
Clevelandia ios	arrow goby	1	4	40.00
Hippoglossoides elassodon	flathead sole	1	4	40.00
Lepidogobius lepidus	bay goby	1	4	40.00
Ruscarius meanyi	Puget Sound sculpin	1	4	40.00
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	53	212	2,120.12

(continued)

Survey: HuB006 (continued) Start Date: 06/28/2022

Cycle: 2	Sample: 10	Station: SW4		
Split Multiplier: 8	Volume: 86.60			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	36	288	3,325.63
Hypomesus pretiosus	surf smelt	3	24	277.14
Artedius spp.	sculpins	1	8	92.38
Lepidogobius lepidus	bay goby	1	8	92.38
Fish Fragments				
larval fish fragment	larval fish fragments	4	32	369.51
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	35	280	3,233.25

Cycle: 2	Sample: 11	Station: SW3		
Split Multiplier: 2	Volume: 114.62			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	25	50	436.23
Hypomesus pretiosus	surf smelt	1	2	17.45
Lepidogobius lepidus	bay goby	1	2	17.45
Pleuronectoidei	flatfishes	1	2	17.45
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	51	102	889.90

Cycle: 2	Sample: 12	Station: E1		
Split Multiplier: 8	Volume: 100.55			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	9	72	716.07
Hypomesus pretiosus	surf smelt	3	24	238.69
Liparis spp.	snailfishes	1	8	79.56
Microgadus proximus	Pacific tomcod	1	8	79.56
Sebastes spp. V_	KGB rockfish larval complex	1	8	79.56
Fish Fragments				
larval fish fragment	larval fish fragments	1	8	79.56
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	51	408	4,057.72
Targeted Invertebrates				
Cancer productus/Romal. spp. (megalops)	rock crab megalops	1	8	79.56

(continued)

Survey: HuB006 (continued) Start Date: 06/28/2022

Cycle: 2	Sample: 13	Station: E2		
Split Multiplier: 4	Volume: 80.68			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	19	76	941.99
Clevelandia ios	arrow goby	5	20	247.89
Hypomesus pretiosus	surf smelt	4	16	198.31
Lepidogobius lepidus	bay goby	2	8	99.16
Liparis spp.	snailfishes	2	8	99.16
Artedius spp.	sculpins	1	4	49.58
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	42	168	2,082.30

Cycle: 2	Sample: 14	Station: SW2		
Split Multiplier: 4	Volume: 100.77			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	48	192	1,905.30
Allosmerus elongatus	whitebait smelt	6	24	238.16
Artedius spp.	sculpins	1	4	39.69
larvae, yolksac	yolksac larvae	1	4	39.69
Lepidogobius lepidus	bay goby	1	4	39.69
Rhinogobiops nicholsii	blackeye goby	1	4	39.69
Fish Fragments				
larval fish fragment	larval fish fragments	1	4	39.69
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	47	188	1,865.61
Engraulidae (eggs)	anchovy eggs	6	24	238.16

Cycle: 2	Sample: 15	Station: SW1		
Split Multiplier: 4	Volume: 89.75			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	14	56	623.95
Clevelandia ios	arrow goby	13	52	579.38
Spirinchus starksi	night smelt	5	20	222.84
Allosmerus elongatus	whitebait smelt	3	12	133.70
Engraulis mordax	northern anchovy	1	4	44.57
Hypomesus pretiosus	surf smelt	1	4	44.57
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	68	272	3,030.60

(continued)

Survey: HuB006 (continued) Start Date: 06/28/2022

Cycle: 2	Sample: 16	Station: SW6		
Split Multiplier: 1	Volume: 86.07			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	16	16	185.89
Hypomesus pretiosus	surf smelt	7	7	81.33
Lepidogobius lepidus	bay goby	2	2	23.24
Cebidichthys violaceus	monkeyface prickleback	1	1	11.62
Clevelandia ios	arrow goby	1	1	11.62
Radulinus spp.	sculpins	1	1	11.62
Stellerina xyosterna	pricklebreast poacher	1	1	11.62
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	223	223	2,590.85
Targeted Invertebrates				
Cancer productus/Romal. spp. (megalops)	rock crab megalops	1	1	11.62

Survey: HuB007 Start Date: 07/29/2022

Cycle: 1	Sample: 1	Station: SW1		
Split Multiplier: 1	Volume: 112.04			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	70	70	624.78
Gillichthys mirabilis	longjaw mudsucker	1	1	8.93
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	7	7	62.48

Cycle: 1	Sample: 2	Station: SW2		
Split Multiplier: 1	Volume: 90.26			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	19	19	210.51
Gillichthys mirabilis	longjaw mudsucker	2	2	22.16
Lepidogobius lepidus	bay goby	1	1	11.08
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	8	8	88.63
Engraulidae (eggs)	anchovy eggs	1	1	11.08

Cycle: 1	Sample: 3	Station: E2		
Split Multiplier: 1	Volume: 85.07			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	10	10	117.55
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	17	17	199.84
Engraulidae (eggs)	anchovy eggs	5	5	58.78

Cycle: 1	Sample: 4	Station: E1		
Split Multiplier: 1	Volume: 116.70			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	211	211	1,808.06
Lepidogobius lepidus	bay goby	19	19	162.81
Citharichthys sordidus	Pacific sanddab	1	1	8.57
Gillichthys mirabilis	longjaw mudsucker	1	1	8.57
Hippoglossoides elassodon	flathead sole	1	1	8.57
larvae, yolksac	yolksac larvae	1	1	8.57
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	89	89	762.64
Engraulidae (eggs)	anchovy eggs	1	1	8.57

(continued)

Survey: HuB007 (continued) Start Date: 07/29/2022

Cycle: 1	Sample: 5	Station: SW3		
Split Multiplier: 1	Volume: 94.02			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	61	61	648.78
Lepidogobius lepidus	bay goby	4	4	42.54
Rhinogobiops nicholsii	blackeye goby	1	1	10.64
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	127	127	1,350.75

Cycle: 1	Sample: 6	Station: SW4		
Split Multiplier: 1	Volume: 46.21			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	4	4	86.56
Lepidogobius lepidus	bay goby	2	2	43.28
Clevelandia ios	arrow goby	1	1	21.64
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	63	63	1,363.25

Cycle: 1	Sample: 7	Station: SW5		
Split Multiplier: 1	Volume: 78.97			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Ammodytes hexapterus	Pacific sand lance	5	5	63.32
larvae, yolksac	yolksac larvae	1	1	12.66
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	213	213	2,697.32

Cycle: 1	Sample: 8	Station: SW6		
Split Multiplier: 2	Volume: 90.24			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	12	24	265.94
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	66	132	1,462.69
Engraulidae (eggs)	anchovy eggs	4	8	88.65

(continued)

Survey: HuB007 (continued) Start Date: 07/29/2022

Cycle: 2	Sample: 9	Station: SW5		
Split Multiplier: 1	Volume: 97.12			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	5	5	51.48
Lepidogobius lepidus	bay goby	2	2	20.59
Citharichthys sordidus	Pacific sanddab	1	1	10.30
Hypomesus pretiosus	surf smelt	1	1	10.30
larvae, yolksac	yolksac larvae	1	1	10.30
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	197	197	2,028.40

Cycle: 2	Sample: 10	Station: SW4		
Split Multiplier: 1	Volume: 77.74			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	11	11	141.50
Lepidogobius lepidus	bay goby	5	5	64.32
Clevelandia ios	arrow goby	2	2	25.73
Fish Fragments				
larval fish fragment	larval fish fragments	2	2	25.73
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	171	171	2,199.74

Cycle: 2	Sample: 11	Station: SW3		
Split Multiplier: 2	Volume: 105.08			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	5	10	95.17
Lepidogobius lepidus	bay goby	3	6	57.10
Hypomesus pretiosus	surf smelt	1	2	19.03
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	112	224	2,131.72

(continued)

Survey: HuB007 (continued) Start Date: 07/29/2022

Cycle: 2	Sample: 12	Station: E1		
Split Multiplier: 1	Volume: 95.89			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	5	5	52.14
Clevelandia ios	arrow goby	1	1	10.43
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	167	167	1,741.63

Cycle: 2	Sample: 13	Station: E2		
Split Multiplier: 1	Volume: 86.55			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	7	7	80.88
Allosmerus elongatus	whitebait smelt	1	1	11.55
Citharichthys sordidus	Pacific sanddab	1	1	11.55
Clevelandia ios	arrow goby	1	1	11.55
Hypomesus pretiosus	surf smelt	1	1	11.55
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	125	125	1,444.32

Cycle: 2	Sample: 14	Station: SW2		
Split Multiplier: 1	Volume: 105.56			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	49	49	464.21
Lepidogobius lepidus	bay goby	4	4	37.89
Allosmerus elongatus	whitebait smelt	1	1	9.47
Engraulis mordax	northern anchovy	1	1	9.47
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	100	100	947.36

(continued)

Survey: HuB007 (continued)

Start Date: 07/29/2022

Cycle: 2	Sample: 15	Station: SW1		
Split Multiplier: 1	Volume: 97.81			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	3	3	30.67
Allosmerus elongatus	whitebait smelt	1	1	10.22
Clevelandia ios	arrow goby	1	1	10.22
Non-Entrainable Fishes				
Pholis ornata	saddleback gunnel	1	1	10.22
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	153	153	1,564.33

Cycle: 2	Sample: 16	Station: SW6		
Split Multiplier: 1	Volume: 113.83			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	4	4	35.14
Allosmerus elongatus	whitebait smelt	3	3	26.36
Lepidogobius lepidus	bay goby	3	3	26.36
Hypomesus pretiosus	surf smelt	2	2	17.57
larvae, yolksac	yolksac larvae	1	1	8.79
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	149	149	1,309.03

Survey: HuB008 | Start Date: 08/18/2022

Cycle: 1	Sample: 1	Station: SW1		
Split Multiplier: 1	Volume: 99.07			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	10	10	100.93
Lepidogobius lepidus	bay goby	3	3	30.28
Gillichthys mirabilis	longjaw mudsucker	1	1	10.09
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	65	65	656.07

Cycle: 1	Sample: 2	Station: SW2		
Split Multiplier: 1	Volume: 109.46			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	126	126	1,151.07
Lepidogobius lepidus	bay goby	10	10	91.35
Gillichthys mirabilis	longjaw mudsucker	1	1	9.14
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	211	211	1,927.59
Engraulidae (eggs)	anchovy eggs	2	2	18.27

Cycle: 1	Sample: 3	Station: E2		
Split Multiplier: 1	Volume: 103.09			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	36	36	349.21
Lepidogobius lepidus	bay goby	7	7	67.90
Genyonemus lineatus	white croaker	1	1	9.70
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	784	784	7,605.05

Cycle: 1	Sample: 4	Station: E1		
Split Multiplier: 1	Volume: 99.37			
Egg Jar Volume: 30	Egg Total Volume: 300			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	106	106	1,066.69
Lepidogobius lepidus	bay goby	12	12	120.76
Allosmerus elongatus	whitebait smelt	1	1	10.06
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	80	800	8,050.45

(continued)

Survey: HuB008 (continued) Start Date: 08/18/2022

Cycle: 1	Sample: 5	Station: SW3		
Split Multiplier: 1	Volume: 107.90			
Egg Jar Volume: 30	Egg Total Volume: 300			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
<u>Entrainable Larval Fishes</u>				
Lepidogobius lepidus	bay goby	47	47	435.60
Clevelandia ios	arrow goby	29	29	268.77
Allosmerus elongatus	whitebait smelt	3	3	27.80
<u>Fish Eggs</u>				
non-engraulidae eggs	non-engraulidae eggs	97	970	8,990.04

Cycle: 1	Sample: 6	Station: SW4		
Split Multiplier: 1	Volume: 80.98			
Egg Jar Volume: 30	Egg Total Volume: 300			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
<u>Entrainable Larval Fishes</u>				
Lepidogobius lepidus	bay goby	18	18	222.28
Artedius spp.	sculpins	1	1	12.35
Pleuronectoidei	flatfishes	1	1	12.35
<u>Fish Eggs</u>				
non-engraulidae eggs	non-engraulidae eggs	40	400	4,939.63
<u>Targeted Invertebrates</u>				
Cancridae (megalops)	cancer crabs megalops	1	1	12.35

Cycle: 1	Sample: 7	Station: SW5		
Split Multiplier: 1	Volume: 96.40			
Egg Jar Volume: 30	Egg Total Volume: 300			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
<u>Entrainable Larval Fishes</u>				
Lepidogobius lepidus	bay goby	10	10	103.74
larvae, yolksac	yolksac larvae	1	1	10.37
<u>Fish Fragments</u>				
larval fish - damaged	damaged larval fishes	1	1	10.37
<u>Fish Eggs</u>				
non-engraulidae eggs	non-engraulidae eggs	58	580	6,016.86

(continued)

Survey: HuB008 (continued) Start Date: 08/18/2022

Cycle: 1	Sample: 8	Station: SW6		
Split Multiplier: 1	Volume: 91.75			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	38	38	414.15
Lepidogobius lepidus	bay goby	2	2	21.80
Rhinogobiops nicholsii	blackeye goby	1	1	10.90
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	158	158	1,721.99
Engraulidae (eggs)	anchovy eggs	2	2	21.80

Cycle: 2	Sample: 9	Station: SW5		
Split Multiplier: 1	Volume: 128.26			
Egg Jar Volume: 30	Egg Total Volume: 300			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	130	130	1,013.53
Allosmerus elongatus	whitebait smelt	1	1	7.80
Clevelandia ios	arrow goby	1	1	7.80
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	54	540	4,210.06
Engraulidae (eggs)	anchovy eggs	1	10	77.96

Cycle: 2	Sample: 10	Station: SW4		
Split Multiplier: 4	Volume: 136.88			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	9	36	263.00
Allosmerus elongatus	whitebait smelt	2	8	58.44
Fish Fragments				
larval fish fragment	larval fish fragments	1	4	29.22
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	210	840	6,136.58
Engraulidae (eggs)	anchovy eggs	1	4	29.22

(continued)

Survey: HuB008 (continued) Start Date: 08/18/2022

Cycle: 2	Sample: 11	Station: SW3		
Split Multiplier: 1	Volume: 110.18			
Egg Jar Volume: 30	Egg Total Volume: 300			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	44	44	399.36
Allosmerus elongatus	whitebait smelt	2	2	18.15
Clevelandia ios	arrow goby	1	1	9.08
Rhinogobiops nicholsii	blackeye goby	1	1	9.08
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	77	770	6,988.82

Cycle: 2	Sample: 12	Station: E1		
Split Multiplier: 2	Volume: 128.54			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	55	110	855.74
Clevelandia ios	arrow goby	8	16	124.47
Syngnathidae	pipefishes	1	2	15.56
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	404	808	6,285.81
Engraulidae (eggs)	anchovy eggs	2	4	31.12

Cycle: 2	Sample: 13	Station: E2		
Split Multiplier: 2	Volume: 109.14			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	169	338	3,096.93
Lepidogobius lepidus	bay goby	21	42	384.83
Gillichthys mirabilis	longjaw mudsucker	1	2	18.33
Fish Fragments				
larval fish fragment	larval fish fragments	4	8	73.30
Non-Entrainable Fishes				
Hypomesus pretiosus	surf smelt	2	4	36.65
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	206	412	3,774.95

(continued)

Survey: HuB008 (continued)

Start Date: 08/18/2022

Cycle: 2	Sample: 14	Station: SW2		
Split Multiplier: 4	Volume: 131.29			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	227	908	6,916.08
Lepidogobius lepidus	bay goby	3	12	91.40
Hypomesus pretiosus	surf smelt	2	8	60.93
Engraulis mordax	northern anchovy	1	4	30.47
Fish Fragments				
larval fish fragment	larval fish fragments	4	16	121.87
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	55	220	1,675.70

Cycle: 2	Sample: 15	Station: SW1		
Split Multiplier: 1	Volume: 109.39			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	77	77	703.92
Lepidogobius lepidus	bay goby	3	3	27.43
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	34	34	310.82

Cycle: 2	Sample: 16	Station: SW6		
Split Multiplier: 2	Volume: 104.17			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	370	740	7,103.58
Gillichthys mirabilis	longjaw mudsucker	3	6	57.60
Lepidogobius lepidus	bay goby	2	4	38.40
Porichthys notatus	plainfin midshipman	2	4	38.40
Hypomesus pretiosus	surf smelt	1	2	19.20
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	25	50	479.97

Survey: HuB009

Start Date: 09/22/2022

Cycle: 1	Sample: 1	Station: SW1		
Split Multiplier: 1	Volume: 108.41			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	9	9	83.01
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	27	27	249.04

Cycle: 1	Sample: 2	Station: SW2		
Split Multiplier: 2	Volume: 97.39			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	18	36	369.66
Lepidogobius lepidus	bay goby	2	4	41.07
larvae, yolksac	yolksac larvae	1	2	20.54
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	6	12	123.22

Cycle: 1	Sample: 3	Station: E2		
Split Multiplier: 1	Volume: 97.15			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	14	14	144.10
Hypomesus pretiosus	surf smelt	1	1	10.29
larval fish - damaged	damaged larval fishes	1	1	10.29
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	148	148	1,523.35

Cycle: 1	Sample: 4	Station: E1		
Split Multiplier: 1	Volume: 93.68			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	12	12	128.10
Hypomesus pretiosus	surf smelt	1	1	10.67
Icichthys lockingtoni	medusa fish	1	1	10.67
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	367	367	3,917.63
Engraulidae (eggs)	anchovy eggs	16	16	170.80

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Survey: HuB009 (continued) Start Date: 09/22/2022

Cycle: 1	Sample: 5	Station: SW3		
Split Multiplier: 1	Volume: 97.53			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	1	1	10.25
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	349	349	3,578.52
Engraulidae (eggs)	anchovy eggs	14	14	143.55

Cycle: 1	Sample: 6	Station: SW4		
Split Multiplier: 1	Volume: 106.75			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	11	11	103.05
Nannobrachium regalis	pinpoint lanternfish	1	1	9.37
Tarletonbeania crenularis	blue lanternfish	1	1	9.37
Trachipterus altivelis	king-of-the-salmon	1	1	9.37
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	394	394	3,690.99
Engraulidae (eggs)	anchovy eggs	36	36	337.25

Cycle: 1	Sample: 7	Station: SW5		
Split Multiplier: 1	Volume: 110.92			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	1	1	9.02
Fish Fragments				
larval fish fragment	larval fish fragments	1	1	9.02
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	394	394	3,552.14
Engraulidae (eggs)	anchovy eggs	35	35	315.55

Cycle: 1	Sample: 8	Station: SW6		
Split Multiplier: 1	Volume: 81.17			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	5	5	61.60
Lepidogobius lepidus	bay goby	2	2	24.64
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	130	130	1,601.66
Engraulidae (eggs)	anchovy eggs	1	1	12.32

(continued)

Survey: HuB009 (continued) Start Date: 09/22/2022

Cycle: 2	Sample: 9	Station: SW5		
Split Multiplier: 1	Volume: 125.44			
Egg Jar Volume: 30	Egg Total Volume: 300			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Citharichthys stigmaeus	speckled sanddab	1	1	7.97
Nannobrachium spp.	lanternfishes	1	1	7.97
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	57	570	4,543.94
Engraulidae (eggs)	anchovy eggs	3	30	239.15

Cycle: 2	Sample: 10	Station: SW4		
Split Multiplier: 1	Volume: 93.34			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	474	474	5,078.14
Engraulidae (eggs)	anchovy eggs	29	29	310.69

Cycle: 2	Sample: 11	Station: SW3		
Split Multiplier: 1	Volume: 90.22			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	3	3	33.25
Rhinogobiops nicholsii	blackeye goby	1	1	11.08
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	240	240	2,660.20
Engraulidae (eggs)	anchovy eggs	10	10	110.84

Cycle: 2	Sample: 12	Station: E1		
Split Multiplier: 1	Volume: 122.51			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	22	22	179.57
Leptocottus armatus	Pacific staghorn sculpin	1	1	8.16
Rhinogobiops nicholsii	blackeye goby	1	1	8.16
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	274	274	2,236.49
Engraulidae (eggs)	anchovy eggs	5	5	40.81

(continued)

Survey: HuB009 (continued)

Start Date: 09/22/2022

Cycle: 2	Sample: 13	Station: E2		
Split Multiplier: 1	Volume: 105.96			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	49	49	462.44
Clevelandia ios	arrow goby	3	3	28.31
Allosmerus elongatus	whitebait smelt	1	1	9.44
Nannobrachium regalis	pinpoint lanternfish	1	1	9.44
Rhinogobiops nicholsii	blackeye goby	1	1	9.44
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	185	185	1,745.96
Engraulidae (eggs)	anchovy eggs	4	4	37.75

Cycle: 2	Sample: 14	Station: SW2		
Split Multiplier: 1	Volume: 90.30			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	23	23	254.72
Clevelandia ios	arrow goby	13	13	143.97
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	74	74	819.53
Engraulidae (eggs)	anchovy eggs	1	1	11.07

Cycle: 2	Sample: 15	Station: SW1		
Split Multiplier: 1	Volume: 92.85			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Hypomesus pretiosus	surf smelt	1	1	10.77
Lepidogobius lepidus	bay goby	1	1	10.77
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	316	316	3,403.23
Engraulidae (eggs)	anchovy eggs	2	2	21.54
Targeted Invertebrates				
Romal. anten./Metacar. grac. (megalops)	cancer crabs	1	1	10.77

(continued)

Survey: HuB009 (continued) Start Date: 09/22/2022

Cycle: 2	Sample: 16	Station: SW6		
Split Multiplier: 1	Volume: 84.70			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	53	53	625.71
Trachipterus altivelis	king-of-the-salmon	1	1	11.81
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	410	410	4,840.40
Engraulidae (eggs)	anchovy eggs	2	2	23.61

Survey: HuB010 | Start Date: 10/11/2022

Cycle: 1	Sample: 1	Station: SW1		
Split Multiplier: 1	Volume: 91.49			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	1	1	10.93
Lepidogobius lepidus	bay goby	1	1	10.93
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	12	12	131.17

Cycle: 1	Sample: 2	Station: SW2		
Split Multiplier: 1	Volume: 110.66			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	6	6	54.22
Lepidogobius lepidus	bay goby	4	4	36.15
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	20	20	180.73

Cycle: 1	Sample: 3	Station: E2		
Split Multiplier: 1	Volume: 88.50			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	6	6	67.80
Clevelandia ios	arrow goby	2	2	22.60
Icichthys lockingtoni	medusa fish	1	1	11.30
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	263	263	2,971.82

Cycle: 1	Sample: 4	Station: E1		
Split Multiplier: 1	Volume: 85.00			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	36	36	423.53
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	246	246	2,894.09

(continued)

Survey: HuB010 (continued) | Start Date: 10/11/2022

Cycle: 1	Sample: 5	Station: SW3		
Split Multiplier: 1	Volume: 91.12			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	16	16	175.59
Clevelandia ios	arrow goby	1	1	10.97
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	227	227	2,491.24

Cycle: 1	Sample: 6	Station: SW4		
Split Multiplier: 1	Volume: 92.86			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	2	2	21.54
Engraulis mordax	northern anchovy	1	1	10.77
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	29	29	312.29

Cycle: 1	Sample: 7	Station: SW5		
Split Multiplier: 1	Volume: 87.18			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	12	12	137.64
Tarletonbeania crenularis	blue lanternfish	2	2	22.94
Psettichthys melanostictus	sand sole	1	1	11.47
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	50	50	573.51
Engraulidae (eggs)	anchovy eggs	2	2	22.94

Cycle: 1	Sample: 8	Station: SW6		
Split Multiplier: 1	Volume: 106.50			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	3	3	28.17
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	238	238	2,234.84

(continued)

Survey: HuB010 (continued) Start Date: 10/11/2022

Cycle: 2	Sample: 9	Station: SW5		
Split Multiplier: 1	Volume: 91.57			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	2	2	21.84
Clevelandia ios	arrow goby	1	1	10.92
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	58	58	633.38

Cycle: 2	Sample: 10	Station: SW4		
Split Multiplier: 1	Volume: 99.13			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	12	12	121.05
Rhinogobiops nicholsii	blackeye goby	1	1	10.09
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	52	52	524.55

Cycle: 2	Sample: 11	Station: SW3		
Split Multiplier: 1	Volume: 97.34			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	4	4	41.09
Gillichthys mirabilis	longjaw mudsucker	1	1	10.27
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	28	28	287.64

Cycle: 2	Sample: 12	Station: E1		
Split Multiplier: 1	Volume: 96.30			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	4	4	41.54
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	23	23	238.84

(continued)

Survey: HuB010 (continued) Start Date: 10/11/2022

Cycle: 2	Sample: 13	Station: E2		
Split Multiplier: 1	Volume: 98.29			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	3	3	30.52
Gillichthys mirabilis	longjaw mudsucker	1	1	10.17
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	14	14	142.43

Cycle: 2	Sample: 14	Station: SW2		
Split Multiplier: 1	Volume: 96.10			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	13	13	135.27
Gillichthys mirabilis	longjaw mudsucker	1	1	10.41
Non-Entrainable Fishes				
Hypomesus pretiosus	surf smelt	1	1	10.41
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	1	1	10.41

Cycle: 2	Sample: 15	Station: SW1		
Split Multiplier: 1	Volume: 109.19			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	6	6	54.95
Clevelandia ios	arrow goby	1	1	9.16
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	1	1	9.16

Cycle: 2	Sample: 16	Station: SW6		
Split Multiplier: 1	Volume: 95.44			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	5	5	52.39
Clevelandia ios	arrow goby	3	3	31.43
Engraulis mordax	northern anchovy	1	1	10.48
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	13	13	136.21

Survey: HuB011 Start Date: 11/07/2022

Cycle: 1	Sample: 1	Station: SW1		
Split Multiplier: 1	Volume: 86.83			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	2	2	23.03
Engraulis mordax	northern anchovy	1	1	11.52
Genyonemus lineatus	white croaker	1	1	11.52
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	44	44	506.72

Cycle: 1	Sample: 2	Station: SW2		
Split Multiplier: 1	Volume: 100.57			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	9	9	89.49
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	52	52	517.05

Cycle: 1	Sample: 3	Station: E2		
Split Multiplier: 1	Volume: 99.68			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	52	52	521.68
Hypomesus pretiosus	surf smelt	5	5	50.16
Leptocottus armatus	Pacific staghorn sculpin	2	2	20.06
Engraulis mordax	northern anchovy	1	1	10.03
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	60	60	601.94

(continued)

Survey: HuB011 (continued) Start Date: 11/07/2022

Cycle: 1	Sample: 4	Station: E1		
Split Multiplier: 1	Volume: 89.40			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Engraulis mordax	northern anchovy	3	3	33.56
Hypomesus pretiosus	surf smelt	2	2	22.37
Fish Fragments				
larval fish fragment	larval fish fragments	11	11	123.05
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	8	8	89.49
Targeted Invertebrates				
Cancer productus/Romal. spp. (megalops)	rock crab megalops	1	1	11.19

Cycle: 1	Sample: 5	Station: SW3		
Split Multiplier: 1	Volume: 91.89			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Engraulis mordax	northern anchovy	3	3	32.65
Leptocottus armatus	Pacific staghorn sculpin	1	1	10.88
Fish Fragments				
larval fish fragment	larval fish fragments	3	3	32.65
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	4	4	43.53

Cycle: 1	Sample: 6	Station: SW4		
Split Multiplier: 1	Volume: 100.55			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Hypomesus pretiosus	surf smelt	3	3	29.84
Genyonemus lineatus	white croaker	2	2	19.89
Engraulis mordax	northern anchovy	1	1	9.95
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	4	4	39.78

(continued)

Survey: HuB011 (continued) Start Date: 11/07/2022

Cycle: 1	Sample: 7	Station: SW5		
Split Multiplier: 1	Volume: 86.80			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	18	18	207.36
Engraulis mordax	northern anchovy	5	5	57.60
Genyonemus lineatus	white croaker	2	2	23.04
Hexagrammos decagrammus	kelp greenling	1	1	11.52
Hypomesus pretiosus	surf smelt	1	1	11.52
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	19	19	218.88

Cycle: 1	Sample: 8	Station: SW6		
Split Multiplier: 1	Volume: 110.91			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	14	14	126.23
Engraulis mordax	northern anchovy	1	1	9.02
Hypomesus pretiosus	surf smelt	1	1	9.02
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	56	56	504.92

Cycle: 2	Sample: 9	Station: SW5		
Split Multiplier: 1	Volume: 109.80			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	6	6	54.65
Leptocottus armatus	Pacific staghorn sculpin	2	2	18.22
Clevelandia ios	arrow goby	1	1	9.11
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	10	10	91.08

(continued)

Survey: HuB011 (continued) Start Date: 11/07/2022

Cycle: 2	Sample: 10	Station: SW4		
Split Multiplier: 1	Volume: 126.32			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	4	4	31.66
Gillichthys mirabilis	longjaw mudsucker	1	1	7.92
Hypomesus pretiosus	surf smelt	1	1	7.92
Non-Entrainable Fishes				
Hypomesus pretiosus	surf smelt	6	6	47.50
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	22	22	174.16

Cycle: 2	Sample: 11	Station: SW3		
Split Multiplier: 1	Volume: 87.40			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Engraulis mordax	northern anchovy	4	4	45.77
Lepidogobius lepidus	bay goby	2	2	22.88
Leptocottus armatus	Pacific staghorn sculpin	2	2	22.88
Clevelandia ios	arrow goby	1	1	11.44
Gillichthys mirabilis	longjaw mudsucker	1	1	11.44
Non-Entrainable Fishes				
Hypomesus pretiosus	surf smelt	1	1	11.44
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	11	11	125.86

Cycle: 2	Sample: 12	Station: E1		
Split Multiplier: 1	Volume: 83.99			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	1	1	11.91
Non-Entrainable Fishes				
Hypomesus pretiosus	surf smelt	4	4	47.63
Sardinops sagax	Pacific sardine	2	2	23.81
Engraulis mordax	northern anchovy	1	1	11.91
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	8	8	95.26

(continued)

Survey: HuB011 (continued) Start Date: 11/07/2022

Cycle: 2	Sample: 13	Station: E2		
Split Multiplier: 1	Volume: 104.83			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	6	6	57.24
Lepidogobius lepidus	bay goby	3	3	28.62
Engraulis mordax	northern anchovy	1	1	9.54
Leptocottus armatus	Pacific staghorn sculpin	1	1	9.54
Non-Entrainable Fishes				
Clupea pallasii	Pacific herring	1	1	9.54
Hypomesus pretiosus	surf smelt	1	1	9.54
Porichthys notatus	plainfin midshipman	1	1	9.54
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	6	6	57.24
Targeted Invertebrates				
Cancer productus/Romal. spp. (megalops)	rock crab megalops	1	1	9.54

Cycle: 2	Sample: 14	Station: SW2		
Split Multiplier: 1	Volume: 87.49			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Gillichthys mirabilis	longjaw mudsucker	3	3	34.29
Clevelandia ios	arrow goby	2	2	22.86
Leptocottus armatus	Pacific staghorn sculpin	1	1	11.43

(continued)

Survey: HuB011 (continued) Start Date: 11/07/2022

Cycle: 2	Sample: 15	Station: SW1		
Split Multiplier: 1	Volume: 103.58			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	2	2	19.31
Engraulis mordax	northern anchovy	1	1	9.65
Leptocottus armatus	Pacific staghorn sculpin	1	1	9.65
Non-Entrainable Fishes				
Hypomesus pretiosus	surf smelt	1	1	9.65
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	6	6	57.92
Targeted Invertebrates				
Cancer productus/Romal. spp. (megalops)	rock crab megalops	1	1	9.65

Cycle: 2	Sample: 16	Station: SW6		
Split Multiplier: 1	Volume: 88.47			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Non-Entrainable Larval Fishes				
Engraulis mordax	northern anchovy	1	1	11.30
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	8	8	90.43

Survey: HuB012 Start Date: 12/06/2022

Cycle: 1	Sample: 1	Station: SW1		
Split Multiplier: 1	Volume: 104.96			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	10	10	95.28
Leptocottus armatus	Pacific staghorn sculpin	1	1	9.53
Sebastes spp. V	blue rockfish larval complex	1	1	9.53
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	11	11	104.80

Cycle: 1	Sample: 2	Station: SW2		
Split Multiplier: 1	Volume: 110.02			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	27	27	245.40
Clevelandia ios	arrow goby	1	1	9.09
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	20	20	181.78

Cycle: 1	Sample: 3	Station: E2		
Split Multiplier: 1	Volume: 98.69			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	7	7	70.93
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	10	10	101.33

Cycle: 1	Sample: 4	Station: E1		
Split Multiplier: 1	Volume: 121.94			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	19	19	155.82
Leptocottus armatus	Pacific staghorn sculpin	3	3	24.60
Fish Fragments				
larval fish fragment	larval fish fragments	1	1	8.20
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	9	9	73.81

(continued)

Survey: HuB012 (continued)   Start Date: 12/06/2022

Cycle: 1	Sample: 5	Station: SW3		
Split Multiplier: 1	Volume: 118.79			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	12	12	101.02
Leptocottus armatus	Pacific staghorn sculpin	3	3	25.26
Hypomesus pretiosus	surf smelt	1	1	8.42
Liparis spp.	snailfishes	1	1	8.42
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	8	8	67.35

Cycle: 1	Sample: 6	Station: SW4		
Split Multiplier: 1	Volume: 88.41			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Tarletonbeania crenularis	blue lanternfish	1	1	11.31
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	2	2	22.62

Cycle: 1	Sample: 7	Station: SW5		
Split Multiplier: 1	Volume: 110.20			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	5	5	45.37
Leptocottus armatus	Pacific staghorn sculpin	2	2	18.15
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	8	8	72.59

Cycle: 1	Sample: 8	Station: SW6		
Split Multiplier: 1	Volume: 119.50			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	7	7	58.58
Leptocottus armatus	Pacific staghorn sculpin	3	3	25.10
Fish Fragments				
larval fish fragment	larval fish fragments	1	1	8.37
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	18	18	150.62

(continued)

Survey: HuB012 (continued) Start Date: 12/06/2022

Cycle: 2	Sample: 9	Station: SW5		
Split Multiplier: 1	Volume: 103.53			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	16	16	154.54
Clevelandia ios	arrow goby	1	1	9.66
Hypomesus pretiosus	surf smelt	1	1	9.66
Leptocottus armatus	Pacific staghorn sculpin	1	1	9.66
Fish Fragments				
larval fish fragment	larval fish fragments	5	5	48.29
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	4	4	38.64

Cycle: 2	Sample: 10	Station: SW4		
Split Multiplier: 1	Volume: 122.08			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	11	11	90.10
Hypomesus pretiosus	surf smelt	4	4	32.77
Leptocottus armatus	Pacific staghorn sculpin	2	2	16.38
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	18	18	147.44

Cycle: 2	Sample: 11	Station: SW3		
Split Multiplier: 1	Volume: 101.55			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	8	8	78.78
Hypomesus pretiosus	surf smelt	5	5	49.23
Engraulis mordax	northern anchovy	1	1	9.85
Leptocottus armatus	Pacific staghorn sculpin	1	1	9.85
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	14	14	137.86

(continued)

Survey: HuB012 (continued)

Start Date: 12/06/2022

Cycle: 2	Sample: 12	Station: E1		
Split Multiplier: 1	Volume: 101.77			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	15	15	147.39
Engraulis mordax	northern anchovy	2	2	19.65
Hypomesus pretiosus	surf smelt	2	2	19.65
Clevelandia ios	arrow goby	1	1	9.83
Fish Fragments				
larval fish fragment	larval fish fragments	1	1	9.83
Non-Entrainable Fishes				
Engraulis mordax	northern anchovy	1	1	9.83
Hypomesus pretiosus	surf smelt	1	1	9.83
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	14	14	137.57

Cycle: 2	Sample: 13	Station: E2		
Split Multiplier: 1	Volume: 95.54			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	7	7	73.27
Non-Entrainable Fishes				
Hypomesus pretiosus	surf smelt	2	2	20.93
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	2	2	20.93

Cycle: 2	Sample: 14	Station: SW2		
Split Multiplier: 1	Volume: 97.90			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Hypomesus pretiosus	surf smelt	3	3	30.64
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	3	3	30.64

(continued)

Survey: HuB012 (continued) Start Date: 12/06/2022

Cycle: 2	Sample: 15	Station: SW1		
Split Multiplier: 1	Volume: 94.64			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Hypomesus pretiosus	surf smelt	6	6	63.40
Engraulis mordax	northern anchovy	2	2	21.13
Lepidogobius lepidus	bay goby	2	2	21.13
Clevelandia ios	arrow goby	1	1	10.57
Gillichthys mirabilis	longjaw mudsucker	1	1	10.57
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	4	4	42.27

Cycle: 2	Sample: 16	Station: SW6		
Split Multiplier: 1	Volume: 90.48			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Hypomesus pretiosus	surf smelt	6	6	66.31
Lepidogobius lepidus	bay goby	2	2	22.10
Non-Entrainable Fishes				
Hypomesus pretiosus	surf smelt	1	1	11.05
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	6	6	66.31

Appendix B

Sample Information

This appendix presents information on each of samples collected. The data from these samples are presented in Appendix A. The following data are included in this appendix with the column title and definition:

Column Heading	Definition
Date Time	Date and time in PST
Survey	Numeric survey number that corresponds to numeric month of the year
Sample Number	Sample number for survey
Station	Station designation
Cycle	1 = day, 2 = night
Depth (ft)	Depth at location of sampling in feet
Split Multiple	Number of times the sample volume was divided before processing
Sample Volume (m^3)	Volume of seawater filtered for sample in cubic meters (1.0 m^3 = 264.2 gal)
Tide Height (m)	Tide height in m relative to MLLW at time of sampling
Tide Flow	Tidal flow during sampling (E = ebb, F = flood, S = slack)
Tide Change	Location in tide cycle (HH = high high, LH = low high, HL = high low, LL = low low)
Burke-o-lator Temperature (˚C)	Temperature at time of sampling from Burke-o-lator at Hog Island Oyster*
Burke-o-lator Salinity (PSU)	Salinity at time of sampling from Burke-o-lator at Hog Island Oyster*
CTD Salinity (PSU) Top	Salinity at time of sampling from near water surface 0.25m to 0.75m
CTD Salinity (PSU) Middle	Salinity at time of sampling from one meter layer at mid-water of CTD cast
CTD Salinity (PSU) Bottom	Salinity at time of sampling from one meter layer at bottom of CTD cast [1]
CTD Temperature (˚C) Top	Water temperature at time of sampling from near water surface 0.25m to 0.75m
CTD Temperature (˚C) Middle	Water temperature at time of sampling from one meter layer at mid-water of CTD cast
CTD Temperature (˚C) Bottom	Water temperature at time of sampling from one meter layer at bottom of CTD cast

* - data from Burke-o-lator at Hog Island Oyster Company used for Survey 1 due to CTD malfunction. Source: https://data.caloos.org/#metadata/100009/station/data.
1 - salinity data not screened for salinity readings at bottom of cast that may have been affected by sediments suspended from CTD hitting the bottom.

								Tide Information			Data from Burkeolator		Data from CTD Casts					
													Salinity (PSU)			Temperature (C)		
DateTime	Survey	Sample	Station	Cycle	Depth (ft)	Split Multiple	Sample Volume (m^3)	Tide Height (m)	Tide Flow	Tide Change	Temperature (C)	Salinity (PSU)	Top	Middle	Bottom	Top	Middle	Bottom
1/11/2022 9:35	1	1	SW1	1	19	1	81.92	1.51	E	HH-LL	10.45	29.91						
1/11/2022 10:18	1	2	SW2	1	22	1	128.87	1.24	E	HH-LL	10.61	29.52						
1/11/2022 10:45	1	3	EA2	1	19	1	104.52	1.07	E	HH-LL	10.77	29.24						
1/11/2022 11:06	1	4	EA1	1	43	1	80.03	0.94	E	HH-LL	10.73	28.87						
1/11/2022 11:27	1	5	SW3	1	43	1	81.68	0.83	E	HH-LL	10.95	28.61						
1/11/2022 11:54	1	6	SW5	1	44	1	82.54	0.69	E	HH-LL	11.06	28.52						
1/11/2022 12:16	1	7	SW4	1	48	1	80.61	0.59	E	HH-LL	11.05	28.42						
1/11/2022 12:48	1	8	SW6	1	19	1	83.91	0.49	E	HH-LL	11.09	28.29						
1/11/2022 18:25	1	9	SW1	2	20	1	79.61	1.22	F	LL-LH	10.58	28.42						
1/11/2022 19:25	1	10	SW2	2	21	1	93.89	1.34	F	LL-LH	10.69	29.04						
1/11/2022 19:55	1	11	EA2	2	32	1	156.01	1.35	S	LH	10.78	29.40						
1/11/2022 20:25	1	12	EA1	2	46	1	118.68	1.35	E	LH-HL	10.82	29.75						
1/11/2022 20:50	1	13	SW3	2	45	1	95.92	1.33	E	LH-HL	10.80	29.72						
2/10/2022 9:20	2	1	SW1	1	20	1	107.88	1.49	E	HH-LL			32.38	32.67	32.85	10.26	10.13	10.10
2/10/2022 9:59	2	2	SW2	1	22.8	1	105.54	1.27	E	HH-LL			32.34	32.58	32.65	10.37	10.27	10.20
2/10/2022 10:22	2	3	EA2	1	20.1	1	118.12	1.14	E	HH-LL			32.79	32.78	32.81	10.10	10.04	10.05
2/10/2022 10:37	2	4	EA1	1	38.4	1	80.61	1.05	E	HH-LL			32.86	32.86	32.88	10.19	10.11	10.09
2/10/2022 10:55	2	5	SW3	1	43.2	1	102.33	0.95	E	HH-LL			32.88	33.03	33.07	10.17	10.03	10.00
2/10/2022 11:17	2	6	SW4	1	40.3	1	81.46	0.83	E	HH-LL			33.36	33.38	33.40	9.88	9.82	9.81
2/10/2022 11:34	2	7	SW5	1	40.3	1	94.08	0.73	E	HH-LL			33.42	33.46	33.46	10.92	10.12	10.06
2/10/2022 12:24	2	8	SW6	1	20.7	1	82.05	0.50	E	HH-LL			31.41	31.42	31.49	11.19	10.94	10.98
2/10/2022 18:03	2	9	SW1	2	15.8	1	125.69	1.01	F	LL-LH			32.25	32.16	32.16	11.07	11.06	11.03
2/10/2022 18:52	2	10	SW2	2	20.1	1	119.45	1.18	F	LL-LH			32.41	32.41	32.41	10.73	10.75	10.75
2/10/2022 19:25	2	11	EA2	2	19.9	1	98.40	1.27	F	LL-LH			32.50	32.65	32.74	10.67	10.46	10.39
2/10/2022 19:45	2	12	EA1	2	41.3	1	97.74	1.31	F	LL-LH			32.80	33.16	33.21	10.31	10.26	10.25
2/10/2022 20:06	2	13	SW3	2	48.1	1	132.22	1.35	F	LL-LH			33.36	33.41	33.42	10.09	10.02	10.00
2/10/2022 20:40	2	14	SW4	2	46	1	103.85	1.38	F	LL-LH			33.59	33.60	33.60	9.74	9.73	9.74
2/10/2022 21:06	2	15	SW5	2	47.7	1	87.71	1.39	S	LH			33.50	33.56	33.59	10.15	9.71	9.67
2/10/2022 22:05	2	16	SW6	2	22.3	1	110.01	1.37	E	LH-HL			32.44	32.68	32.77	10.49	10.39	10.46

								Tide Information			Data from Burkeolator		Data from CTD Casts: Salinity (PSU)			Data from CTD Casts: Temperature (C)		
DateTime	Survey	Sample	Station	Cycle	Depth (ft)	Split Multiple	Sample Volume (m^3)	Tide Height (m)	Tide Flow	Tide Change	Temperature (C)	Salinity (PSU)	Top	Middle	Bottom	Top	Middle	Bottom
3/17/2022 8:17	3	1	SW1	1	18	1	117.54	1.44	F	HL-HH			21.44	33.09	33.01	11.84	11.84	11.84
3/17/2022 8:58	3	2	SW2	1	22	1	100.11	1.68	F	HL-HH			33.07	33.10	33.10	11.87	11.89	11.89
3/17/2022 9:29	3	3	EA2	1	26	1	114.44	1.83	F	HL-HH			33.26	33.37	33.38	11.13	10.75	10.69
3/17/2022 10:20	3	4	EA1	1	48	1	100.72	2.01	F	HL-HH			33.43	33.57	33.57	10.54	9.96	9.93
3/17/2022 10:48	3	5	SW3	1	48	1	98.51	2.05	S	HH			33.61	33.62	33.62	9.93	9.79	9.75
3/17/2022 11:19	3	6	SW4	1	52	1	102.72	2.05	E	HH-LL			33.61	33.63	33.63	9.95	9.78	9.73
3/17/2022 12:04	3	7	SW5	1	48	1	84.24	1.92	E	HH-LL			33.56	33.65	33.67	10.34	9.78	9.70
3/17/2022 12:56	3	8	SW6	1	25	1	114.43	1.63	E	HH-LL			33.16	33.21	33.22	12.13	11.94	11.90
3/17/2022 18:50	3	9	SW5	2	41	1	102.21	0.22	F	LL-LH			33.45	33.50	33.54	11.97	11.50	11.18
3/17/2022 19:10	3	10	SW4	2	47	1	106.94	0.34	F	LL-LH			33.40	33.41	33.41	11.26	11.10	11.09
3/17/2022 19:37	3	11	SW3	2	40	1	158.82	0.51	F	LL-LH			33.02	33.14	33.14	12.27	12.33	12.32
3/17/2022 20:00	3	12	EA1	2	42	1	101.99	0.68	F	LL-LH			33.08	33.11	33.12	12.63	12.59	12.55
3/17/2022 20:19	3	13	EA2	2	16	1	93.70	0.82	F	LL-LH			32.94	33.00	31.62	12.97	12.98	12.98
3/17/2022 20:48	3	14	SW2	2	20	1	105.42	1.04	F	LL-LH			32.93	32.94	32.95	13.39	13.41	13.41
3/17/2022 21:30	3	15	SW1	2	20	1	114.46	1.34	F	LL-LH			33.03	33.06	33.06	12.58	12.63	12.64
3/17/2022 21:54	3	16	SW6	2	24	1	100.59	1.50	F	LL-LH			32.96	33.04	33.08	12.44	12.34	12.26
4/26/2022 8:57	4	1	SW1	1	17	1	110.73	1.68	E	LH-LL			9.74	31.57	31.59	11.83	11.77	11.75
4/26/2022 9:45	4	2	SW2	1	19	1	153.39	1.51	E	LH-LL			31.29	31.41	31.39	12.18	12.02	11.91
4/26/2022 10:08	4	3	EA2	1	23	1	105.50	1.40	E	LH-LL			31.10	32.48	31.99	11.10	10.76	10.70
4/26/2022 10:21	4	4	EA1	1	42	1	92.63	1.33	E	LH-LL			32.13	32.63	32.68	11.34	10.61	10.55
4/26/2022 10:39	4	5	SW3	1	47	1	116.58	1.22	E	LH-LL			31.71	32.70	32.87	11.08	10.56	10.33
4/26/2022 11:03	4	6	SW4	1	48	1	82.58	1.07	E	LH-LL			32.96	33.16	33.20	10.42	9.95	9.87
4/26/2022 11:19	4	7	SW5	1	36	1	80.12	0.96	E	LH-LL			32.80	32.89	33.05	10.81	10.54	10.08
4/26/2022 12:08	4	8	SW6	1	25	1	114.46	0.62	E	LH-LL			30.46	30.49	27.50	13.38	13.30	13.27
4/26/2022 20:13	4	9	SW5	2	44	1	113.95	1.75	F	LL-HH			33.01	33.14	33.14	10.39	10.24	10.24
4/26/2022 20:33	4	10	SW4	2	52	1	74.98	1.81	F	LL-HH			32.94	33.23	33.23	10.25	10.28	10.28
4/26/2022 21:07	4	11	SW3	2	42	1	102.69	1.87	S	HH			31.74	32.91	32.95	11.20	10.72	10.47
4/26/2022 21:25	4	12	EA1	2	46	1	101.29	1.87	S	HH			32.62	32.80	32.84	11.13	10.91	10.87
4/26/2022 21:40	4	13	EA2	2	26	1	100.28	1.86	E	HH-HL			30.61	32.63	32.63	11.93	11.18	11.19

								Tide Information			Data from Burkeolator		Data from CTD Casts: Salinity (PSU)			Data from CTD Casts: Temperature (C)		
DateTime	Survey	Sample	Station	Cycle	Depth (ft)	Split Multiple	Sample Volume (m^3)	Tide Height (m)	Tide Flow	Tide Change	Temperature (C)	Salinity (PSU)	Top	Middle	Bottom	Top	Middle	Bottom
4/26/2022 22:11	4	14	SW2	2	23	1	79.62	1.80	E	HH-HL			31.42	31.89	31.89	12.40	12.04	11.96
4/26/2022 23:05	4	15	SW1	2	22	1	74.77	1.58	E	HH-HL			31.31	32.03	31.65	12.25	11.88	11.79
4/26/2022 23:31	4	16	SW6	2	24	1	87.31	1.44	E	HH-HL			31.43	32.24	29.60	12.06	11.64	11.36
5/26/2022 6:57	5	1	SW1	1	22	2	161.37	1.11	F	LL-LH			32.53	32.58	26.93	15.00	14.73	14.82
5/26/2022 7:47	5	2	SW2	1	21	4	129.70	1.33	F	LL-LH			32.46	32.66	32.51	14.66	14.47	14.43
5/26/2022 8:20	5	3	EA2	1	21.4	1	129.34	1.42	F	LL-LH			32.39	33.20	32.45	13.55	11.93	11.73
5/26/2022 8:37	5	4	EA1	1	43	1	85.73	1.45	F	LL-LH			33.32	33.52	32.50	11.63	10.83	10.80
5/26/2022 8:56	5	5	SW3	1	46.6	1	120.19	1.47	S	LH			33.66	33.71	33.80	10.07	9.66	9.02
5/26/2022 9:28	5	6	SW4	1	48.2	2	96.85	1.47	S	LH			33.98	33.93	33.94	8.24	8.07	8.03
5/26/2022 9:50	5	7	SW5	1	42.8	1	101.54	1.44	E	LH-HL			33.64	33.83	33.79	11.18	8.80	8.73
5/26/2022 10:40	5	8	SW6	1	23.8	1	107.97	1.30	E	LH-HL			31.98	32.99	33.34	13.87	12.98	11.59
5/26/2022 19:43	5	9	SW5	2	50	1	95.99	1.87	F	HL-HH			33.92	33.92	33.92	8.38	8.39	8.37
5/26/2022 20:05	5	10	SW4	2	54	2	88.83	1.95	F	HL-HH			33.88	33.88	33.87	8.71	8.69	8.70
5/26/2022 20:35	5	11	SW3	2	47	1	123.18	2.03	F	HL-HH			33.78	33.84	33.50	9.66	9.04	9.02
5/26/2022 20:54	5	12	EA1	2	47	1	102.14	2.06	F	HL-HH			33.78	33.79	33.81	9.54	9.43	9.34
5/26/2022 21:10	5	13	EA2	2	22	1	94.60	2.06	S	HH			33.40	33.64	30.65	11.47	10.50	9.89
5/26/2022 21:39	5	14	SW2	2	28	1	95.17	2.04	E	HH-LL			33.20	33.46	33.51	12.45	11.37	11.21
5/26/2022 22:26	5	15	SW1	2	21	4	85.39	1.89	E	HH-LL			32.82	33.34	33.51	14.17	12.10	11.31
5/26/2022 22:51	5	16	SW6	2	26	1	112.01	1.77	E	HH-LL			32.99	33.39	33.42	12.10	11.75	11.62
6/28/2022 7:54	6	1	SW1	1	10.4	1	117.95	0.30	F	LL-LH			33.41	33.46	31.55	19.60	19.59	19.57
6/28/2022 8:41	6	2	SW2	1	19.3	4	116.98	0.60	F	LL-LH			33.52	33.55	33.54	18.97	19.03	19.04
6/28/2022 9:12	6	3	EA2	1	17.7	4	90.11	0.80	F	LL-LH			33.48	33.46	32.00	18.42	18.20	17.96
6/28/2022 9:28	6	4	EA1	1	39.7	8	97.07	0.91	F	LL-LH			30.24	31.16	31.25	17.38	16.69	16.52
6/28/2022 9:51	6	5	SW3	1	42.4	8	104.14	1.05	F	LL-LH			31.59	33.36	33.36	14.89	14.57	14.43
6/28/2022 10:25	6	6	SW4	1	51.6	4	77.61	1.24	F	LL-LH			32.33	33.43	33.43	12.00	11.41	11.19
6/28/2022 10:54	6	7	SW5	1	35.2	4	87.13	1.37	F	LL-LH			33.37	33.35	33.34	12.19	11.70	11.68
6/28/2022 11:55	6	8	SW6	1	23.1	1	92.15	1.53	F	LL-LH			30.20	26.86	23.22	16.23	15.17	15.27
6/28/2022 20:02	6	9	SW5	2	30	4	99.99	1.62	F	HL-HH			29.63	33.42	33.41	12.32	11.91	11.94
6/28/2022 20:31	6	10	SW4	2	52.5	8	86.60	1.76	F	HL-HH			33.06	33.53	32.60	11.05	10.90	10.96

								Tide Information			Data from Burkeolator		Data from CTD Casts					
													Salinity (PSU)			Temperature (C)		
DateTime	Survey	Sample	Station	Cycle	Depth (ft)	Split Multiple	Sample Volume (m^3)	Tide Height (m)	Tide Flow	Tide Change	Temperature (C)	Salinity (PSU)	Top	Middle	Bottom	Top	Middle	Bottom
6/28/2022 21:07	6	11	SW3	2	48	2	114.62	1.91	F	HL-HH			33.20	33.41	32.68	12.21	12.14	12.05
6/28/2022 21:31	6	12	EA1	2	48	8	100.55	2.00	F	HL-HH			31.57	33.41	33.41	12.29	12.15	12.15
6/28/2022 21:50	6	13	EA2	2	24	4	80.68	2.05	F	HL-HH			33.32	33.42	33.36	14.13	13.17	12.74
6/28/2022 22:26	6	14	SW2	2	16.4	4	100.77	2.13	F	HL-HH			33.23	33.40	32.05	16.46	15.32	14.93
6/28/2022 23:15	6	15	SW1	2	17.4	4	89.75	2.13	E	HH-LL			33.37	33.40	32.08	14.82	14.77	14.59
6/28/2022 23:42	6	16	SW6	2	28	1	86.07	2.07	E	HH-LL			33.04	33.38	33.38	14.64	13.70	13.26
7/29/2022 7:33	7	1	SW1	1	14	1	112.04	0.00	F	LL-LH			33.39	34.11	33.20	20.08	20.12	20.12
7/29/2022 8:17	7	2	SW2	1	17	1	90.26	0.23	F	LL-LH			30.91	34.08	33.93	19.42	19.75	19.70
7/29/2022 8:48	7	3	EA2	1	17	1	85.07	0.42	F	LL-LH			33.25	33.97	33.51	18.83	18.92	18.87
7/29/2022 9:04	7	4	EA1	1	37	1	116.70	0.53	F	LL-LH			32.35	33.89	33.88	18.17	17.91	17.65
7/29/2022 9:27	7	5	SW3	1	43	1	94.02	0.69	F	LL-LH			33.79	33.81	33.79	17.04	16.66	16.12
7/29/2022 9:58	7	6	SW4	1	51	1	46.21	0.90	F	LL-LH			31.72	33.67	33.67	11.46	11.14	10.90
7/29/2022 10:53	7	7	SW5	1	46	1	78.97	1.24	F	LL-LH			33.64	33.63	33.63	12.68	12.17	12.03
7/29/2022 11:55	7	8	SW6	1	34	2	90.24	1.53	F	LL-LH			31.38	33.70	29.34	17.33	15.74	15.79
7/29/2022 19:52	7	9	SW5	2	43	1	97.12	1.21	F	HL-HH			30.61	33.61	33.61	12.81	12.77	12.65
7/29/2022 20:21	7	10	SW4	2	49	1	77.74	1.35	F	HL-HH			33.63	33.64	33.64	12.18	11.55	11.56
7/29/2022 20:57	7	11	SW3	2	45	2	105.08	1.53	F	HL-HH			33.62	33.67	33.65	13.35	13.12	12.78
7/29/2022 21:19	7	12	EA1	2	44	1	95.89	1.65	F	HL-HH			33.26	33.70	33.69	14.30	13.65	13.42
7/29/2022 21:39	7	13	EA2	2	22	1	86.55	1.74	F	HL-HH			31.87	33.69	30.05	15.66	14.30	14.10
7/29/2022 22:14	7	14	SW2	2	20	1	105.56	1.90	F	HL-HH			32.85	33.80	32.57	16.71	16.47	16.38
7/29/2022 22:59	7	15	SW1	2	15	1	97.81	2.05	F	HL-HH			33.70	33.71	30.51	14.35	14.33	14.34
7/29/2022 23:31	7	16	SW6	2	24	1	113.83	2.10	F	HL-HH			29.42	26.90	25.26	13.28	13.08	13.08
8/18/2022 7:56	8	1	SW1	1	13.7	1	99.07	0.94	E	LH-HL			20.42	31.88	30.79	19.07	19.07	19.06
8/18/2022 8:53	8	2	SW2	1	20	1	109.46	0.79	E	LH-HL			32.42	33.58	33.58	19.09	19.13	19.09
8/18/2022 9:21	8	3	EA2	1	18	1	103.09	0.74	E	LH-HL			33.44	33.46	33.46	18.30	18.20	18.15
8/18/2022 9:36	8	4	EA1	1	41	1	99.37	0.73	E	LH-HL			33.47	33.47	33.47	18.00	17.93	17.89
8/18/2022 9:54	8	5	SW3	1	43	1	107.90	0.73	S	HL			33.15	33.40	33.39	17.27	16.97	16.81
8/18/2022 10:26	8	6	SW4	1	47	1	80.98	0.75	F	HL-HH			32.78	33.29	33.29	14.87	14.55	14.30
8/18/2022 10:48	8	7	SW5	1	44.5	1	96.40	0.79	F	HL-HH			33.27	33.30	33.34	13.98	12.77	12.06

								Tide Information			Data from Burkeolator		Data from CTD Casts					
													Salinity (PSU)			Temperature (C)		
DateTime	Survey	Sample	Station	Cycle	Depth (ft)	Split Multiple	Sample Volume (m^3)	Tide Height (m)	Tide Flow	Tide Change	Temperature (C)	Salinity (PSU)	Top	Middle	Bottom	Top	Middle	Bottom
8/18/2022 11:46	8	8	SW6	1	19.6	1	91.75	0.98	F	HL-HH			33.52	33.54	33.53	18.48	18.47	18.26
8/18/2022 19:33	8	9	SW5	2	46	1	128.26	1.31	E	HH-LL			33.23	33.23	33.23	15.37	15.32	14.80
8/18/2022 19:56	8	10	SW4	2	52	4	136.88	1.17	E	HH-LL			33.28	33.28	33.28	12.94	12.88	12.86
8/18/2022 20:28	8	11	SW3	2	44	1	110.18	0.97	E	HH-LL			33.35	33.36	33.36	16.20	16.08	15.87
8/18/2022 20:48	8	12	EA1	2	42	2	128.54	0.85	E	HH-LL			33.42	33.43	33.42	17.25	17.24	17.23
8/18/2022 21:06	8	13	EA2	2	15	2	109.14	0.75	E	HH-LL			33.43	33.46	33.45	17.83	17.81	17.67
8/18/2022 21:38	8	14	SW2	2	19	4	131.29	0.59	E	HH-LL			33.71	33.72	33.67	19.93	19.79	19.50
8/18/2022 22:21	8	15	SW1	2	13	1	109.39	0.43	E	HH-LL			33.70	33.73	33.72	20.54	20.32	20.25
8/18/2022 22:44	8	16	SW6	2	20	2	104.17	0.38	E	HH-LL			33.67	33.71	33.69	20.69	20.59	20.47
9/22/2022 7:37	9	1	SW1	1	13	1	108.41	1.21	F	LL-LH			32.79	33.36	31.51	17.37	17.45	17.47
9/22/2022 8:33	9	2	SW2	1	23	2	97.39	1.48	F	LL-LH			31.80	33.37	29.72	17.36	17.38	17.44
9/22/2022 9:04	9	3	EA2	1	19	1	97.15	1.58	F	LL-LH			32.02	33.26	31.63	16.80	16.71	16.66
9/22/2022 9:25	9	4	EA1	1	45	1	93.68	1.63	F	LL-LH			32.69	32.71	32.72	14.37	14.38	14.39
9/22/2022 9:52	9	5	SW3	1	45	1	97.53	1.67	F	LL-LH			31.86	32.60	32.61	14.29	14.17	14.16
9/22/2022 10:25	9	6	SW4	1	60	1	106.75	1.67	S	LH			30.90	32.63	32.64	14.33	13.62	13.42
9/22/2022 10:51	9	7	SW5	1	47	1	110.92	1.64	E	LH-HL			32.10	32.62	32.63	14.17	13.84	13.77
9/22/2022 11:54	9	8	SW6	1	26	1	81.17	1.48	E	LH-HL			32.67	33.20	33.18	16.97	16.72	16.62
9/22/2022 18:38	9	9	SW5	2	46	1	125.44	1.44	F	HL-HH			32.63	32.62	32.62	14.68	14.64	14.48
9/22/2022 19:01	9	10	SW4	2	50	1	93.34	1.54	F	HL-HH			32.54	32.62	32.62	14.34	14.33	14.29
9/22/2022 19:28	9	11	SW3	2	46	1	90.22	1.66	F	HL-HH			32.09	32.68	32.68	14.67	14.67	14.67
9/22/2022 19:46	9	12	EA1	2	47	1	122.51	1.73	F	HL-HH			32.73	32.73	32.73	14.82	14.80	14.79
9/22/2022 20:02	9	13	EA2	2	21	1	105.96	1.79	F	HL-HH			31.98	32.98	32.60	15.96	15.84	15.65
9/22/2022 20:28	9	14	SW2	2	15	1	90.30	1.87	F	HL-HH			33.03	33.23	32.22	17.07	17.10	17.05
9/22/2022 21:15	9	15	SW1	2	16	1	92.85	1.93	S	HH			32.35	32.92	31.95	15.64	15.72	15.73
9/22/2022 21:38	9	16	SW6	2	22	1	84.70	1.92	E	HH-LL			32.28	32.86	31.72	15.47	15.53	15.55
10/11/2022 7:36	10	1	SW1	1	12	1	91.49	0.77	F	HL-HH			20.72	32.99	32.69	15.11	15.14	15.13
10/11/2022 8:18	10	2	SW2	1	20	1	110.66	1.04	F	HL-HH			32.98	33.02	32.99	15.21	15.24	15.25
10/11/2022 8:47	10	3	EA2	1	19	1	88.50	1.24	F	HL-HH			32.97	32.98	32.97	14.29	14.29	14.28
10/11/2022 9:03	10	4	EA1	1	45	1	85.00	1.36	F	HL-HH			32.94	32.96	32.96	12.90	12.87	12.88

								Tide Information			Data from Burkeolator		Data from CTD Casts					
													Salinity (PSU)			Temperature (C)		
DateTime	Survey	Sample	Station	Cycle	Depth (ft)	Split Multiple	Sample Volume (m^3)	Tide Height (m)	Tide Flow	Tide Change	Temperature (C)	Salinity (PSU)	Top	Middle	Bottom	Top	Middle	Bottom
10/11/2022 9:24	10	5	SW3	1	46	1	91.12	1.51	F	HL-HH			32.97	32.98	32.98	11.38	11.39	11.43
10/11/2022 9:57	10	6	SW4	1	52	1	92.86	1.73	F	HL-HH			32.97	32.99	33.00	10.56	10.50	10.43
10/11/2022 10:16	10	7	SW5	1	36	1	87.18	1.85	F	HL-HH			33.01	33.05	33.05	10.31	10.22	10.19
10/11/2022 11:03	10	8	SW6	1	25	1	106.50	2.08	F	HL-HH			33.02	32.98	32.88	11.89	11.64	11.63
10/11/2022 18:03	10	9	SW5	2	43	1	91.57	-0.04	E	HH-LL			32.95	32.95	32.96	12.62	12.60	12.60
10/11/2022 18:24	10	10	SW4	2	45	1	99.13	-0.09	E	HH-LL			32.88	32.98	32.98	13.93	13.68	13.55
10/11/2022 18:52	10	11	SW3	2	40	1	97.34	-0.10	S	LL			32.99	33.00	33.00	15.35	15.22	15.20
10/11/2022 19:10	10	12	EA1	2	37	1	96.30	-0.08	F	LL-LH			32.98	33.02	33.02	15.65	15.66	15.64
10/11/2022 19:25	10	13	EA2	2	16	1	98.29	-0.04	F	LL-LH			33.01	33.03	32.99	15.73	15.74	15.71
10/11/2022 19:52	10	14	SW2	2	15	1	96.10	0.06	F	LL-LH			33.04	33.06	33.05	16.14	15.88	15.78
10/11/2022 20:42	10	15	SW1	2	17	1	109.19	0.34	F	LL-LH			32.95	33.01	32.86	15.97	15.99	15.98
10/11/2022 21:12	10	16	SW6	2	20	1	95.44	0.55	F	LL-LH			32.95	32.99	30.45	15.35	15.32	15.32
11/7/2022 8:28	11	1	SW1	1	17	1	86.83	1.88	F	HL-HH			32.27	32.38	32.38	11.07	11.10	11.11
11/7/2022 9:06	11	2	SW2	1	24	1	100.57	2.09	F	HL-HH			32.34	32.43	32.44	11.02	11.00	11.00
11/7/2022 9:30	11	3	EA2	1	21	1	99.68	2.19	F	HL-HH			32.39	32.57	32.09	10.82	10.66	10.59
11/7/2022 9:46	11	4	EA1	1	47	1	89.40	2.24	F	HL-HH			32.77	32.80	32.81	10.48	10.49	10.49
11/7/2022 10:09	11	5	SW3	1	47	1	91.89	2.29	F	HL-HH			32.83	32.83	32.83	10.57	10.57	10.57
11/7/2022 10:42	11	6	SW4	1	51	1	100.55	2.29	E	HH-LL			32.80	32.81	32.81	10.57	10.56	10.54
11/7/2022 11:00	11	7	SW5	1	50	1	86.80	2.26	E	HH-LL			32.85	32.87	32.88	10.59	10.57	10.58
11/7/2022 11:49	11	8	SW6	1	26	1	110.91	2.08	E	HH-LL			32.60	32.66	32.67	10.64	10.54	10.47
11/7/2022 17:27	11	9	SW5	2	43	1	109.80	-0.12	F	LL-LH			32.46	32.48	32.53	10.66	10.67	10.68
11/7/2022 17:44	11	10	SW4	2	43	1	126.32	-0.09	F	LL-LH			32.23	32.27	32.27	11.24	11.29	11.28
11/7/2022 18:09	11	11	SW3	2	39	1	87.40	0.00	F	LL-LH			32.04	32.05	32.06	11.43	11.45	11.45
11/7/2022 18:28	11	12	EA1	2	41	1	83.99	0.09	F	LL-LH			31.83	31.99	32.06	11.42	11.54	11.54
11/7/2022 18:42	11	13	EA2	2	27	1	104.83	0.16	F	LL-LH			31.85	31.84	31.84	11.35	11.36	11.36
11/7/2022 19:06	11	14	SW2	2	20	1	87.49	0.31	F	LL-LH			31.49	31.53	31.55	11.22	11.25	11.26
11/7/2022 19:43	11	15	SW1	2	18	1	103.58	0.57	F	LL-LH			31.38	31.46	31.48	11.31	11.35	11.35
11/7/2022 20:11	11	16	SW6	2	21	1	88.47	0.78	F	LL-LH			30.89	31.93	31.04	11.21	11.41	11.44
12/6/2022 8:38	12	1	SW1	1	18	1	104.96	2.20	F	HL-HH			22.46	31.75	31.75	9.64	9.76	9.76

											Data from		Data from CTD Casts					
								Tide Information			Burkeolator		Salinity (PSU)			Temperature (C)		
DateTime	Survey	Sample	Station	Cycle	Depth (ft)	Split Multiple	Sample Volume (m^3)	Tide Height (m)	Tide Flow	Tide Change	Temperature (C)	Salinity (PSU)	Top	Middle	Bottom	Top	Middle	Bottom
12/6/2022 9:41	12	2	SW2	1	25	1	110.02	2.35	S	HH			31.03	31.80	31.84	9.15	9.81	9.85
12/6/2022 10:06	12	3	EA2	1	23	1	98.69	2.35	E	HH-LL			31.90	32.08	32.16	9.92	10.05	10.09
12/6/2022 10:24	12	4	EA1	1	45	1	121.94	2.32	E	HH-LL			31.88	32.11	32.13	10.23	10.21	10.19
12/6/2022 10:44	12	5	SW3	1	48	1	118.79	2.27	E	HH-LL			32.05	32.12	32.17	10.22	10.24	10.24
12/6/2022 11:11	12	6	SW4	1	51	1	88.41	2.16	E	HH-LL			31.96	32.08	32.13	10.24	10.23	10.26
12/6/2022 11:28	12	7	SW5	1	41	1	110.20	2.07	E	HH-LL			32.36	32.38	32.39	10.44	10.43	10.43
12/6/2022 12:17	12	8	SW6	1	25	1	119.50	1.73	E	HH-LL			31.01	31.25	31.26	9.53	9.59	9.61
12/6/2022 16:27	12	9	SW5	2	40	1	103.53	-0.16	E	HH-LL			27.95	31.38	31.82	9.93	10.03	10.14
12/6/2022 17:20	12	10	SW4	2	44	1	122.08	-0.16	F	LL-LH			29.98	30.76	30.81	9.37	9.43	9.45
12/6/2022 17:44	12	11	SW3	2	42	1	101.55	-0.10	F	LL-LH			30.31	30.40	30.45	9.25	9.27	9.27
12/6/2022 18:00	12	12	EA1	2	40	1	101.77	-0.04	F	LL-LH			29.55	30.18	30.42	8.99	9.18	9.24
12/6/2022 18:16	12	13	EA2	2	19	1	95.54	0.03	F	LL-LH			28.66	30.08	30.02	8.88	9.19	9.19
12/6/2022 18:37	12	14	SW2	2	20	1	97.90	0.14	F	LL-LH			26.89	29.55	29.33	8.74	8.96	8.96
12/6/2022 19:14	12	15	SW1	2	16	1	94.64	0.36	F	LL-LH			26.32	29.33	29.27	8.81	9.09	9.09
12/6/2022 19:37	12	16	SW6	2	18	1	90.48	0.52	F	LL-LH			24.44	29.72	26.80	8.81	9.20	9.27

Appendix C

CTD Data Graphs

This appendix presents plots of data collected using an AML Oceanographic AML-3 multiparameter sonde configured to collect conductivity, temperature and depth (pressure) data (CTD). The CTD was configured to collect data at 5 Hz (five samples per second). The CTD instrument was deployed at each of the sampling stations during each sampling event during the study. The CTD was deployed by allowing the instrument to drop through the water column to the bottom and then was pulled back up to the surface. The data from each deployment was filtered to remove data at the surface (measured depths < 0.25m) and also at the deepest 0.15 m depths of the deployment. These data were removed due to potential erroneous salinity readings at the surface when the instrument was potentially out of the water and at the bottom where the salinity probe could be affected by fine sediments suspended at the bottom by the instrument.

There are no plots shown for Survey 1 due to an instrument malfunction.

Survey 2 – 2022-02-10

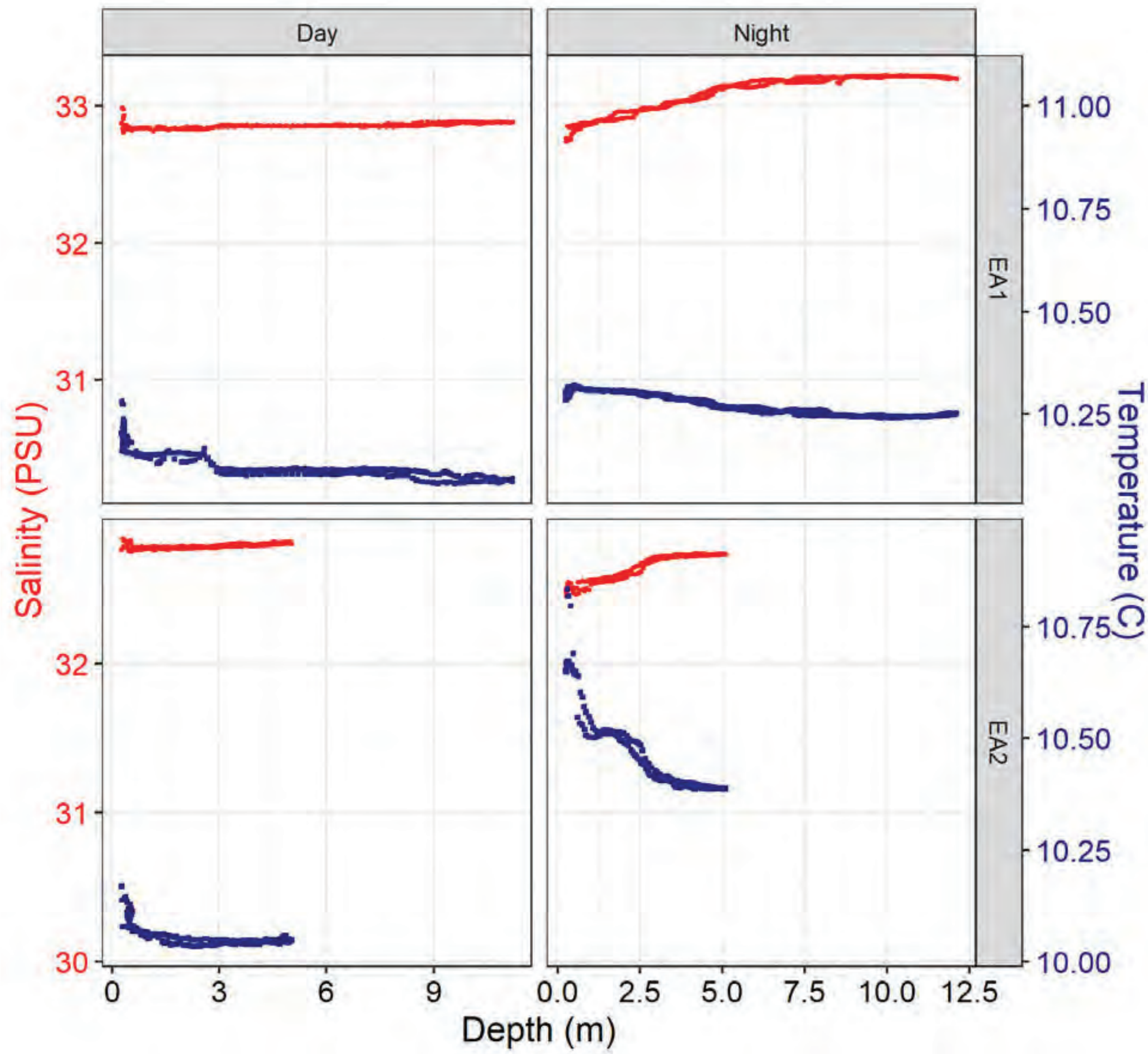

Figure C-1. Plot of Salinity (PSU) and temperature (°C) with depth (m) at entrainment stations EA1 and EA2 during Survey 02 on February 10, 2022 during day and night sampling.

Survey 2 – 2022-02-10

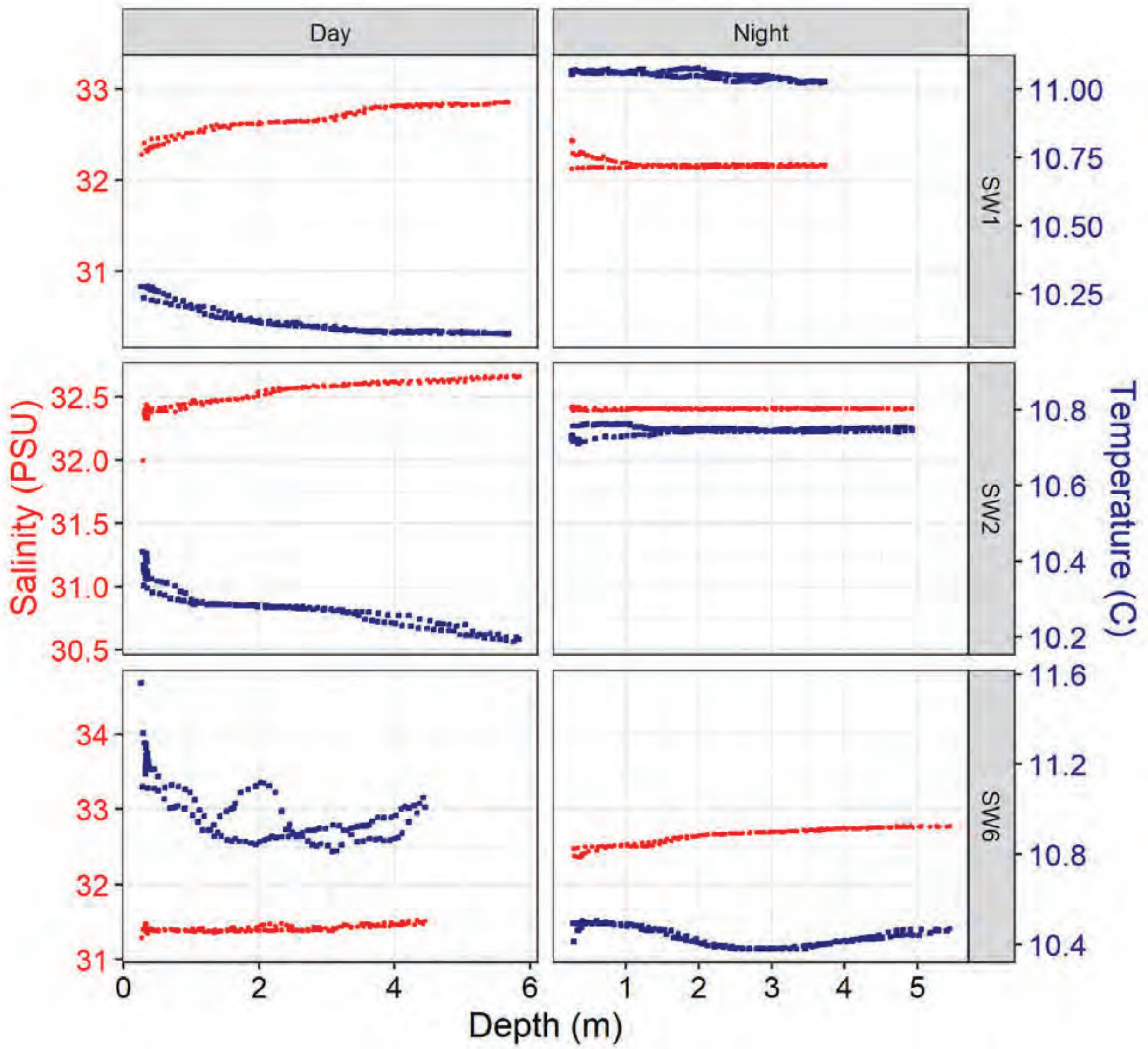

Figure C-2. Plot of Salinity (PSU) and temperature (°C) with depth (m) at source water stations SW1, SW2, and SW6 during Survey 02 on February 10, 2022 during day and night sampling.

Survey 2 – 2022-02-10

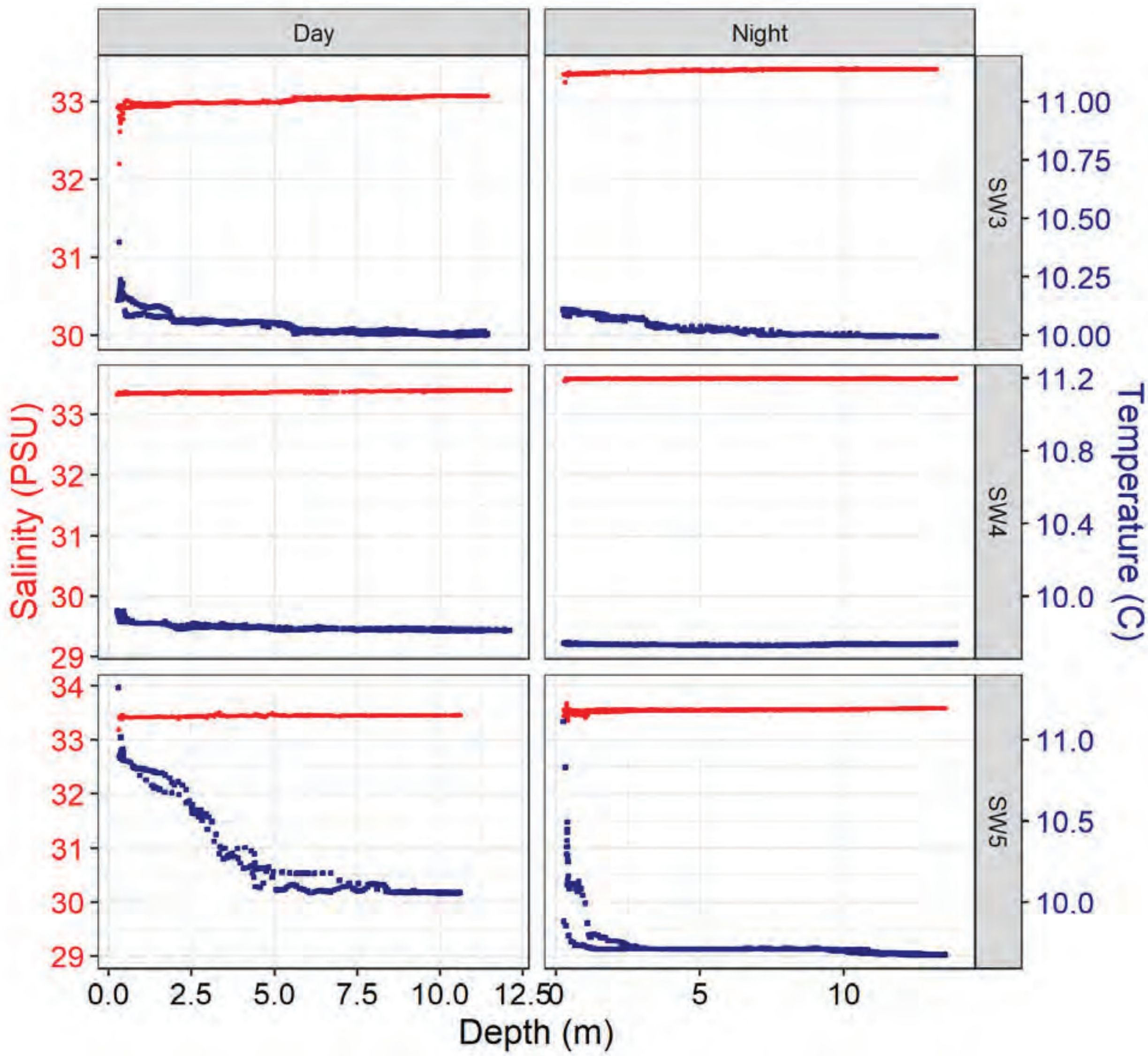

Figure C-3. Plot of Salinity (PSU) and temperature (°C) with depth (m) at source water stations SW3, SW4, and SW5 during Survey 02 on February 10, 2022 during day and night sampling.

Survey 3 – 2022-03-18

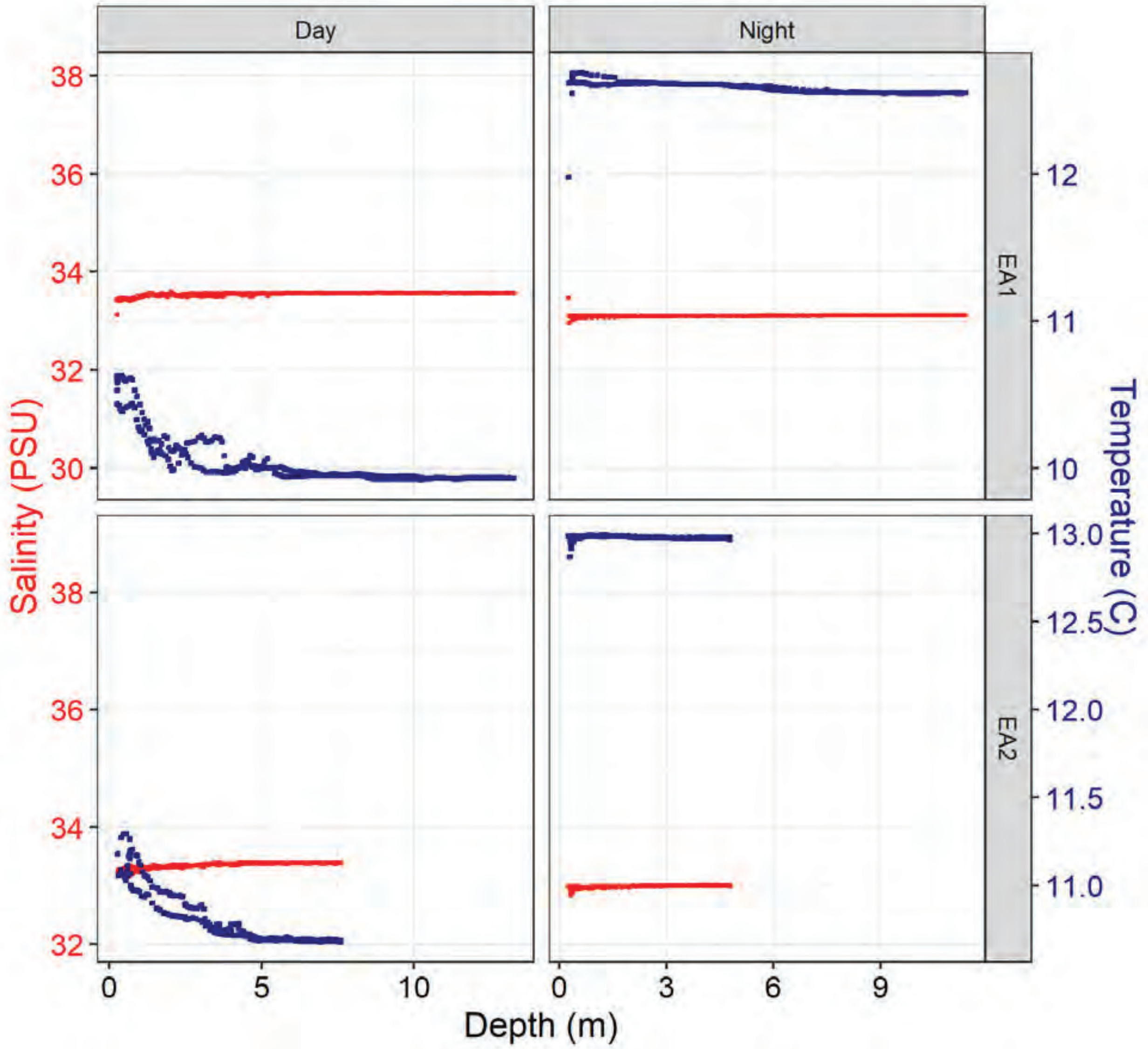

Figure C-4. Plot of Salinity (PSU) and temperature (°C) with depth (m) at entrainment stations EA1 and EA2 during Survey 03 on March 18, 2022 during day and night sampling.

Survey 3 – 2022-03-18

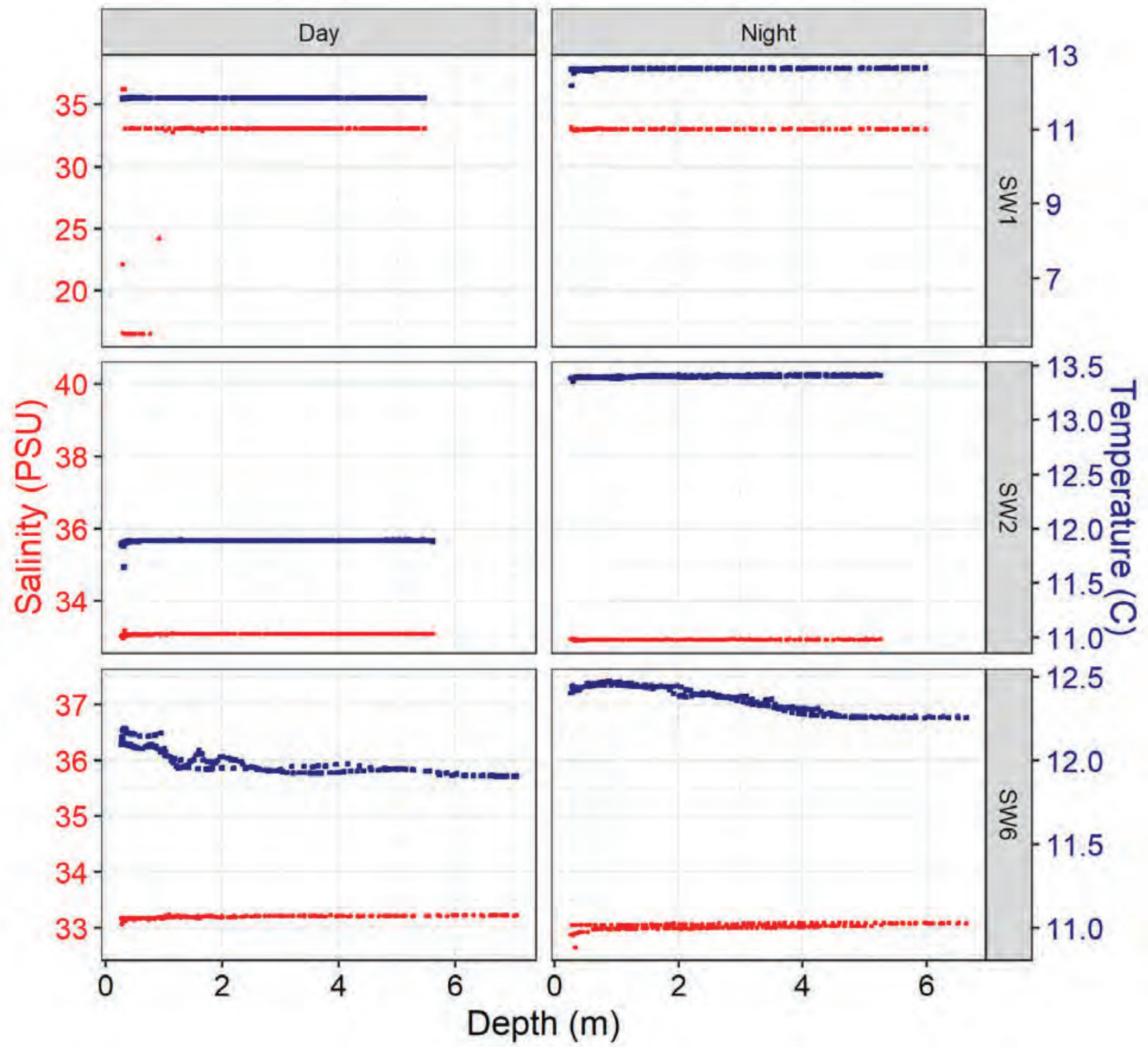

Figure C-5. Plot of Salinity (PSU) and temperature (°C) with depth (m) at source water stations SW1, SW2, and SW6 during Survey 03 on March 18, 2022 during day and night sampling.

Survey 3 – 2022-03-18

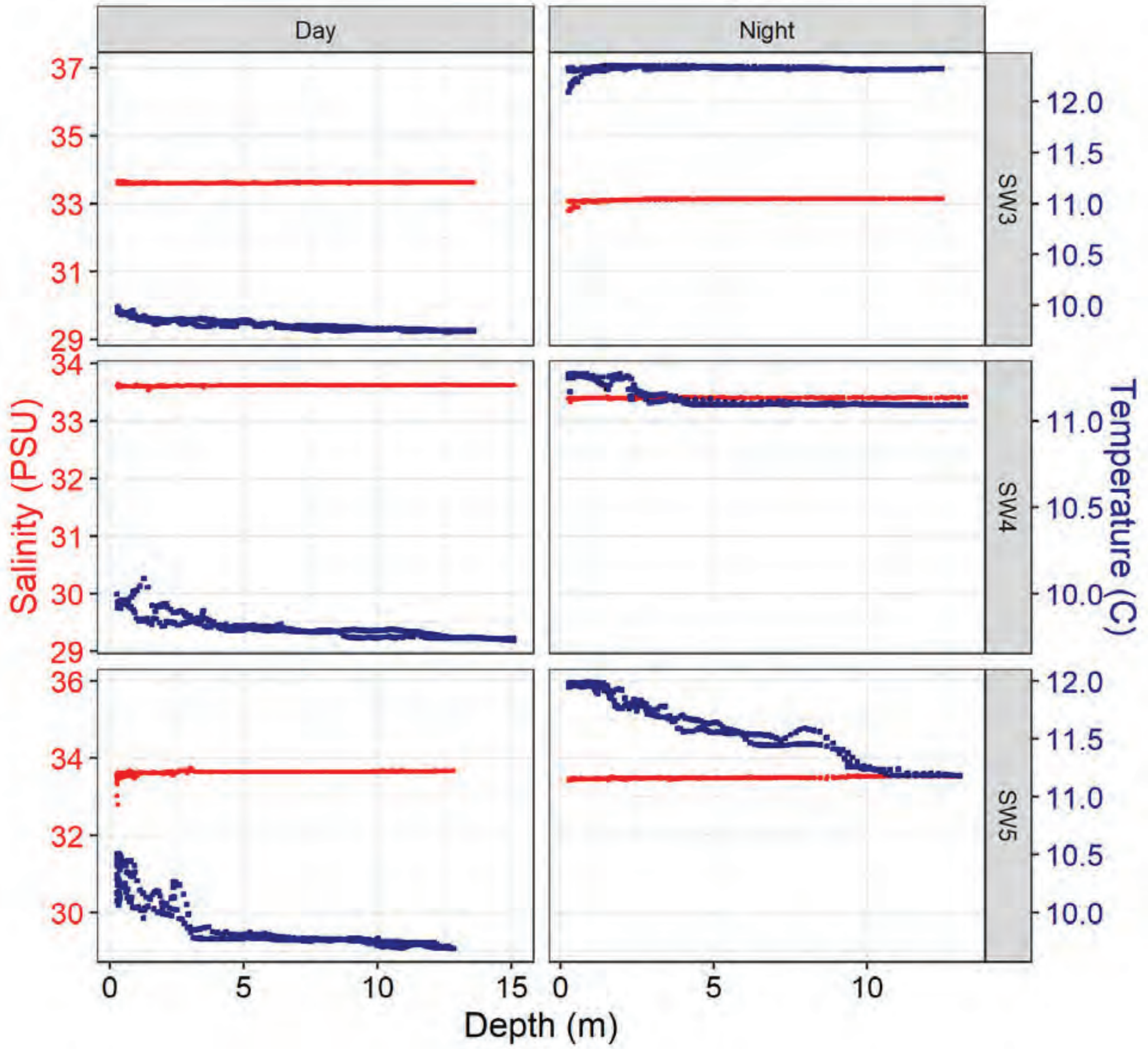

Figure C-6. Plot of Salinity (PSU) and temperature (°C) with depth (m) at source water stations SW3, SW4, and SW5 during Survey 03 on March 18, 2022 during day and night sampling.

Survey 4 – 2022-04-26

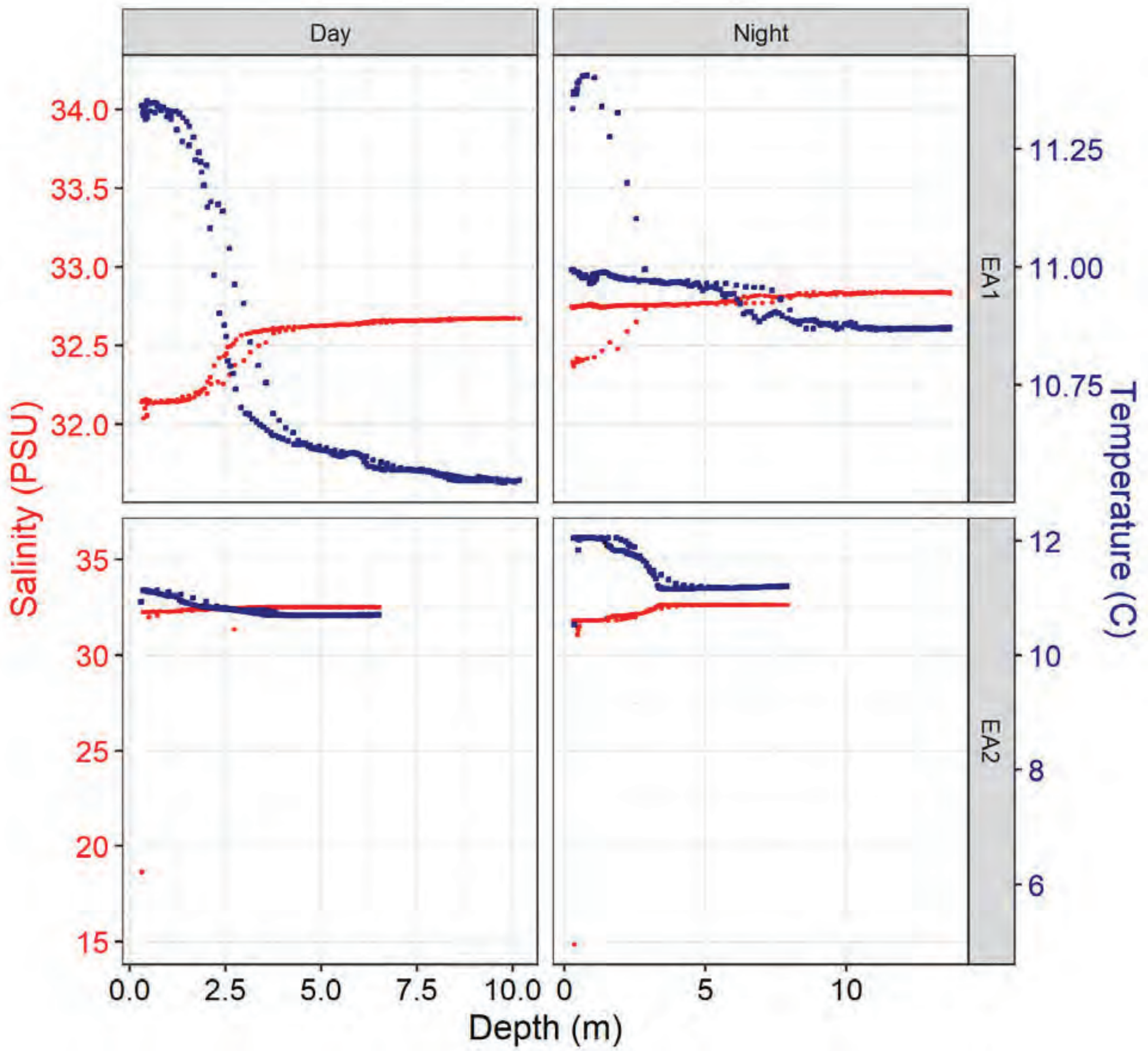

Figure C-7. Plot of Salinity (PSU) and temperature (°C) with depth (m) at entrainment stations EA1 and EA2 during Survey 04 on April 26, 2022 during day and night sampling.

Survey 4 – 2022-04-26

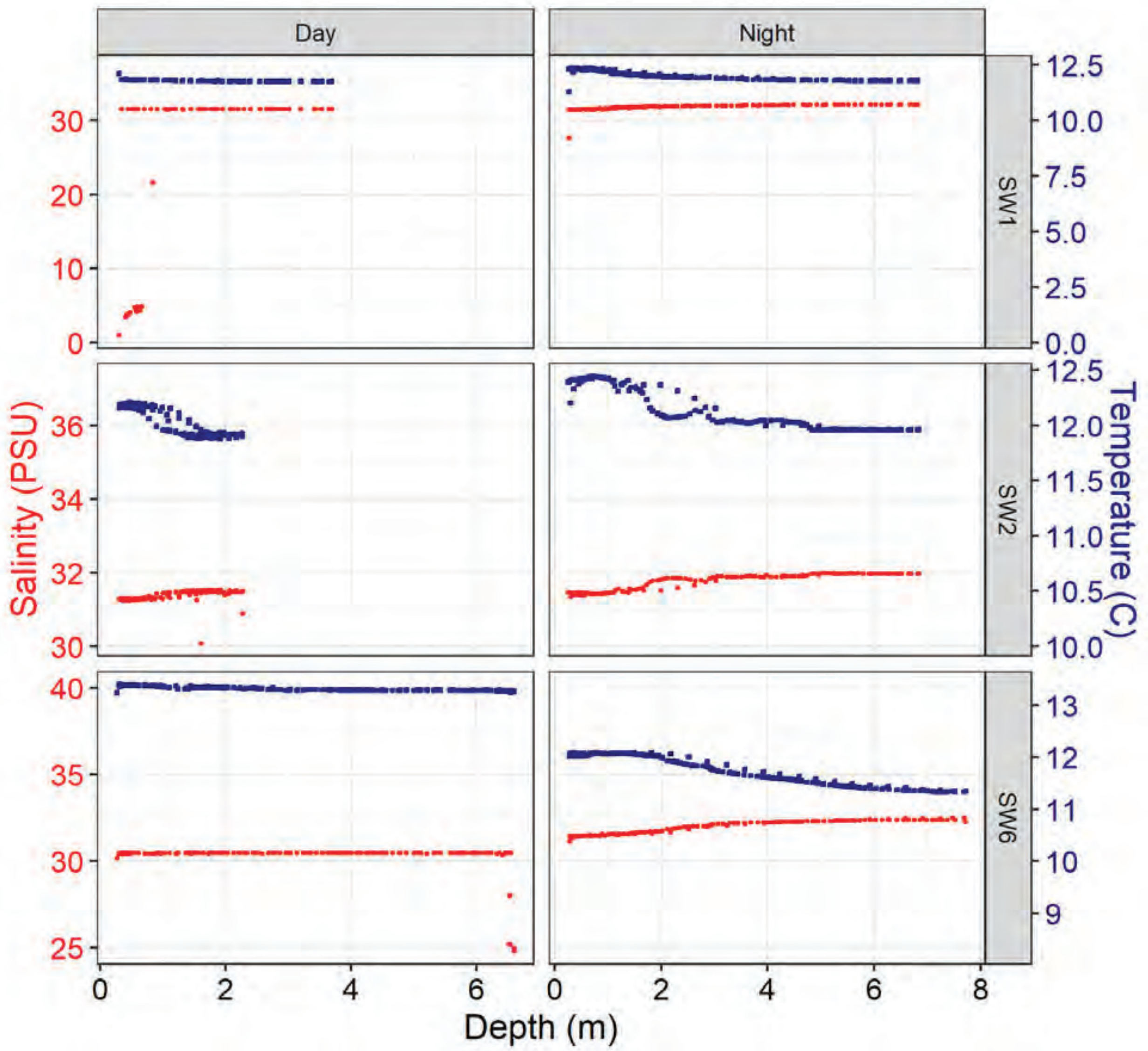

Figure C-8. Plot of Salinity (PSU) and temperature (°C) with depth (m) at source water stations SW1, SW2, and SW6 during Survey 04 on April 26, 2022 during day and night sampling.

Survey 4 – 2022-04-26

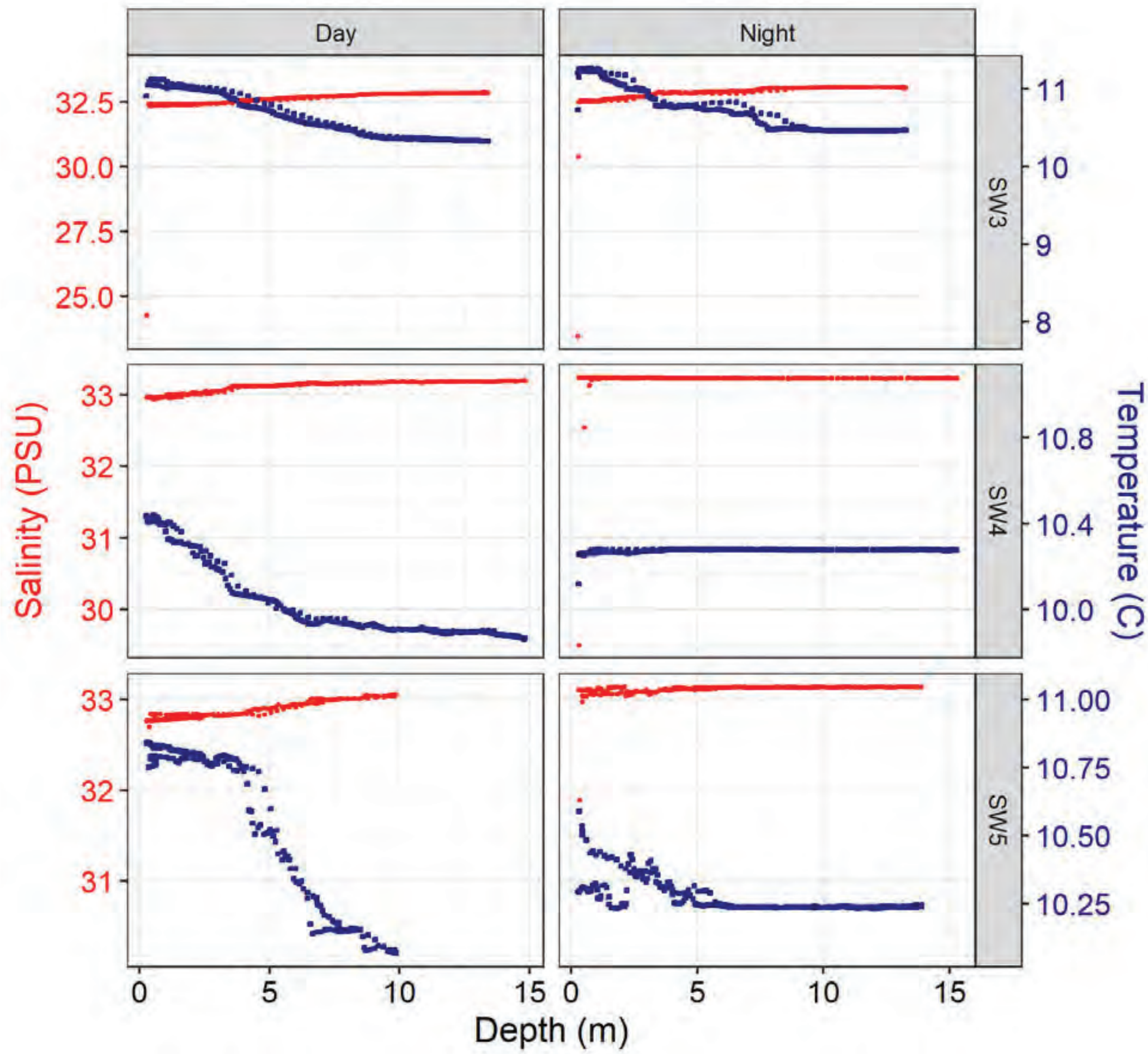

Figure C-9. Plot of Salinity (PSU) and temperature (°C) with depth (m) at source water stations SW3, SW4, and SW5 during Survey 04 on April 26, 2022 during day and night sampling.

Survey 5 – 2022-05-26

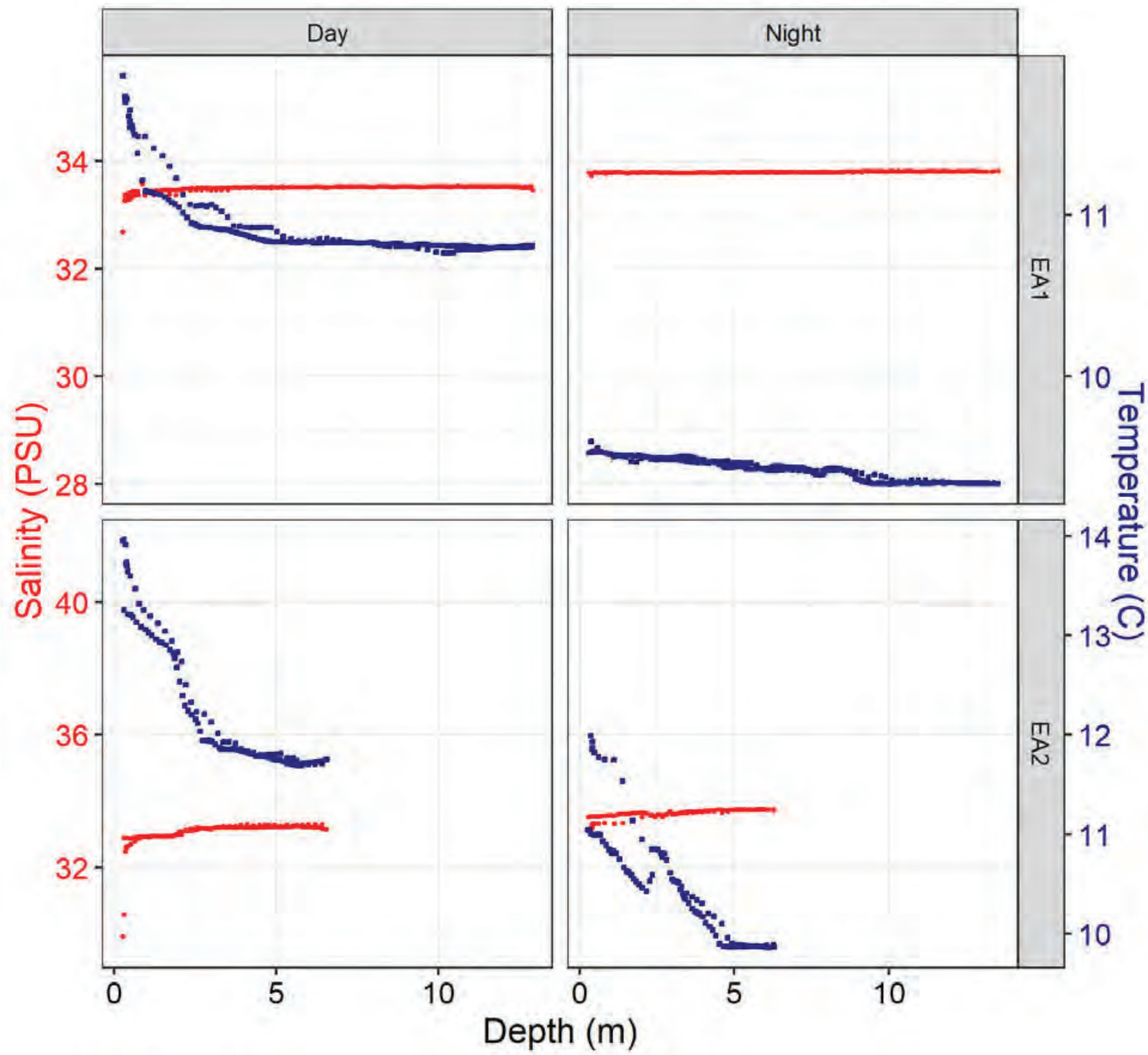

Figure C-10. Plot of Salinity (PSU) and temperature (°C) with depth (m) at entrainment stations EA1 and EA2 during Survey 05 on May 26, 2022 during day and night sampling.

Survey 5 – 2022-05-26

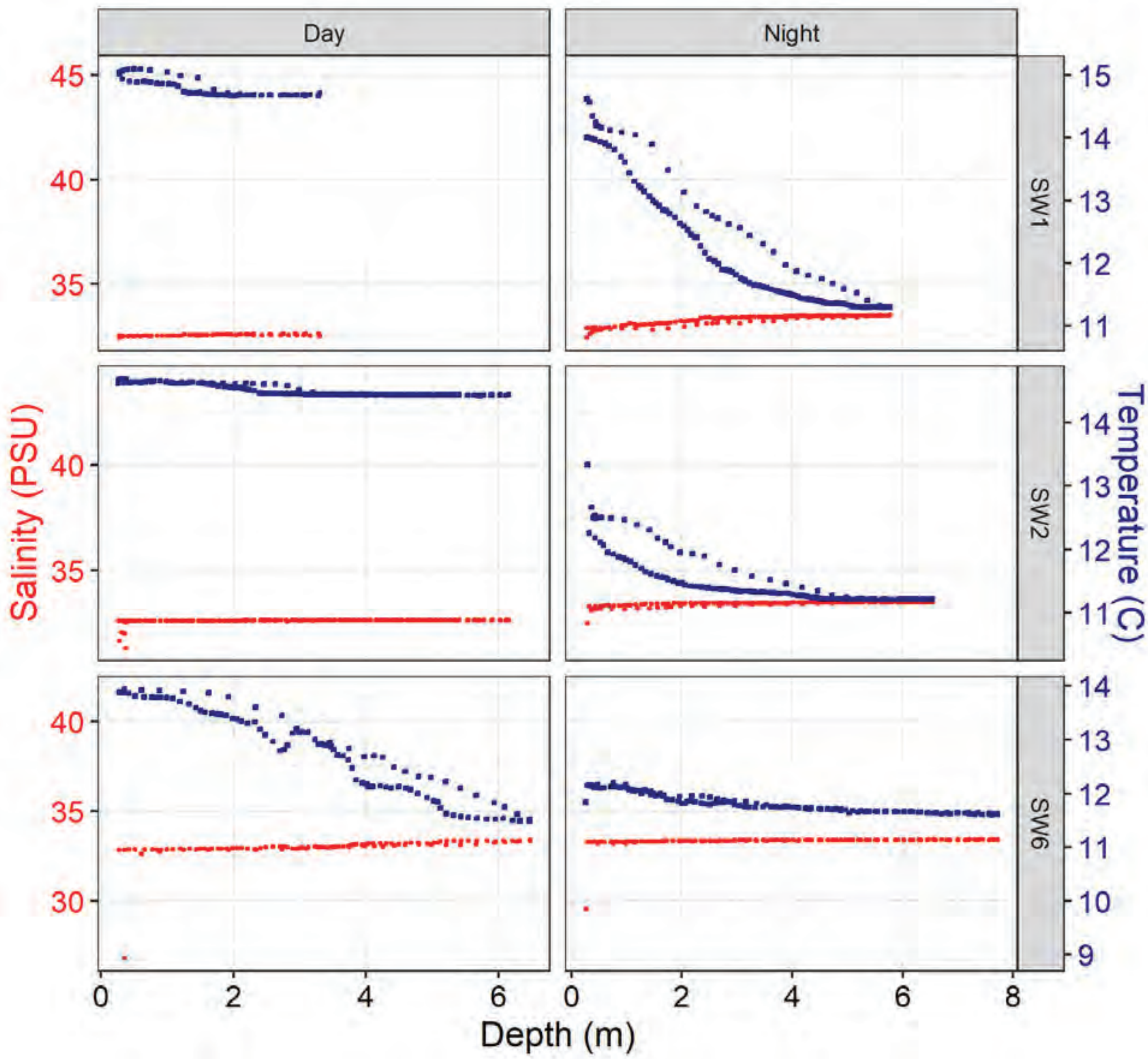

Figure C-11. Plot of Salinity (PSU) and temperature (°C) with depth (m) at source water stations SW1, SW2, and SW6 during Survey 05 on May 26, 2022 during day and night sampling.

Survey 5 – 2022-05-26

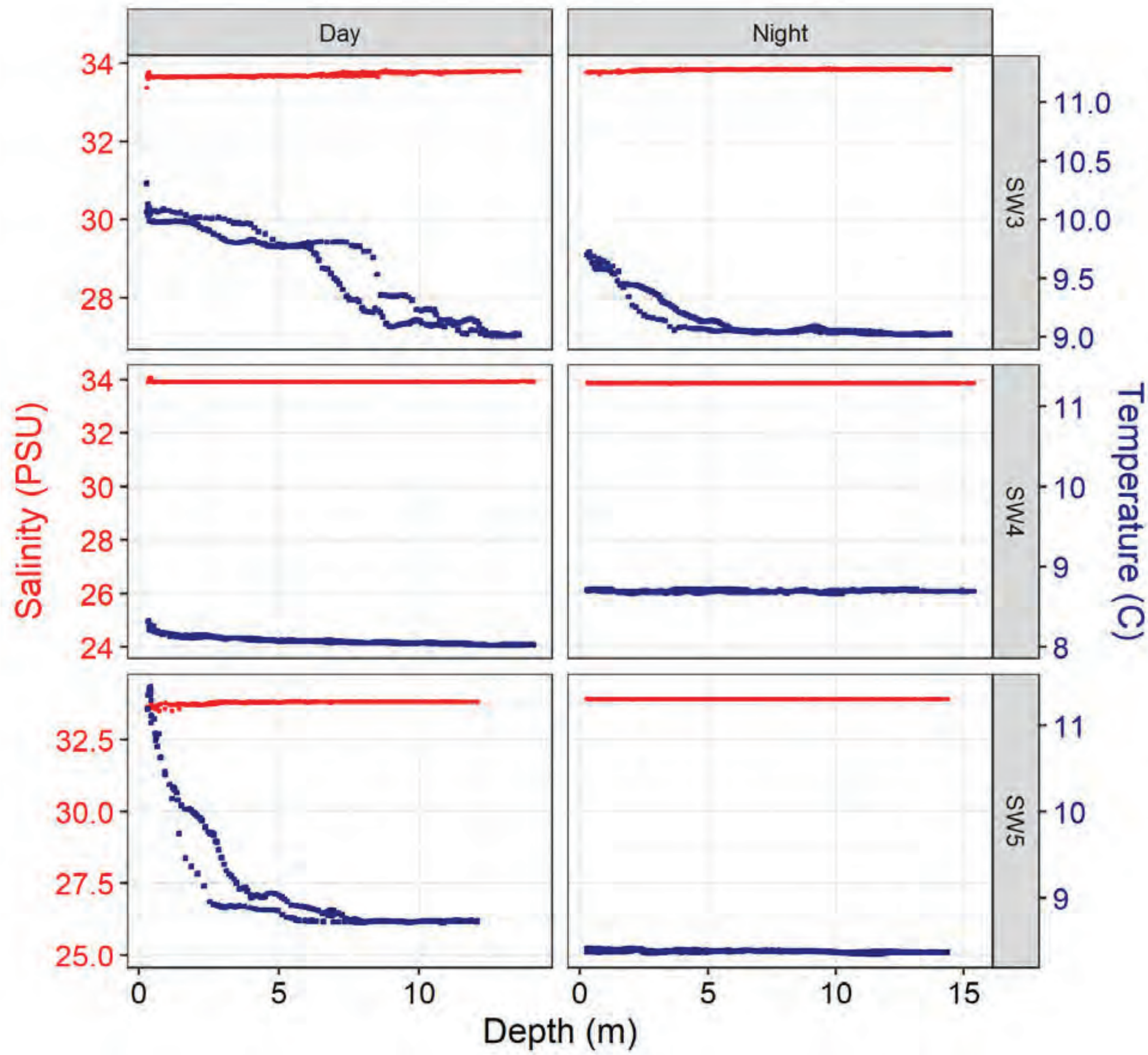

Figure C-12. Plot of Salinity (PSU) and temperature (°C) with depth (m) at source water stations SW3, SW4, and SW5 during Survey 05 on May 26, 2022 during day and night sampling.

Survey 6 – 2022-06-28

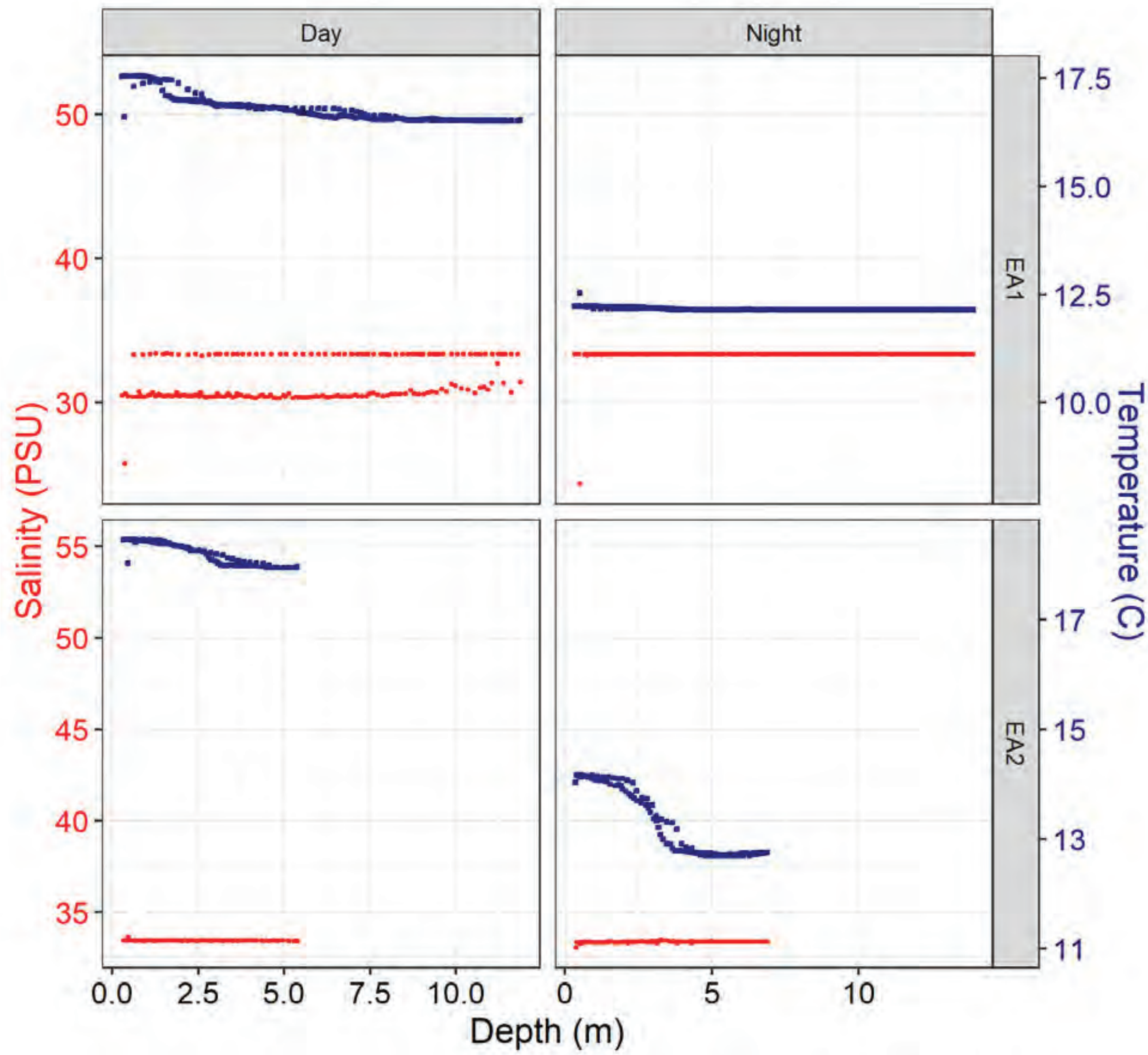

Figure C-13. Plot of Salinity (PSU) and temperature (°C) with depth (m) at entrainment stations EA1 and EA2 during Survey 06 on June 28, 2022 during day and night sampling.

Survey 6 – 2022-06-28

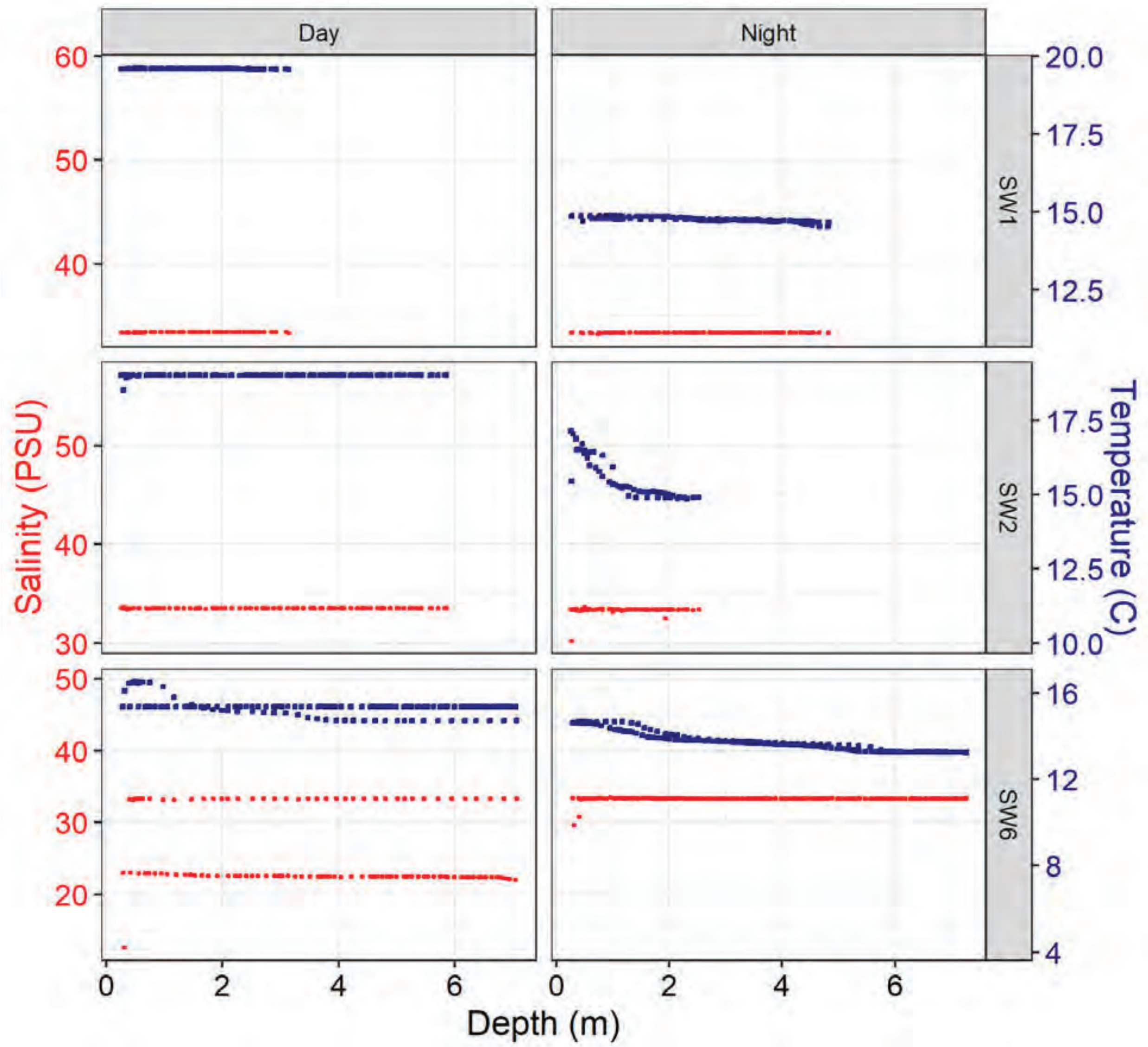

Figure C-14. Plot of Salinity (PSU) and temperature (°C) with depth (m) at source water stations SW1, SW2, and SW6 during Survey 06 on June 28, 2022 during day and night sampling.

Survey 6 – 2022-06-28

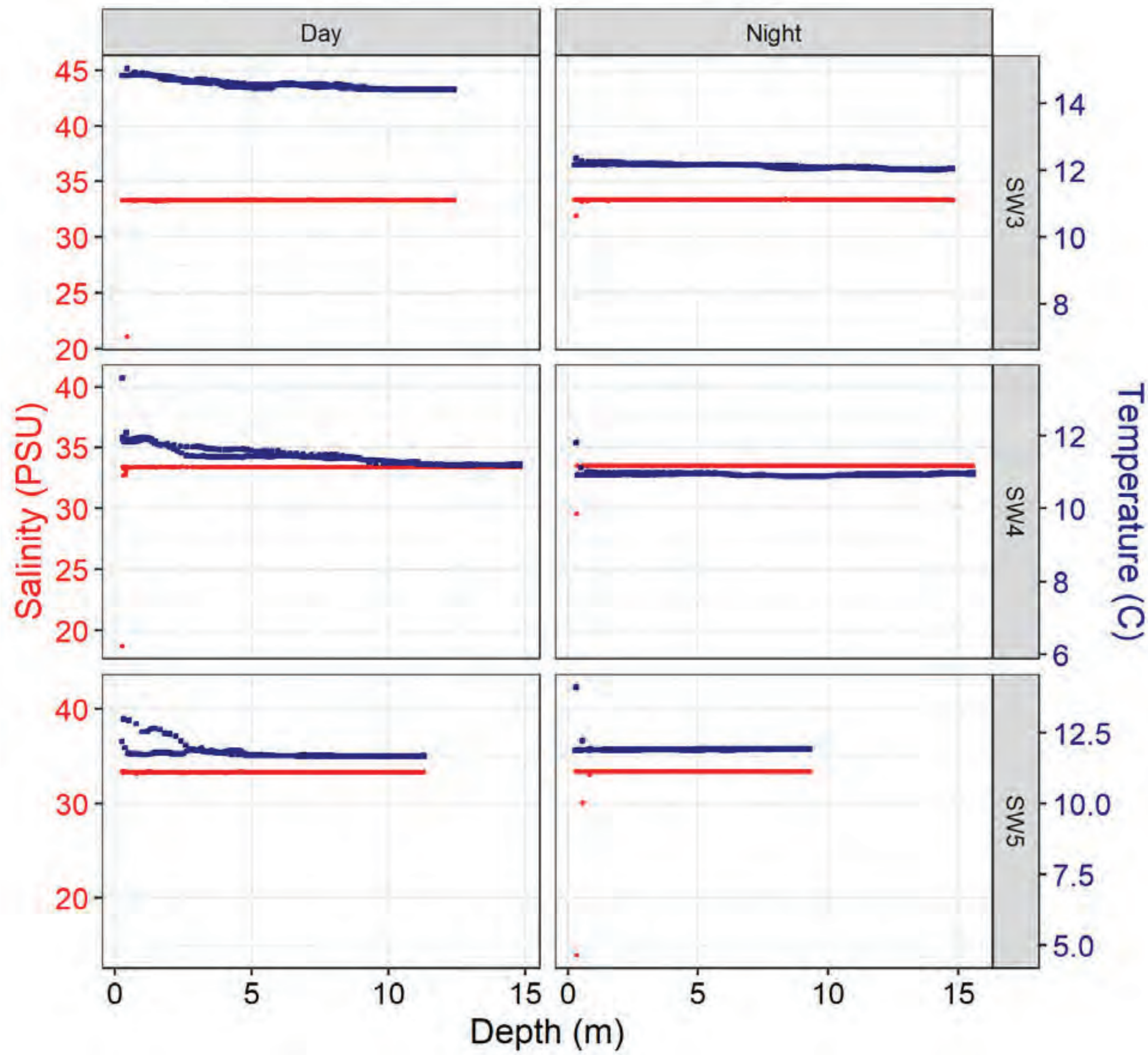

Figure C-15. Plot of Salinity (PSU) and temperature (°C) with depth (m) at source water stations SW3, SW4, and SW5 on Survey 06 on June 28, 2022 during day and night sampling.

Survey 7 – 2022-07-29

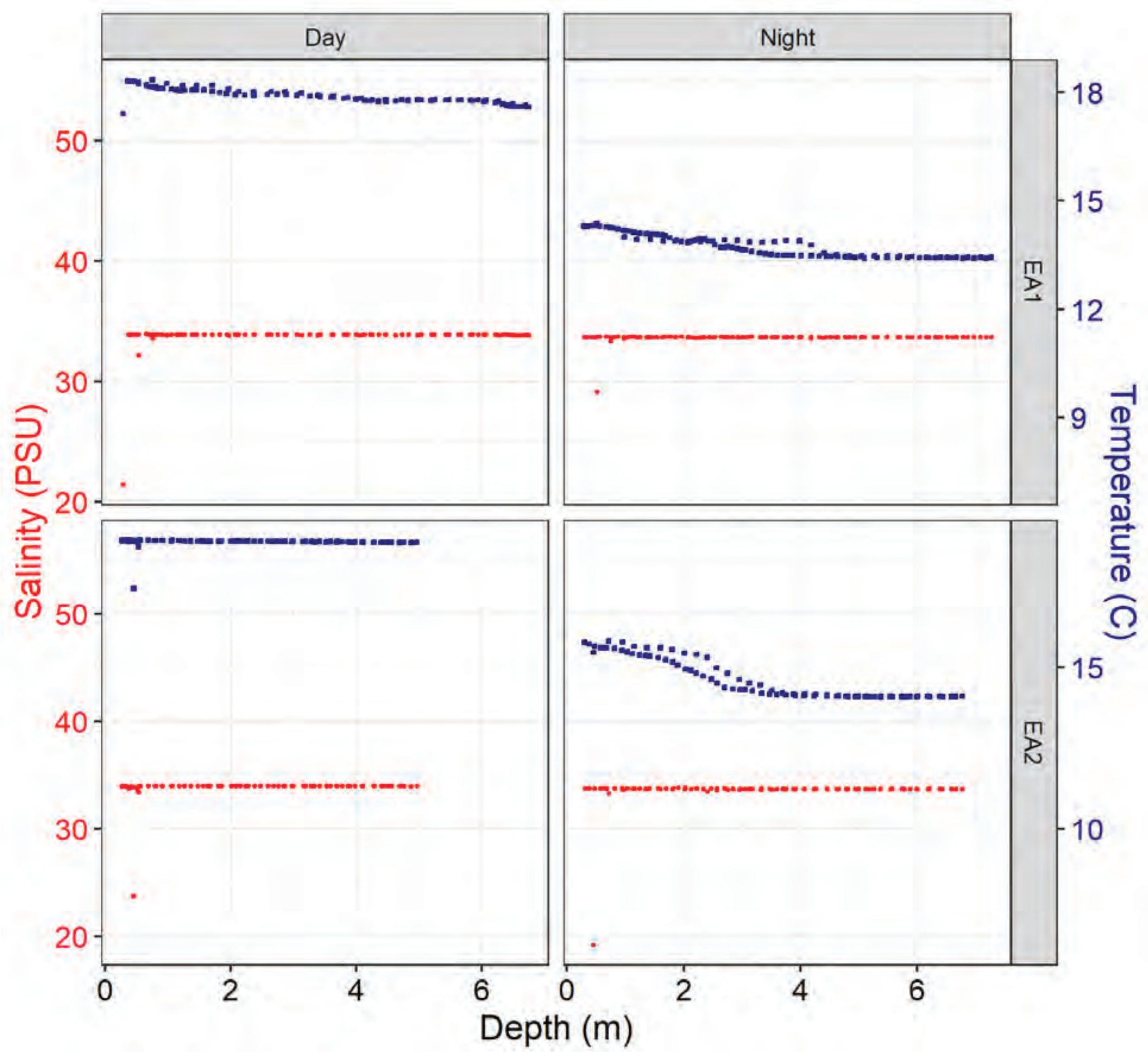

Figure C-16. Plot of Salinity (PSU) and temperature (°C) with depth (m) at entrainment stations EA1 and EA2 during Survey 07 on July 29, 2022 during day and night sampling.

Survey 7 – 2022-07-29

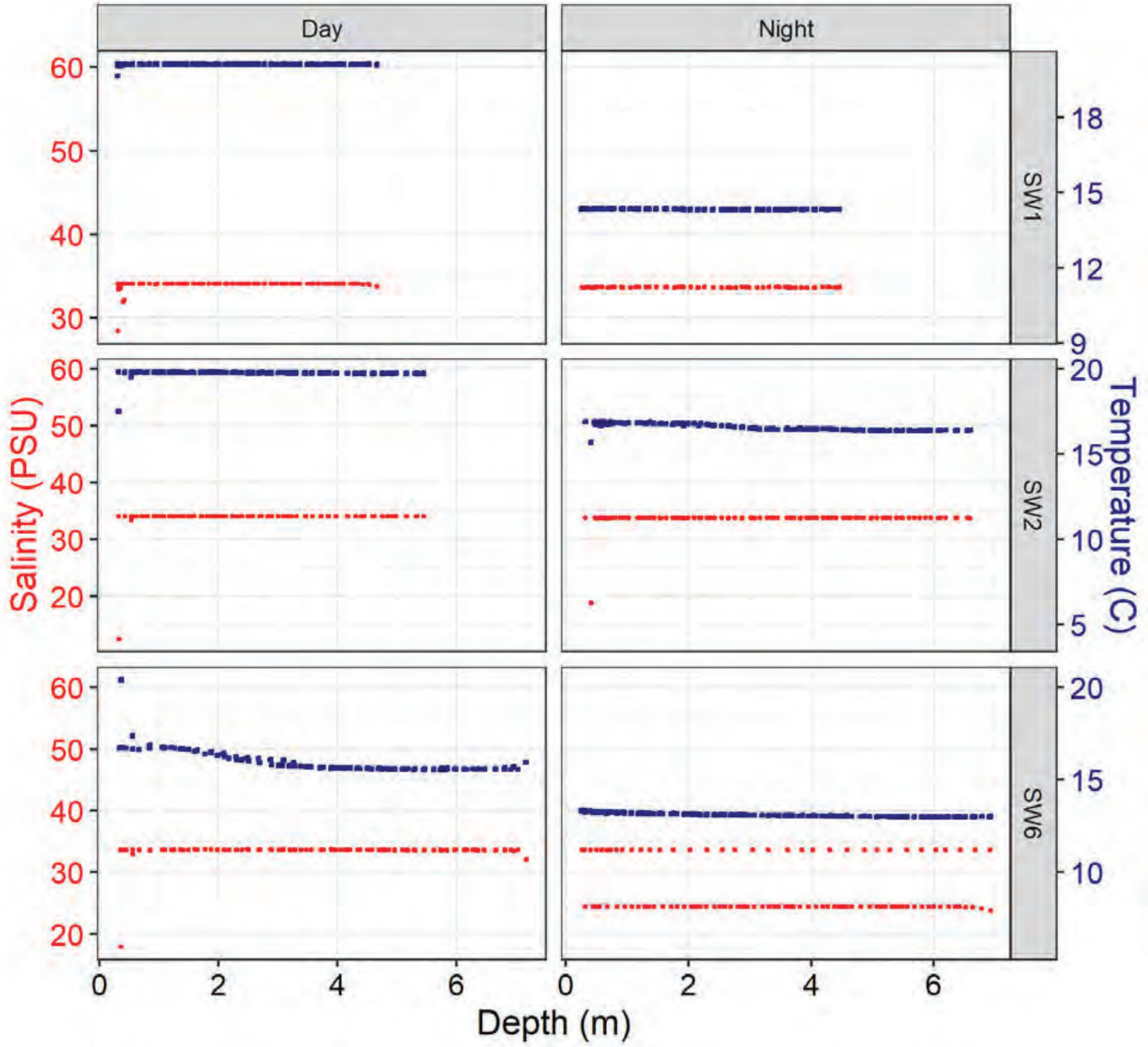

Figure C-17. Plot of Salinity (PSU) and temperature (°C) with depth (m) at source water stations SW1, SW2, and SW6 during Survey 07 on July 29, 2022 during day and night sampling.

Survey 7 – 2022-07-29

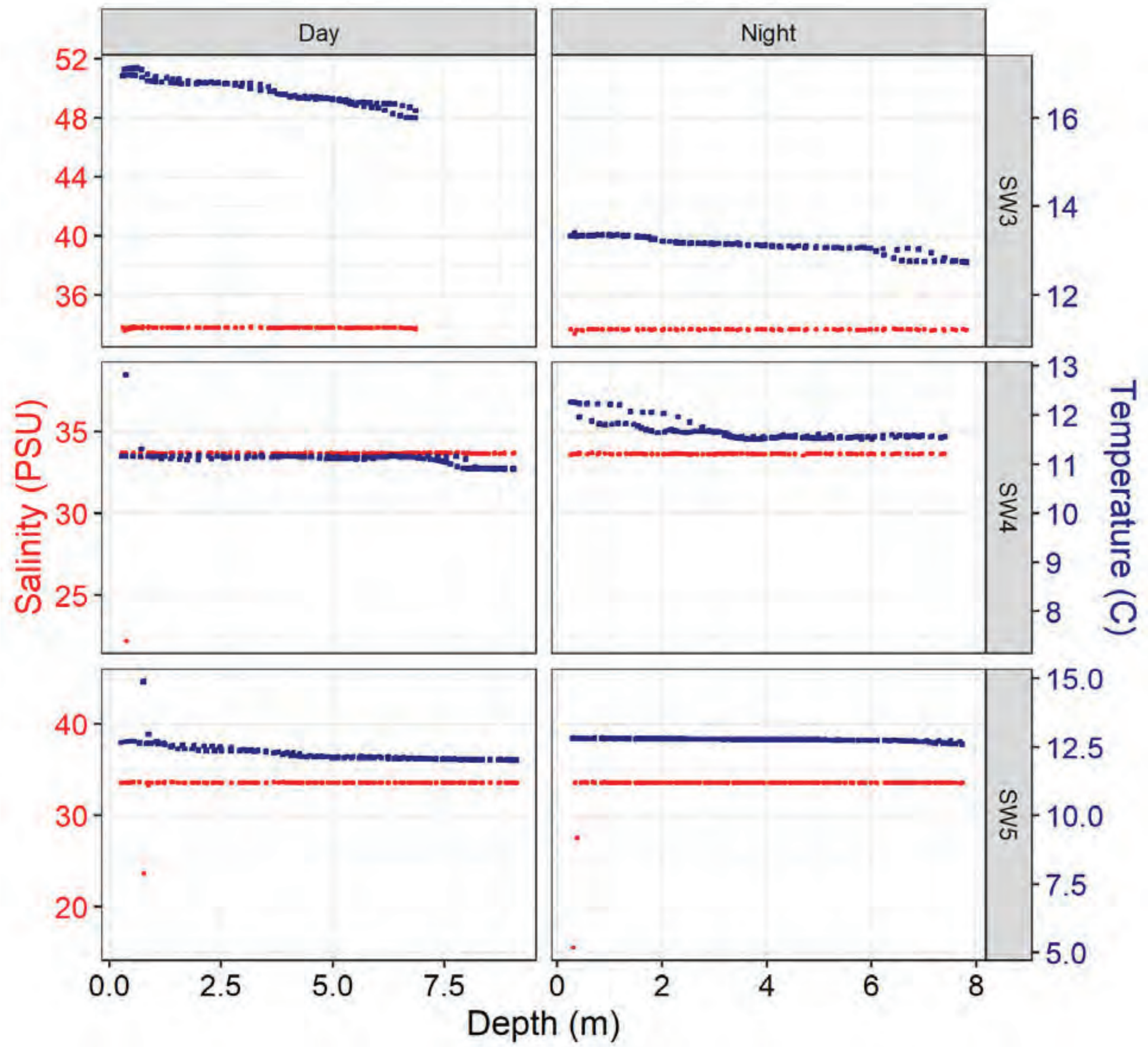

Figure C-18. Plot of Salinity (PSU) and temperature (°C) with depth (m) at source water stations SW3, SW4, and SW5 on Survey 07 on July 29, 2022 during day and night sampling.

Survey 8 – 2022-08-18

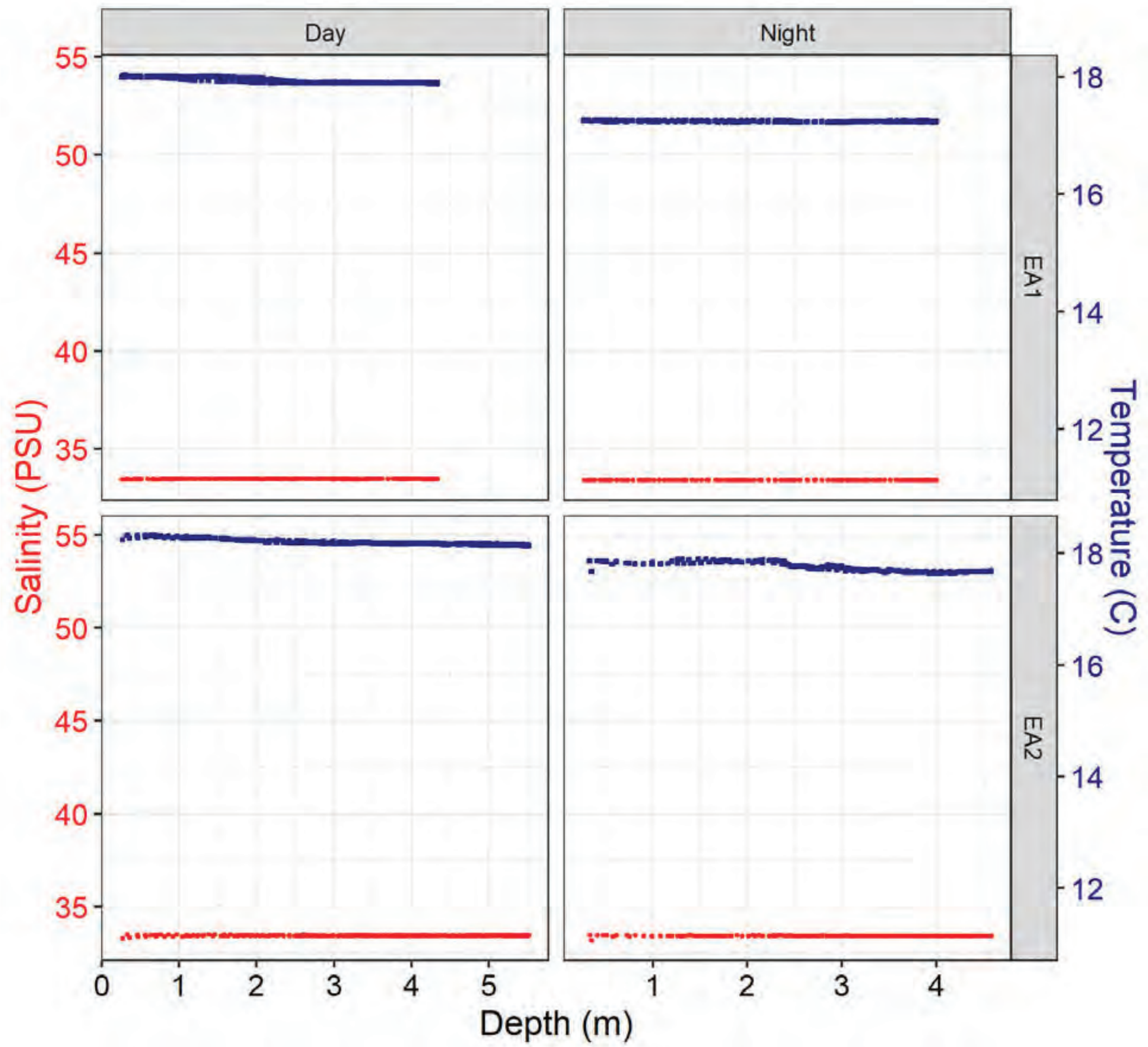

Figure C-19. Plot of Salinity (PSU) and temperature (°C) with depth (m) at entrainment stations EA1 and EA2 during Survey 08 on August 18, 2022 during day and night sampling.

Survey 8 – 2022-08-18

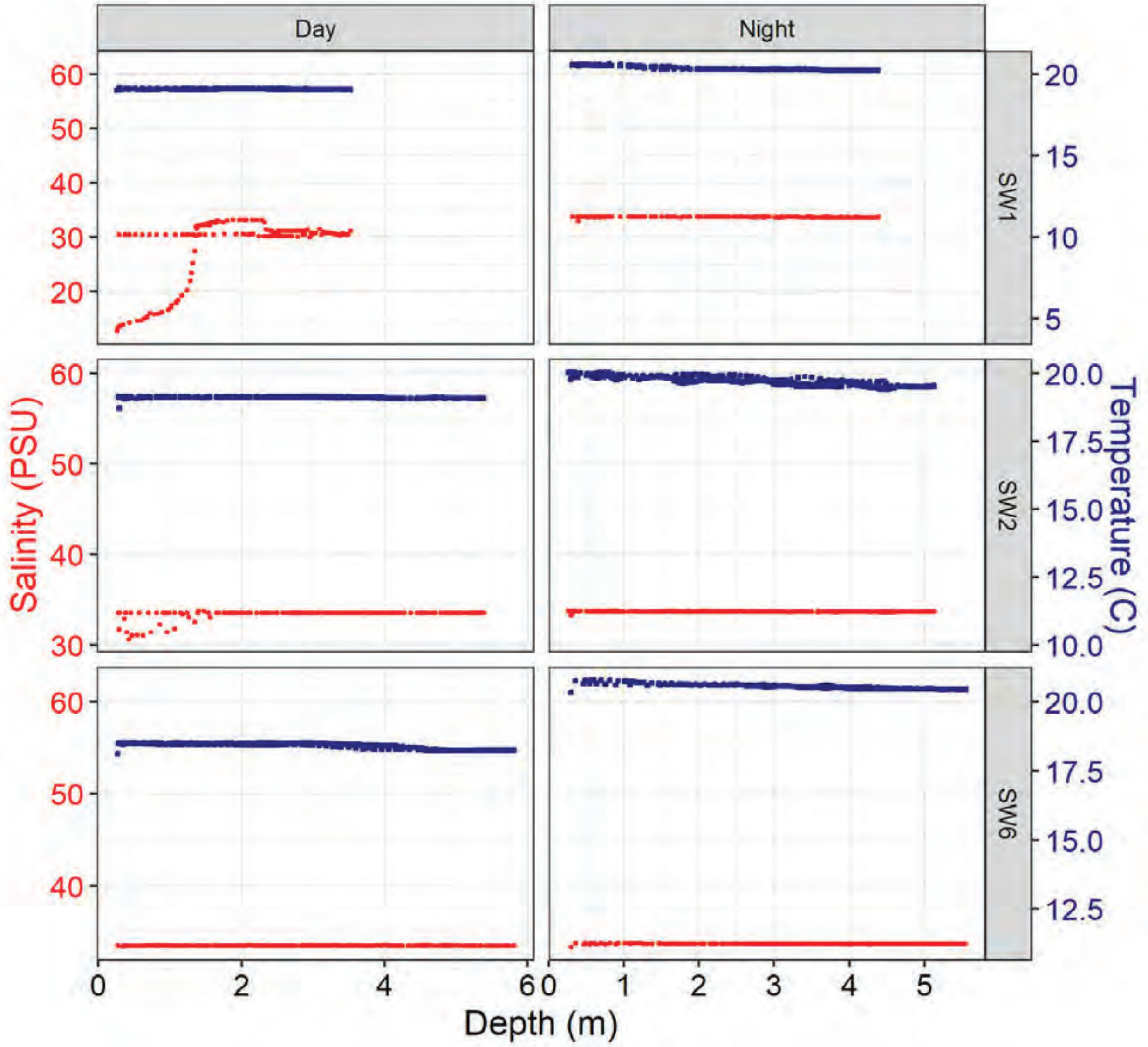

Figure C-20. Plot of Salinity (PSU) and temperature (°C) with depth (m) at source water stations SW1, SW2, and SW6 during Survey 08 on August 18, 2022 during day and night sampling.

Survey 8 – 2022-08-18

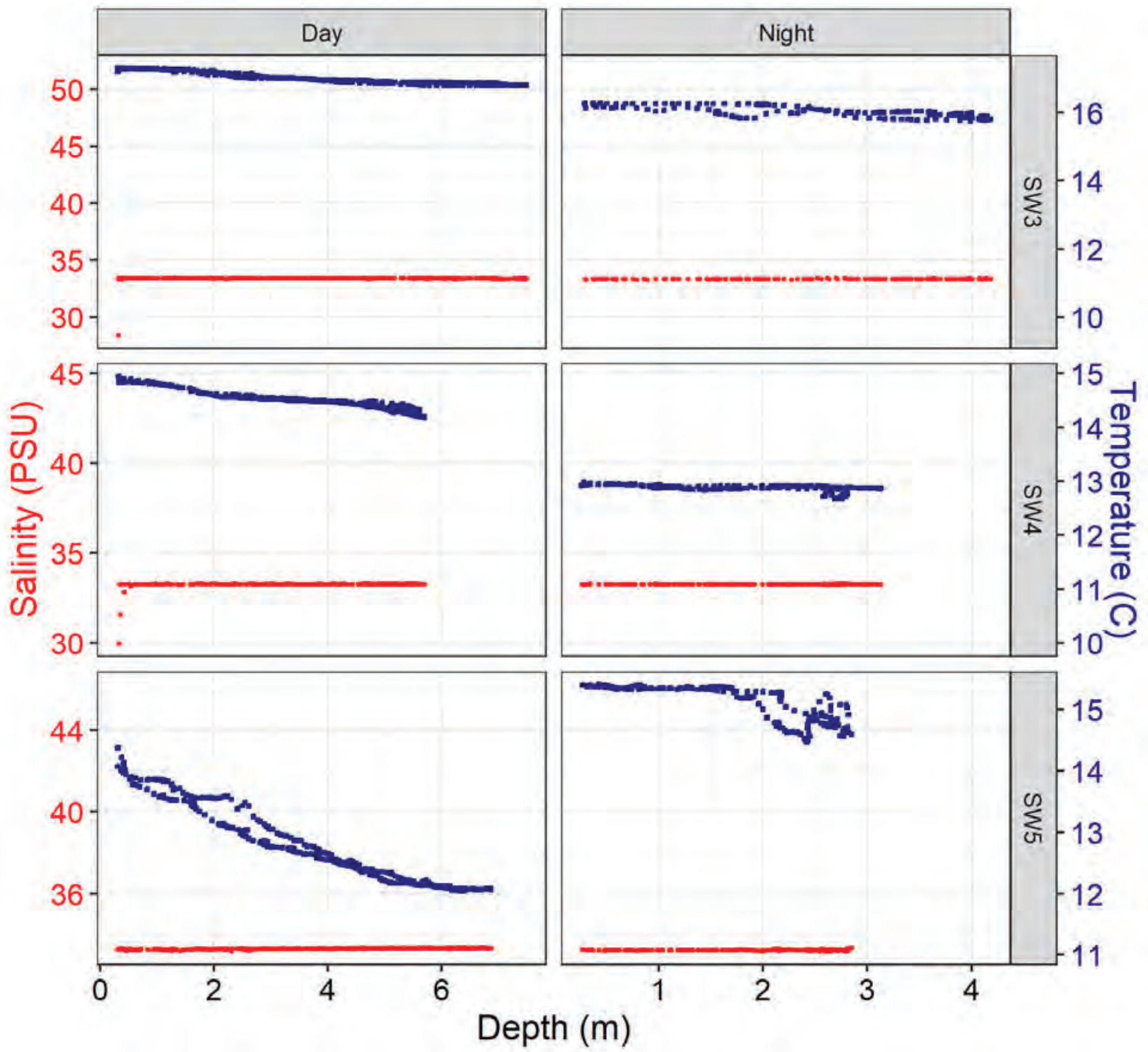

Figure C-21. Plot of Salinity (PSU) and temperature (°C) with depth (m) at source water stations SW3, SW4, and SW5 on Survey 08 on August 18, 2022 during day and night sampling.

Survey 9 – 2022-09-22

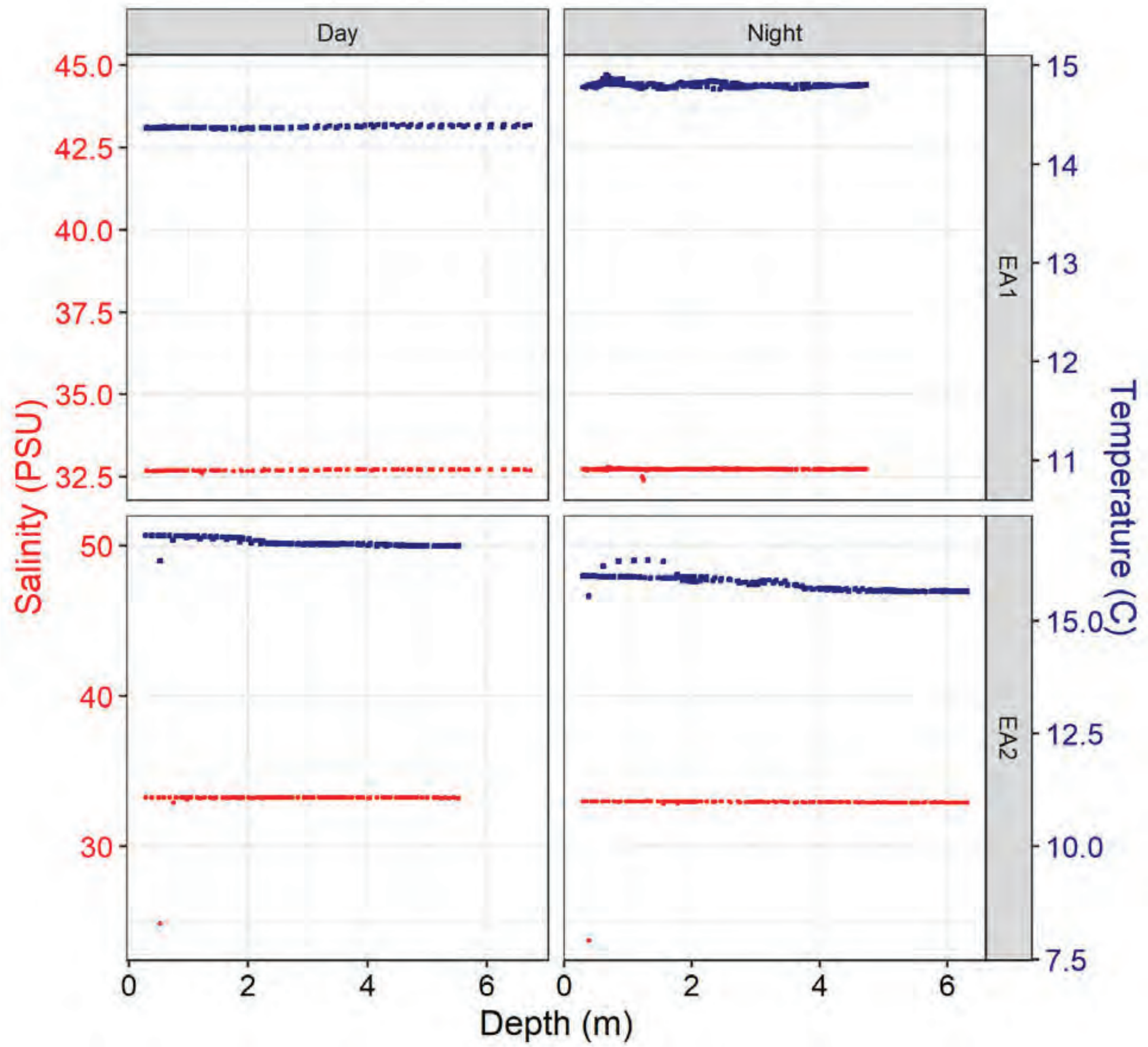

Figure C-22. Plot of Salinity (PSU) and temperature (°C) with depth (m) at entrainment stations EA1 and EA2 during Survey 09 on September 22, 2022 during day and night sampling.

Survey 9 – 2022-09-22

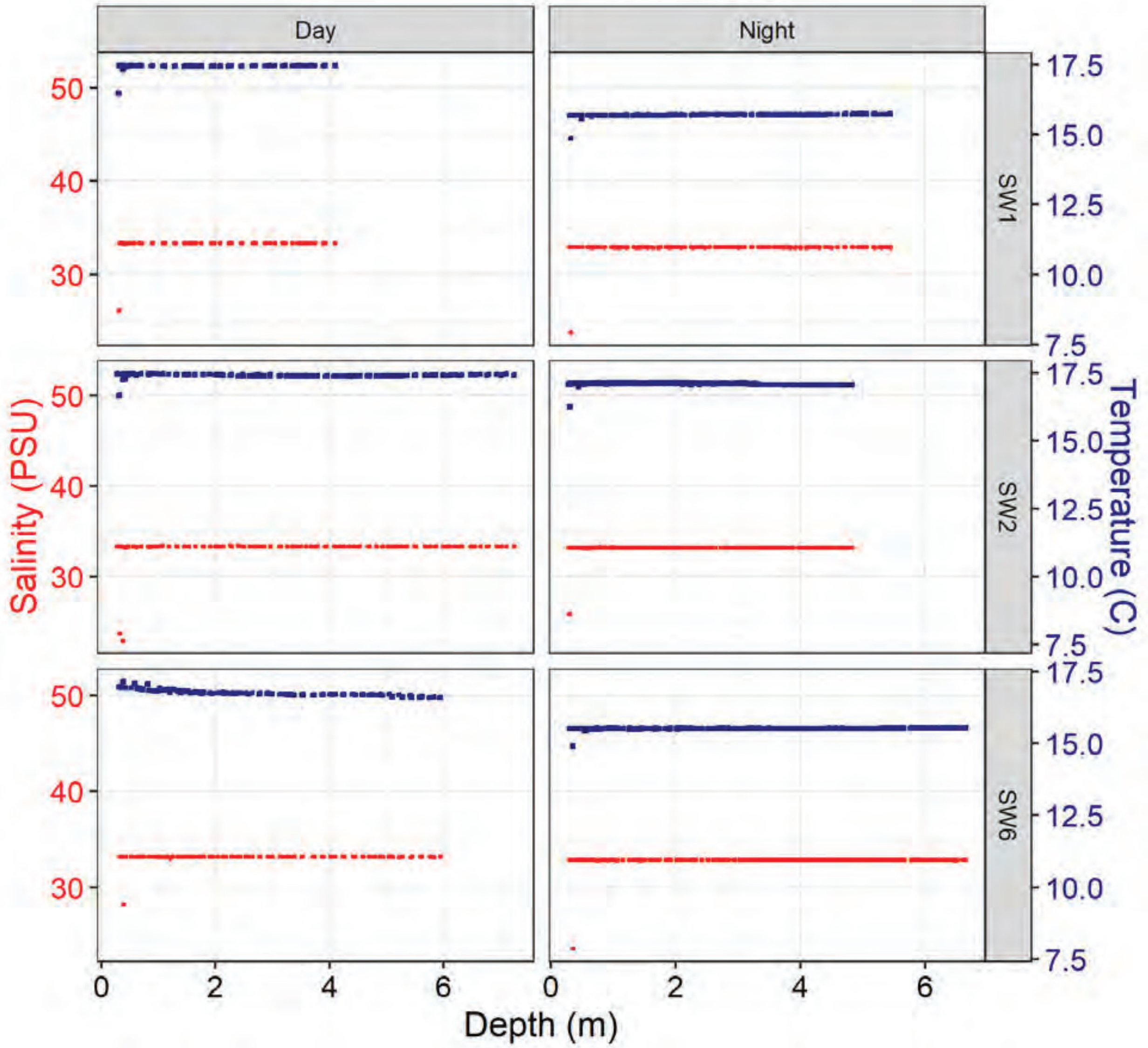

Figure C-23. Plot of Salinity (PSU) and temperature (°C) with depth (m) at source water stations SW1, SW2, and SW6 during Survey 09 on September 22, 2022 during day and night sampling.

Survey 9 – 2022-09-22

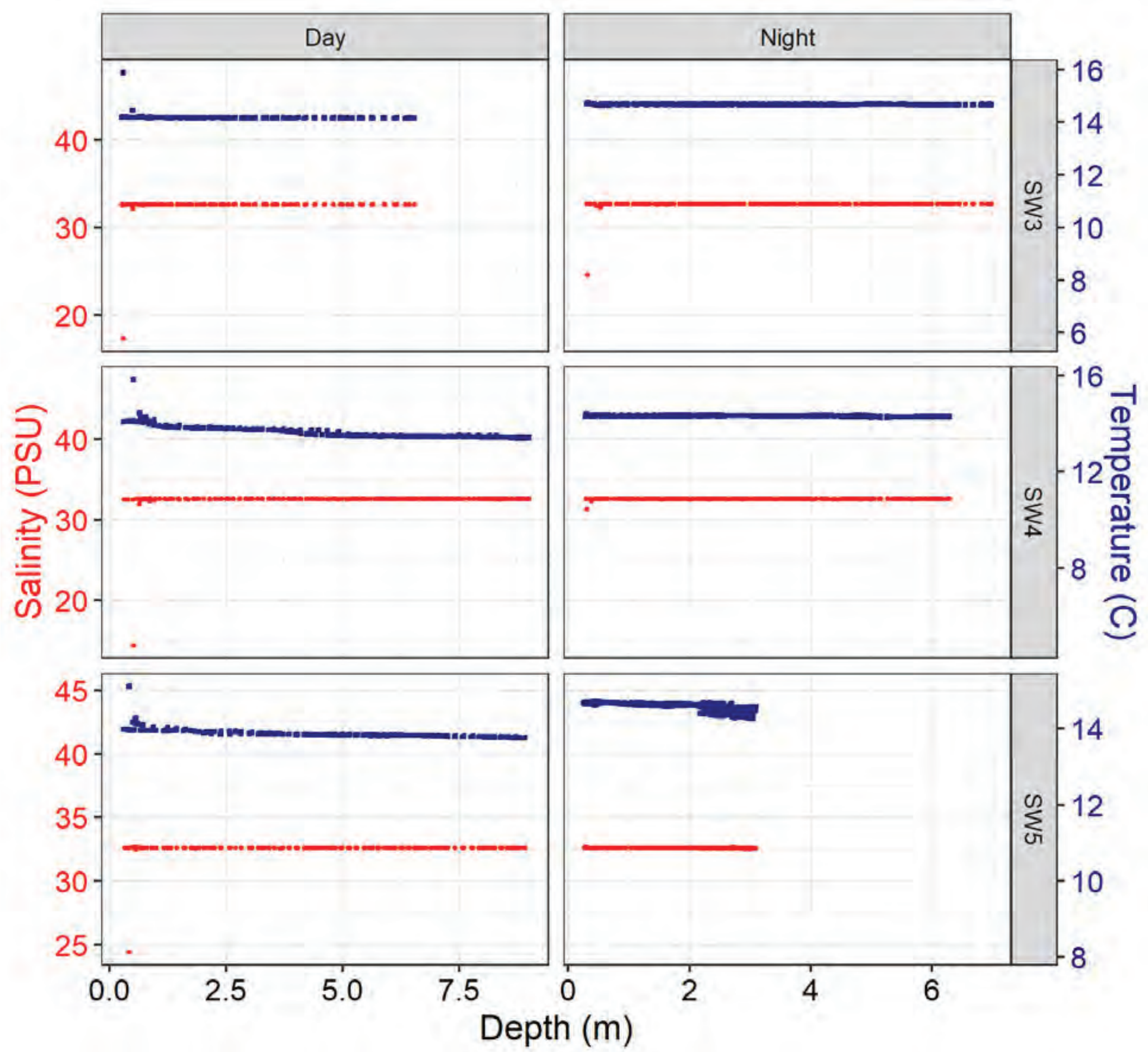

Figure C-24. Plot of Salinity (PSU) and temperature (°C) with depth (m) at source water stations SW3, SW4, and SW5 on Survey 09 on September 22, 2022 during day and night sampling.

Survey 10 – 2022-10-11

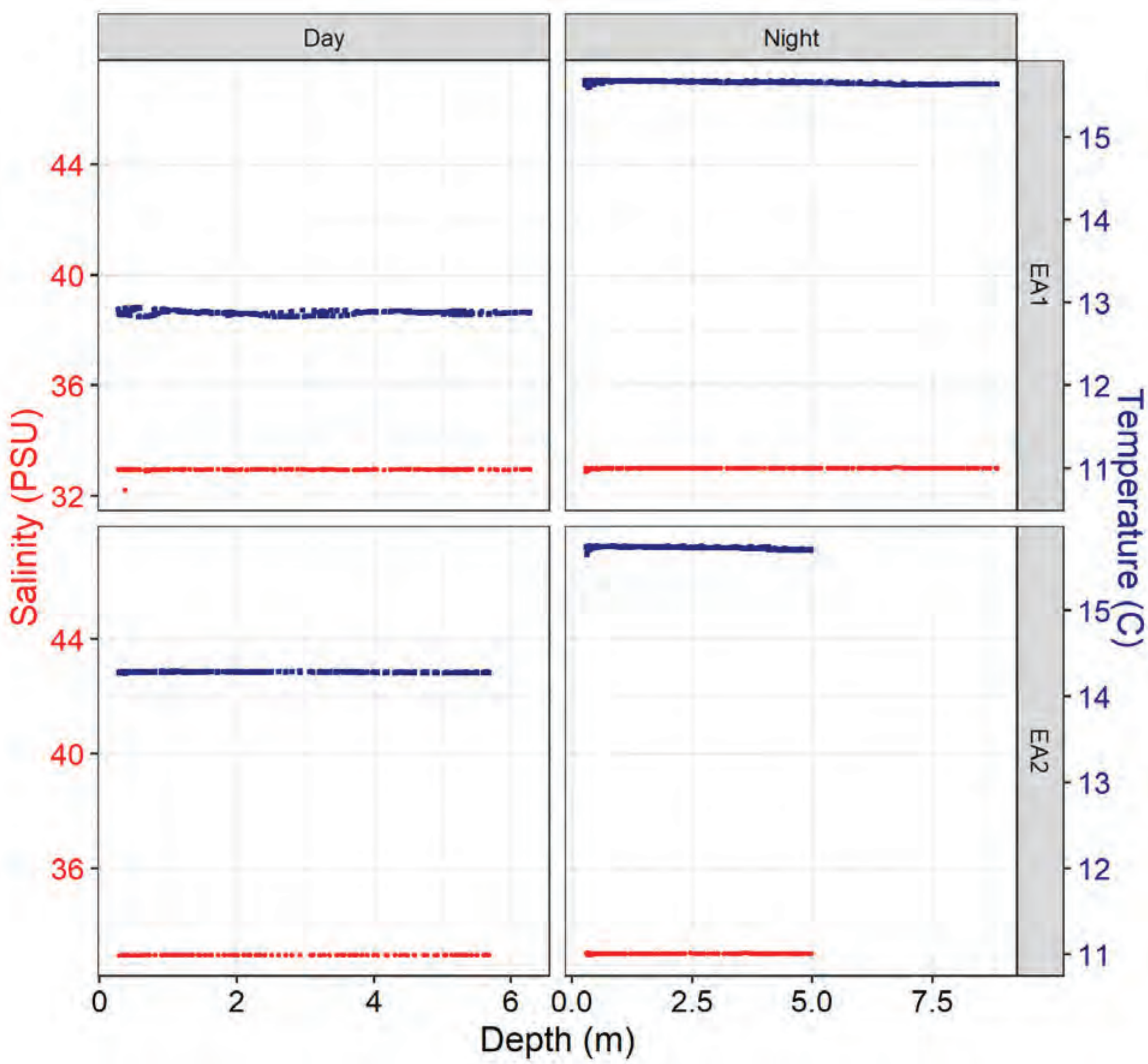

Figure C-25. Plot of Salinity (PSU) and temperature (°C) with depth (m) at entrainment stations EA1 and EA2 during Survey 10 on October 11, 2022 during day and night sampling.

Survey 10 – 2022-10-11

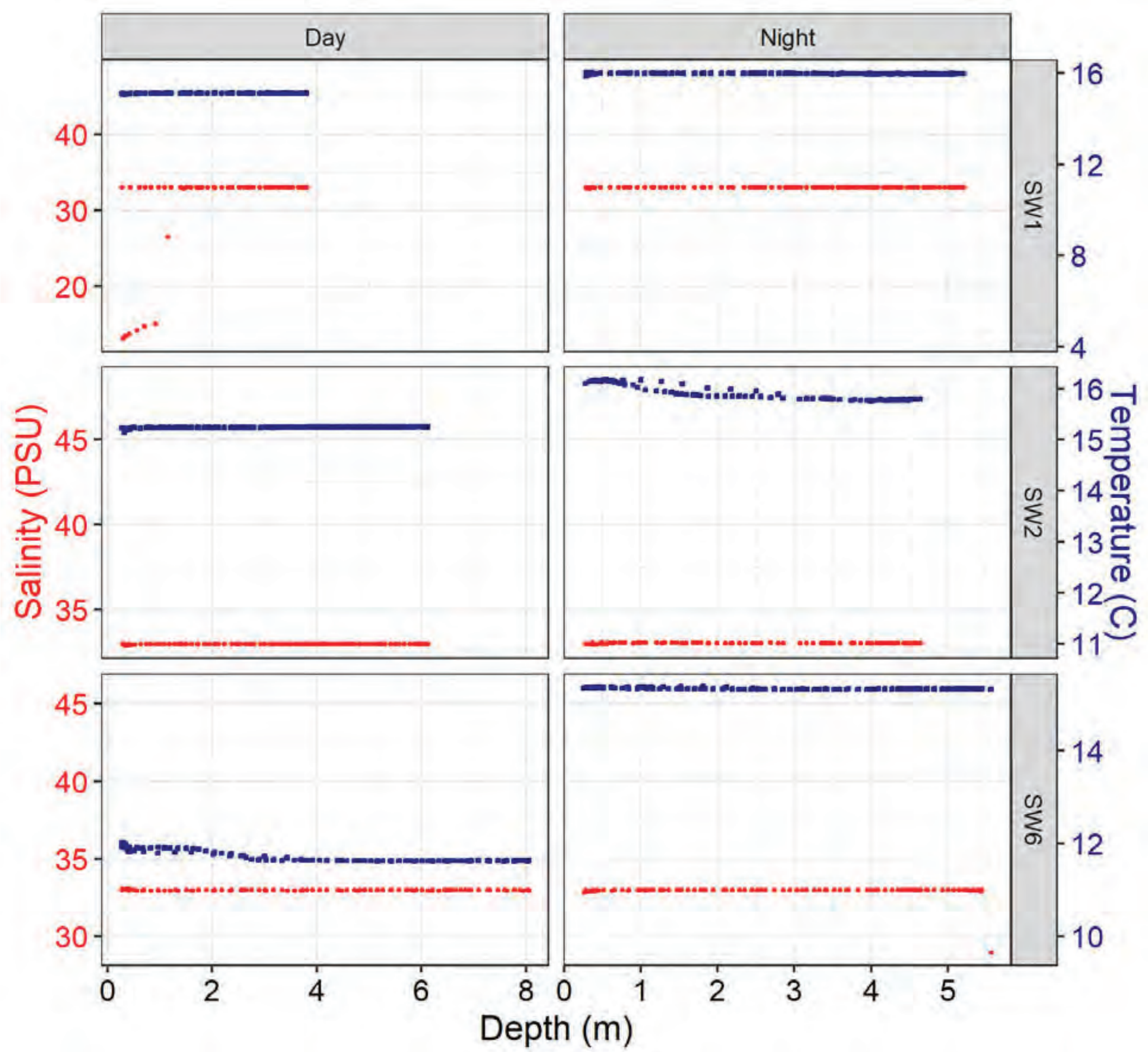

Figure C-26. Plot of Salinity (PSU) and temperature (°C) with depth (m) at source water stations SW1, SW2, and SW6 during Survey 10 on October 11, 2022 during day and night sampling.

Survey 10 – 2022-10-11

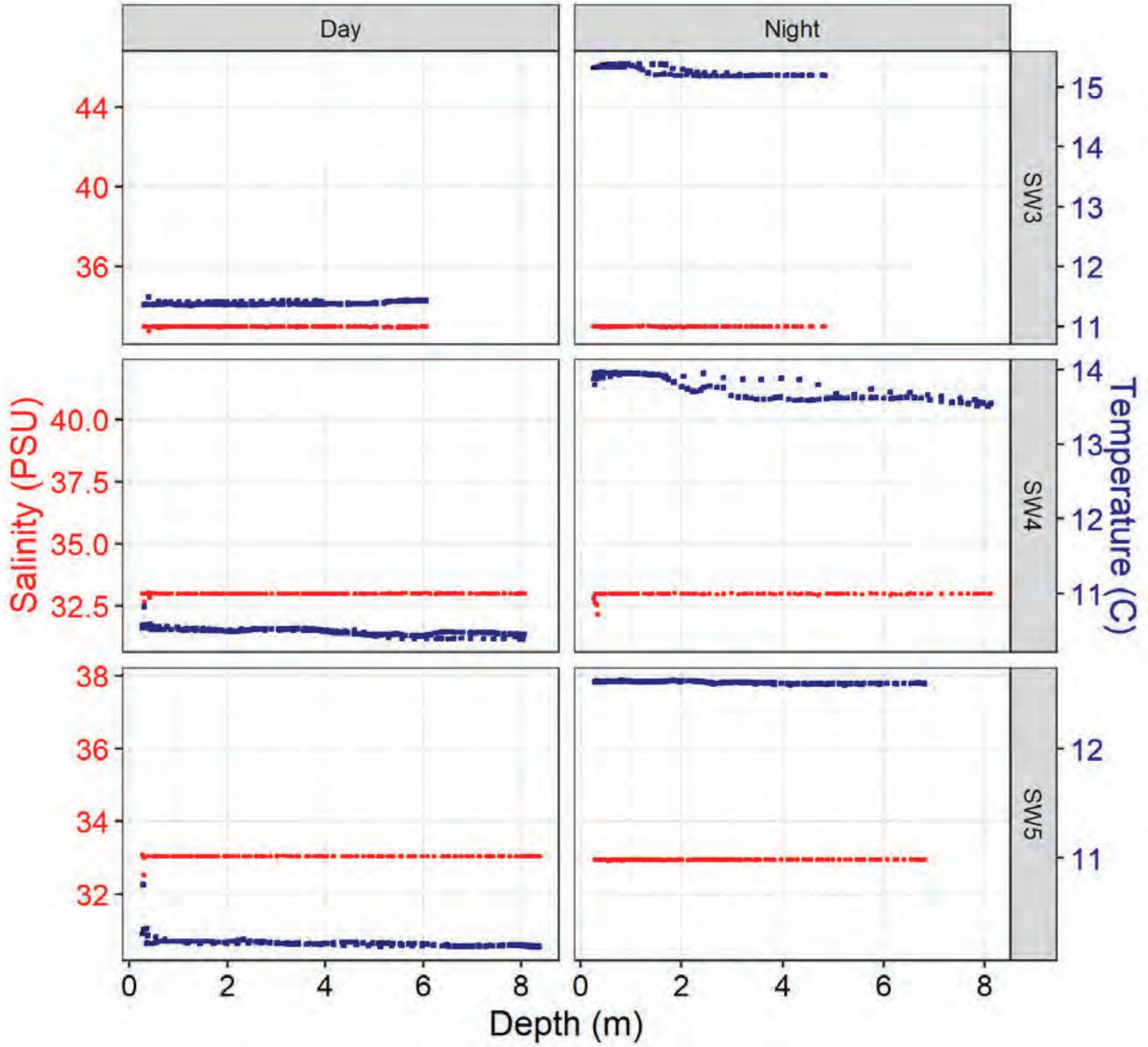

Figure C-27. Plot of Salinity (PSU) and temperature (°C) with depth (m) at source water stations SW3, SW4, and SW5 on Survey 10 on October 11, 2022 during day and night sampling.

Survey 11 – 2022-11-07

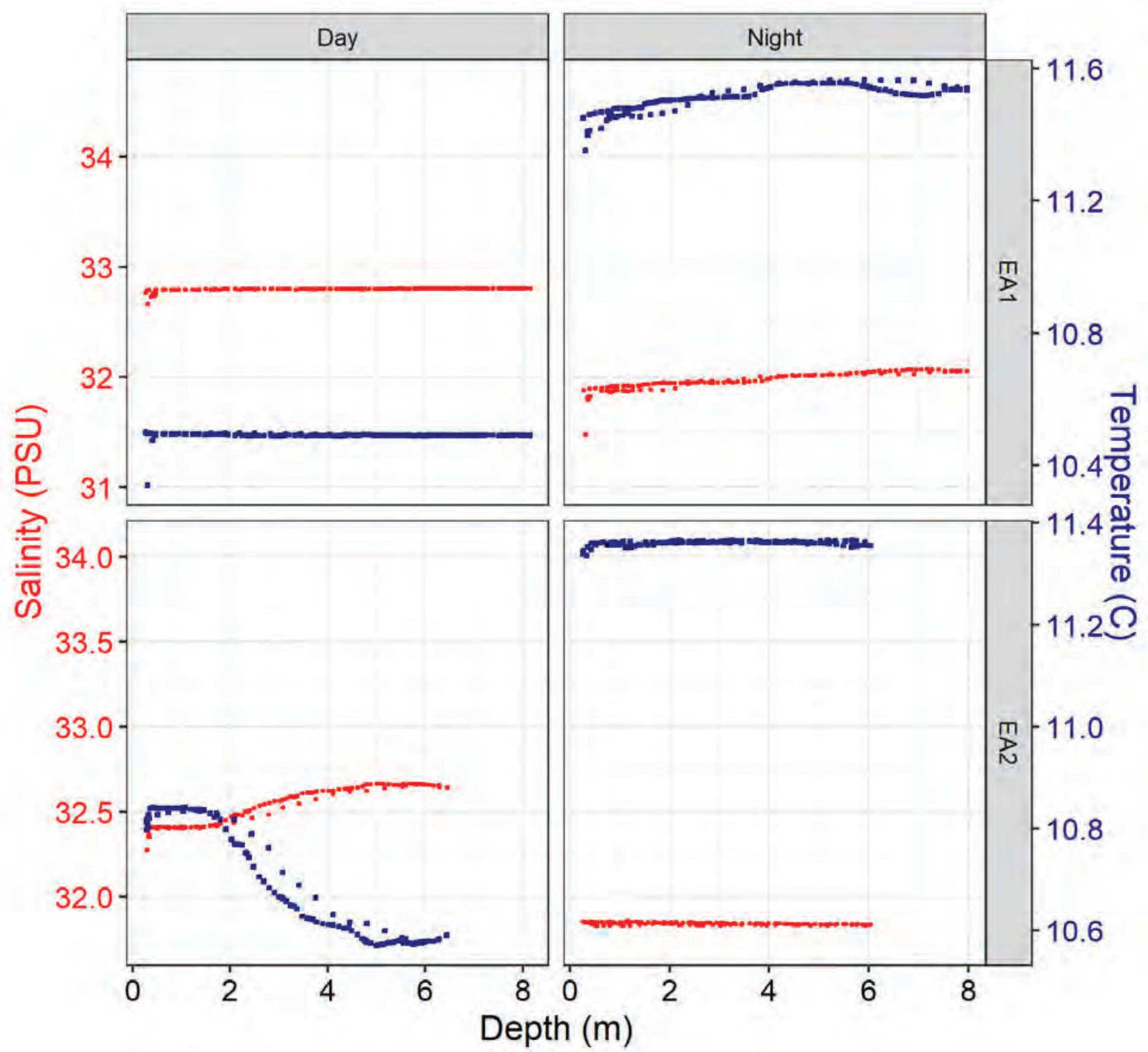

Figure C-28. Plot of Salinity (PSU) and temperature (°C) with depth (m) at entrainment stations EA1 and EA2 during Survey 11 on November 7, 2022 during day and night sampling.

Survey 11 – 2022-11-07

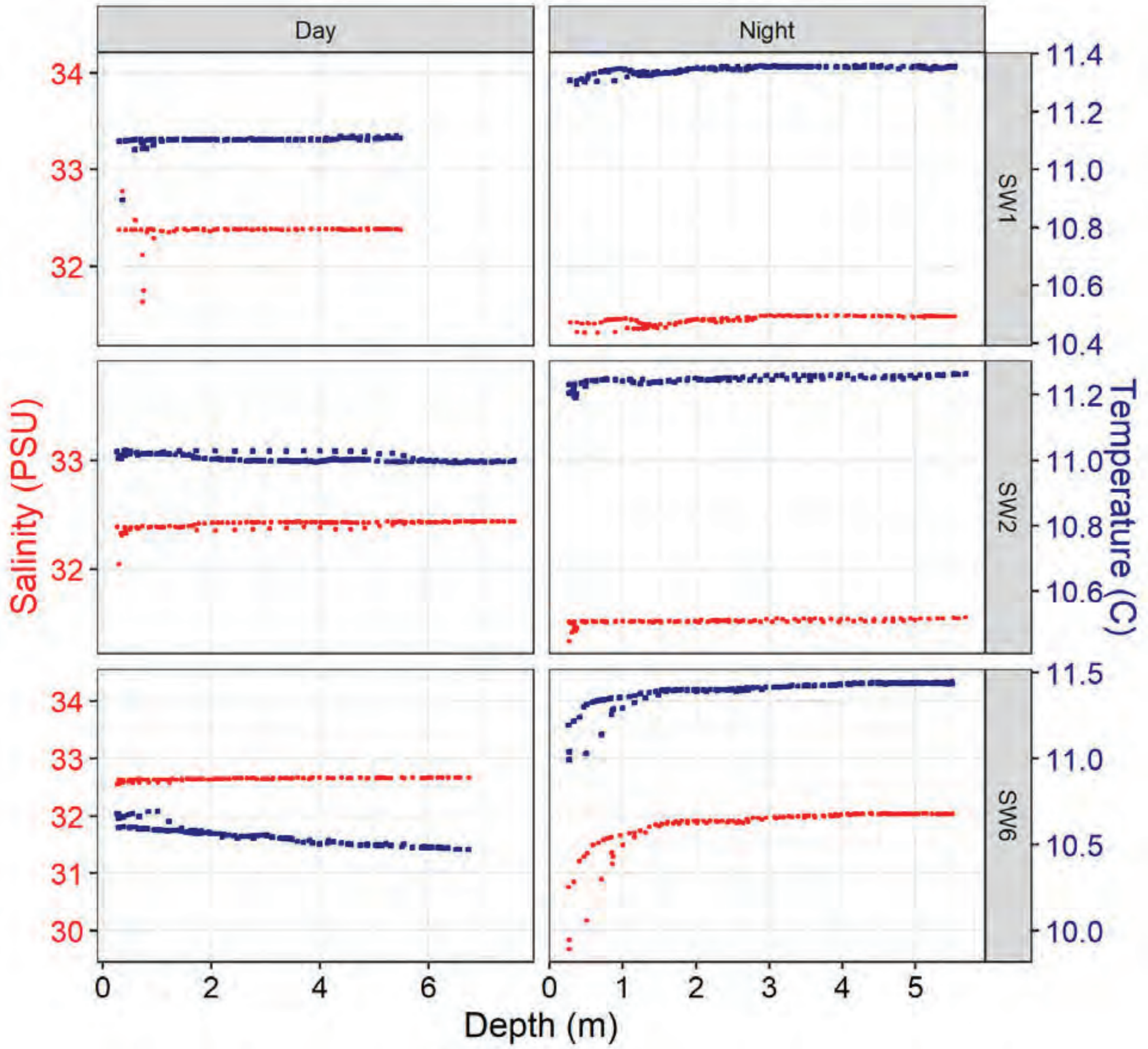

Figure C-29. Plot of Salinity (PSU) and temperature (°C) with depth (m) at source water stations SW1, SW2, and SW6 during Survey 11 on November 7, 2022 during day and night sampling.

Survey 11 – 2022-11-07

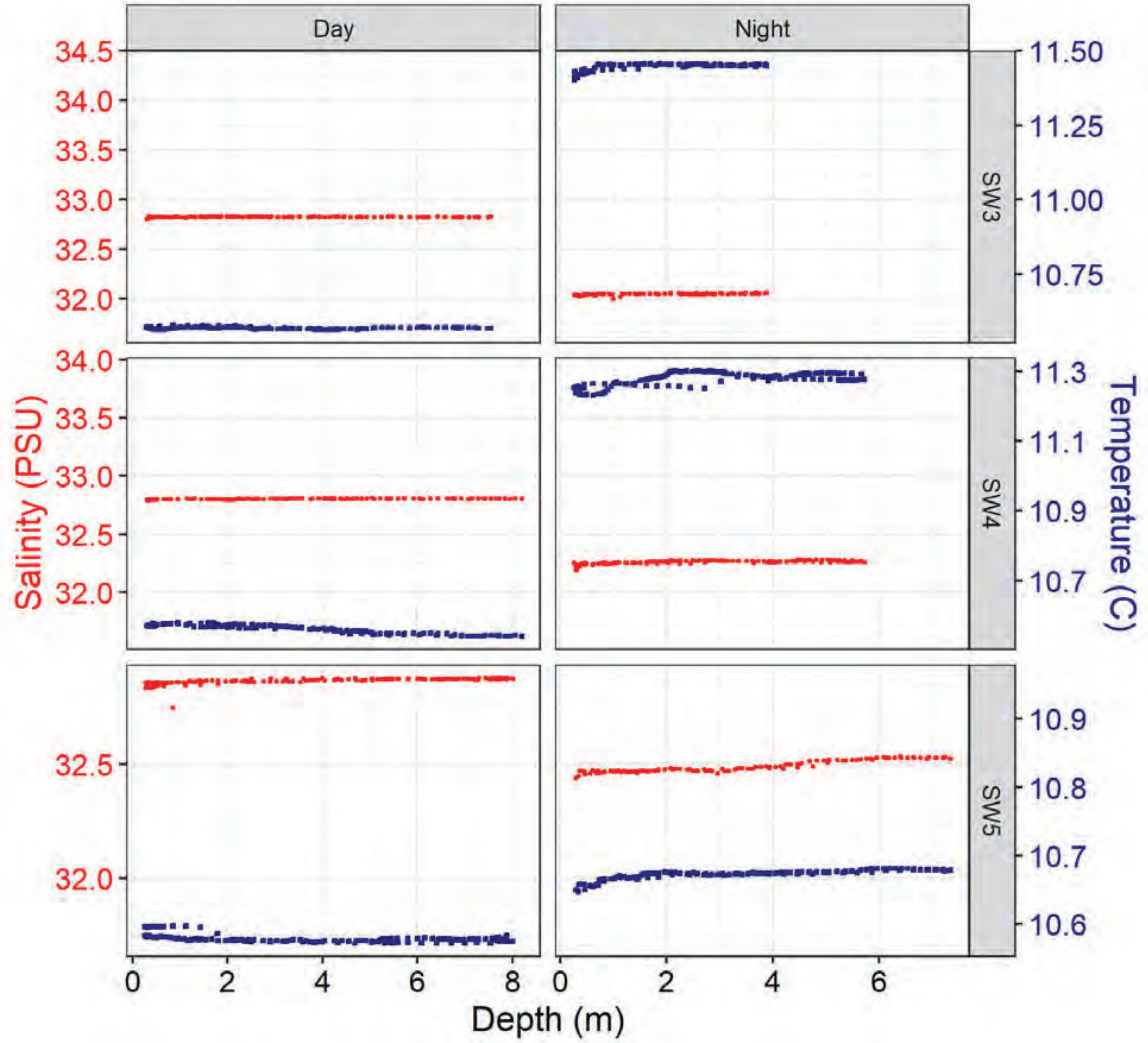

Figure C-30. Plot of Salinity (PSU) and temperature (°C) with depth (m) at source water stations SW3, SW4, and SW5 on Survey 11 on November 7, 2022 during day and night sampling.

Survey 12 – 2022-12-06

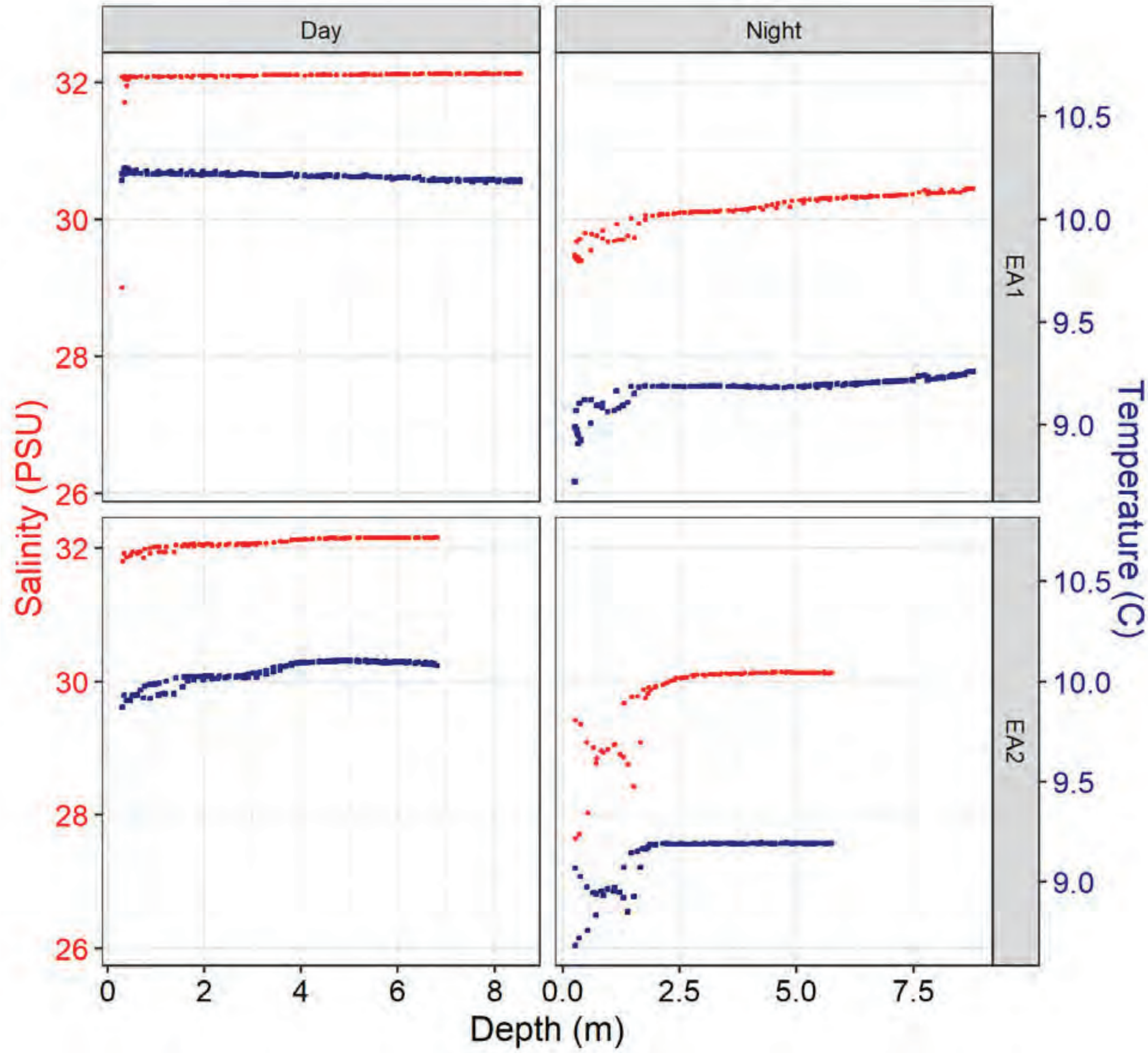

Figure C-31. Plot of Salinity (PSU) and temperature (°C) with depth (m) at entrainment stations EA1 and EA2 during Survey 12 on December 6, 2022 during day and night sampling.

Survey 12 – 2022-12-06

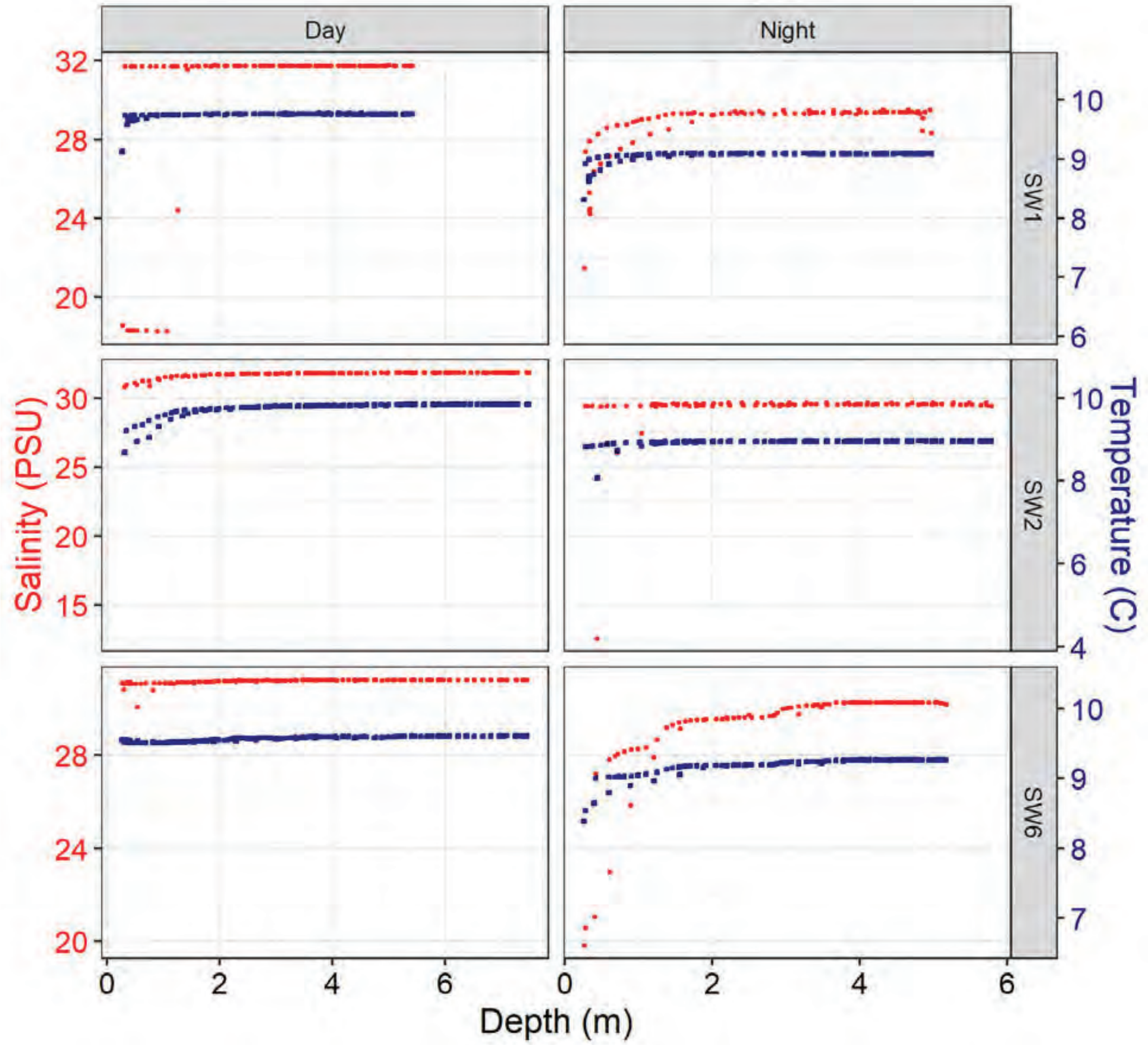

Figure C-32. Plot of Salinity (PSU) and temperature (°C) with depth (m) at source water stations SW1, SW2, and SW6 during Survey 12 on December 6, 2022 during day and night sampling.

Survey 12 – 2022-12-06

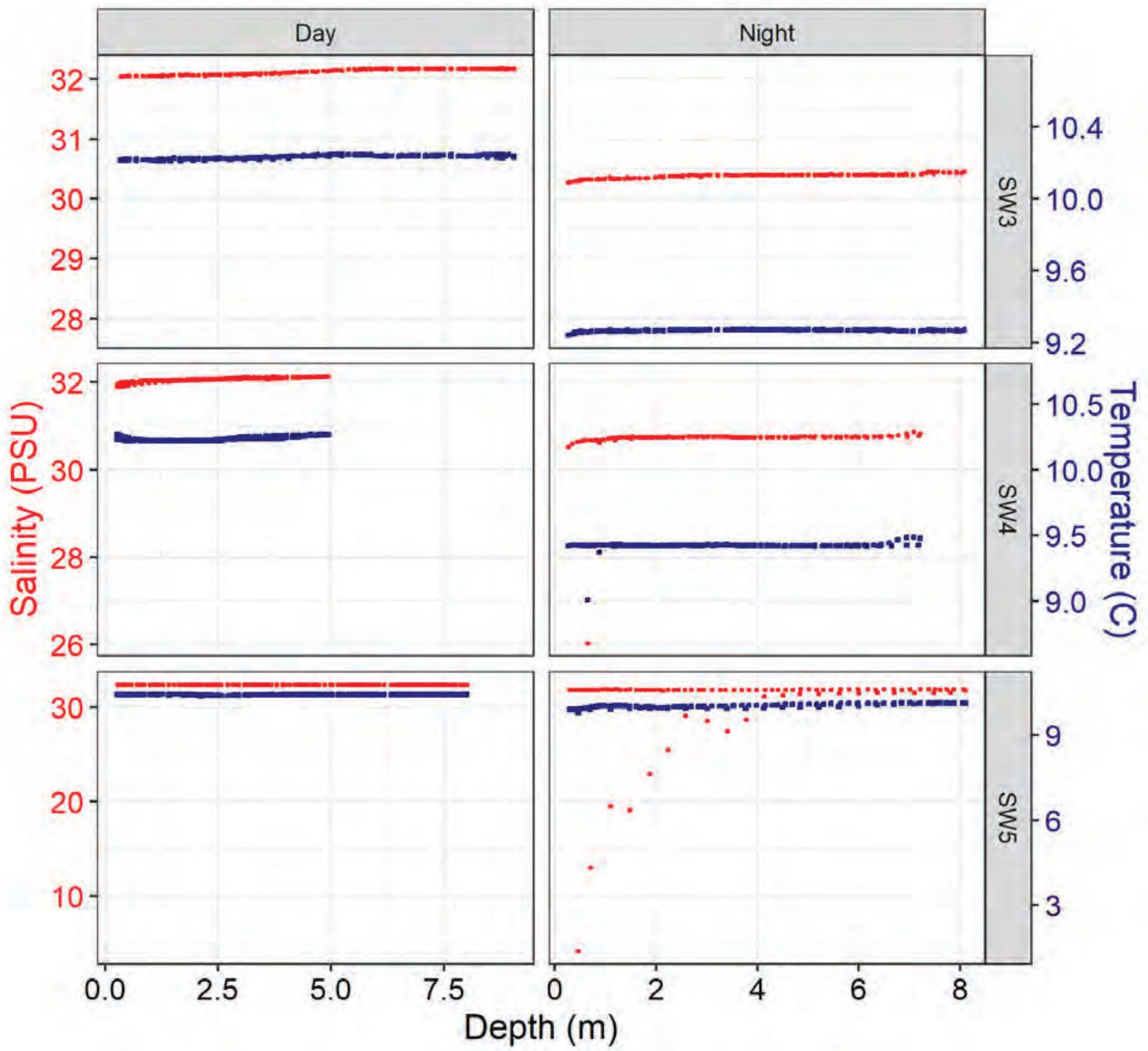

Figure C-33. Plot of Salinity (PSU) and temperature (°C) with depth (m) at source water stations SW3, SW4, and SW5 on Survey 12 on December 6, 2022 during day and night sampling.