CALIFORNIA COASTAL COMMISSION
455 MARKET STREET, SUITE 300
SAN FRANCISCO, CA 94105-2219
FAX (415) 904-5200
TDD (415) 904-5400

Th3a

CD-0006-20 (National Park Service)

April 22, 2021

CORRESPONDENCE

(received as of March 26, 2021)

Organized Groups
Part I

Resource Renewal Institute
25 Years. Innovations for a Sustainable Future.

March 3, 2021

Superintendent Craig Kenkel
Point Reyes National Seashore
1 Bear Valley Road
Point Reyes Station, CA 94956

RE: Request for an introductory meeting to share concerns regarding Point Reyes National Seashore

Dear Superintendent Kenkel:

I am writing on behalf of Resource Renewal Institute to welcome you to Marin and to Point Reyes National Seashore, and to request a meeting to learn about your vision and share our concerns for Point Reyes National Seashore.

The Resource Renewal Institute (RRI) is an environmental nonprofit organization located in Mill Valley, California. The organization's mission is to foster innovative solutions for increasingly complex environmental problems, and to test new ideas. This innovation focuses on sustainable practices and solutions to natural resource management. RRI has programs focusing on advocacy, education, organizational development, policy analysis, and applied research. RRI has successfully incubated and nurtured new programs and strategies to improve our environment and well-being, and leaders who have become catalysts for change.

Environmental leadership and inventive land and water management practices are at the heart of RRI's work. For example, *Fish in the Fields* is an integrated agricultural land use system with implications for carbon sequestration, protein sourcing, and ocean conservation. *Defense of Place* and *Public Trust Alliance* are organizations that uphold the inviolability of protected lands through policy analysis and collaboration with citizen activists nationwide.

Huey Johnson, the founder of RRI, was involved in issues in Point Reyes since he moved to Marin decades ago. In the 1970s, Huey founded the Trust for Public Land and, through that organization, acquired various parcels from the RCA Corporation in the 1970s. For example, in 1976 and 1977, the Trust for Public Land announced the purchase of 2,300 acres (G Ranch and what is now Niman Ranch/Commonweal area) of coastal Marin property for eventual inclusion into the Golden Gate National Recreation Area and Point Reyes National Seashore.

As you may know, RRI has been an active stakeholder in public deliberations regarding the past and current management of Point Reyes National Seashore, as well as the concerning proposals before the public today.

As we have shared via public outreach and correspondence with staff at Point Reyes National Seashore on numerous occasions, we remain troubled by routine lease violations and lack of enforcement of leases (and special use permits and letters of authorization) held by commercial beef and dairy ranching companies operating on federal lands managed by the National Park Service at Point Reyes National Seashore (PORE) and the Golden Gate National Recreation Area (GOGA).

187 East Blithedale Avenue, Mill Valley CA 94941 p 415-928-3774 f 415-373-6978 RRI.ORG

Resource Renewal Institute
25 Years. Innovations for a Sustainable Future.

In the past, RRI has shared our concerns regarding overgrazed (based on residual dry matter standards) and potentially overstocked pastures (based on spot counts by public citizens and National Park Service employees in documents obtained via a Freedom of Information Act request) in both PORE and the GOGA. Furthermore, our 2016 complaint also raised concerns about troubling illegal signage used to deter the public from exploring lands within what is presently the pastoral zone, as well as routine discoveries of cattle buried at PORE, cattle carcasses found in ditches that run into Drake's Estero, as well as wildlife (e.g., ravens, coyotes, etc.) feasting on cattle carcasses that were not removed from the premises of various ranches in PORE.

Since the 2016 complaint was settled in July of 2017, enforcement of lease violations has not improved. Throughout 2018, cattle have been found grazing in various sensitive habitat areas, including Abbott's Lagoon (Sept. 15) and Schooner Creek (December, 20). In January of 2019 we received reports of a rancher's guard dog in the street approaching vehicles of public visitors at C. Rodgers Ranch. Once again, on November 29, 2019, cattle (presumably from G Ranch) were in the wetlands at Abbott's Lagoon, defecating and consuming wetland plant species. *(Some photo documentation of these problems is included in Attachment A.)*

In recent months, enforcement has appeared to have gotten worse. On November 27th, 2020, RRI received a report of a commercial hog operation at A Ranch. Such an operation violates the agreed upon uses of the premises as set forth in Article 4 of the A Ranch lease. Please let us know how the NPS responded and how the company at A ranch was held responsible for this lease/permit violation.

In the weeks that followed, between November 26th and December 7th, nearly a half dozen individuals contacted RRI to share that commercial agriculture operations received "emergency permits" to extract from what surface water remains from various wetland ecosystems in the planning area. Pumps have been found between Abbotts Lagoon and Kehoe Creek, siphoning even more water from numerous freshwater emergent wetlands and freshwater forested/shrub wetlands, which can be found in the US Fish and Wildlife Service's National Wetlands Inventory. These wetlands provide a crucial water supply for the Riverine intermittent streambed and Riverine tidal drainage at Kehoe Beach. *(Some photos documenting this problem are included in Attachment A.)*

Another member of the public alerted us to a new well that has been established directly across from Abbott's Lagoon, within the zone of a freshwater emergent wetland that feeds the lagoon. Abbotts is one of the most important water features in the planning area, and RRI is deeply concerned that the removal of more water from the coastal watershed compounds documented concerns at Abbott's Lagoon, such as eutrophication of water resources due to high nutrient input from the ranching operations. We are aware that, due to drought conditions in the National Seashore, the NPS may have issued emergency permits to allow for the pumping of sensitive surface waters within PORE. We request that the NPS explain to the public how the NPS plans to provide commercial ranches with additional water resources without jeopardizing the water availability for wildlife and hydrological functioning of natural systems.

Just a few weeks after we were alerted to the various new pumping operations, on December 23rd, 2020, the Point Reyes Light released a story about an illegal barley operation for Elk Fence Distillery at Kehoe Ranch. Has NPS responded with an investigation and held the company at the Kehoe ranch responsible?

187 East Blithedale Avenue, Mill Valley CA 94941 p 415-928-3774 f 415-373-6978 RRI.ORG

Resource Renewal Institute
25 Years. Innovations for a Sustainable Future.

To start the new year, on January 14th, the public again encountered undisposed cattle carcasses on F Ranch at PORE. (We believe the park was notified the very same day, but more than two weeks later a carcass remained, along with an abundance of ravens and a scavenging coyote.) *(See Attachment A for photo.)* What is the NPS's process for addressing lease violations under Article 14 of each respective lease, and why have such violations have rarely been mitigated?

In addition, in late this January we were made aware of the erection of new fencing that harms wildlife. This fencing is inconsistent with basic range management requirements for other federal land management agencies who have lower duties to wildlife. We are disappointed that the NPS/ranchers are rushing to install new, harmful fencing that is inconsistent with the proposed efforts to improve wildlife conditions as described in PORE's General Management Plan Amendment / Final Environmental Impact Statement (*see example photos of the new fencing from the Sierra Club SF Bay Chapter's letter dated February 4, 2021, in Attachment A).*

On January 30th, we received notice of 50 sheep at M ranch. *(See example photo in Attachment A.)* While this may be the maximum allowed under the "pet" clause in each of the leases, we remain doubtful these "pets" were not livestock for commercial production. How does NPS determine whether livestock are kept for personal or commercial purposes, and has it investigated this issue related to M ranch?

In addition to the myriad lease violations that have been documented over the last 7 years and which the NPS has previously been made aware of on numerous occasions, we hope to have a productive conversation about the difficultly the NPS has had with the protection of the snowy plover habitat and ongoing difficulties in successfully implementing raven deterrence best management practices at PORE. Additionally, we hope to learn more about water quality testing at PORE. Finally, we would like to have a full discussion about the opportunities to center and uplift a more complete and enduring cultural history at Point Reyes, namely that of the Coast Miwok.

We recognize that you are inheriting many of these issues, which is why we are bringing them to your attention. We want to support the NPS to ensure problems don't continue under your watch. We greatly appreciate your time, welcome your new leadership, and look forward to a robust discussion on the aforementioned topics.

Sincerely,

Chance Cutrano
Director of Programs
Resource Renewal Institute

187 East Blithedale Avenue, Mill Valley CA 94941 p 415-928-3774 f 415-373-6978 RRI.ORG

Resource Renewal Institute
25 Years. Innovations for a Sustainable Future.

ATTACHMENT A: Photo Documentation of Concerns at Point Reyes National Seashore

Cattle grazing at Abbott's Lagoon (we have videos of them walking through the lagoon)[1]

Cattle standing in Abbott's Lagoon and grazing 11/29/2019

[1] Special status species, including amphibians and reptiles, can be harmed our killed by trampling due to concentrations of cattle in these areas. Fish experience adverse impacts from increased turbidity, sedimentation and alternative of stream and other watershed habitat associated with grazing in these riparian corridors. In addition, the concentration of cattle in these fragile areas contribute water quality challenges documented at Abbott's Lagoon, such as eutrophication due to manure runoff.

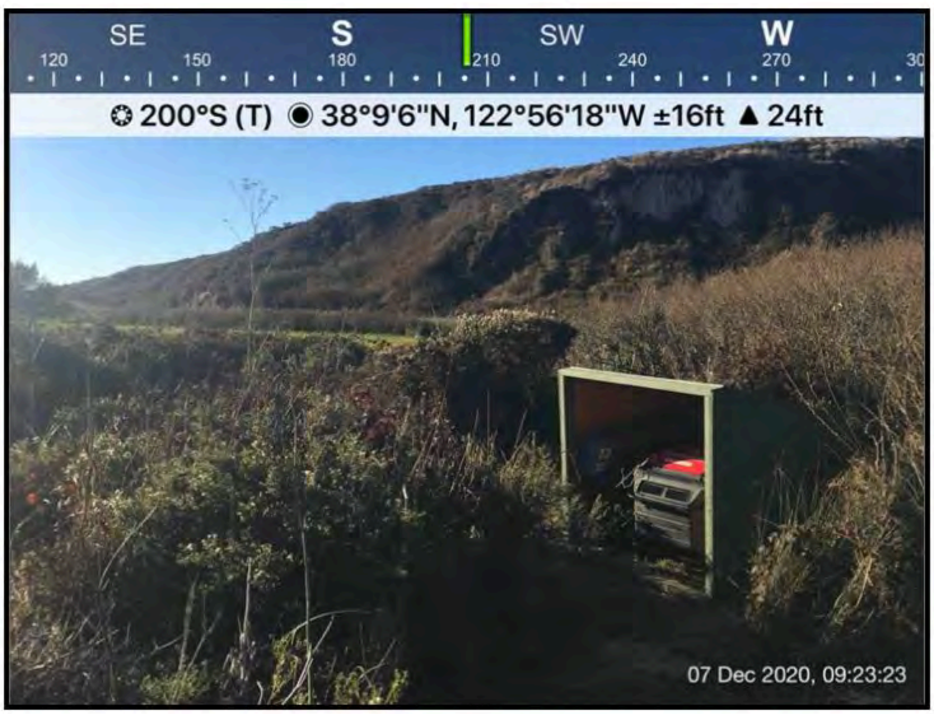
187 East Blithedale Avenue, Mill Valley CA 94941 p 415-928-3774 f 415-373-6978 RRI.ORG

Resource Renewal Institute
25 Years. Innovations for a Sustainable Future.

Cattle eating vegetation in Abbott's Lagoon on 11/29/2019

187 East Blithedale Avenue, Mill Valley CA 94941 p 415-928-3774 f 415-373-6978 RRI.ORG

Resource Renewal Institute
25 Years. Innovations for a Sustainable Future.



Pumping of freshwater emergent wetlands and freshwater forested/shrub wetlands at the Kehoe Ranch. These wetlands are integral water supply for the Riverine intermittent streambed and Riverine tidal drainage at Kehoe Beach. Photo taken on 12/7/2020

187 East Blithedale Avenue, Mill Valley CA 94941 p 415-928-3774 f 415-373-6978 RRI.ORG

Resource Renewal Institute
25 Years. Innovations for a Sustainable Future.

Newly erected pumps in within the zone of a freshwater emergent wetland that feeds Abbott's Lagoon. Photo taken on 12/7/2020.

187 East Blithedale Avenue, Mill Valley CA 94941 p 415-928-3774 f 415-373-6978 RRI.ORG

Resource Renewal Institute
25 Years. Innovations for a Sustainable Future.

The remains of a cattle carcass that had not been removed from F Ranch for over a month, even after the National Park Service was notified and responded on 1/14/2021

New fencing on land leased/permitted to A Ranch for cattle grazing, which is shared with the Drake's Beach Tule elk herd. An increase to 7-strand barbed wire fences from previous 5-strand fencing increases hazards and barriers for wildlife, hindering daily wildlife movements, access to forage and water, and resulting in injury or death should wildlife collide or become entangled.

187 East Blithedale Avenue, Mill Valley CA 94941 p 415-928-3774 f 415-373-6978 RRI.ORG

Resource Renewal Institute
25 Years. Innovations for a Sustainable Future.

Newly placed strands of barbed wire on fencing that was previously adapted to support the free and safe movement of the free-ranching Tule elk herd at Drake's Beach.

"Pet" sheep out to pasture at M Ranch on 1/30/2021

187 East Blithedale Avenue, Mill Valley CA 94941 p 415-928-3774 f 415-373-6978 RRI.ORG

From: Kenkel, Craig A <Craig_Kenkel@nps.gov>
Sent: Friday, March 5, 2021 8:21 AM
To: Laura Cunningham <lcunningham@westernwatersheds.org>
Cc: Simon, Larry@Coastal <Larry.Simon@coastal.ca.gov>; WB-DIT-info2 <info2@waterboards.ca.gov>; OPA@waterboards.ca.gov; Gunn, Melanie <Melanie_Gunn@nps.gov>; Coastal Point Reyes Management Plan <PointReyesManagementPlan@coastal.ca.gov>; Weber, John@Coastal <john.weber@coastal.ca.gov>; Ortiz, Edward@Waterboards <Edward.Ortiz@Waterboards.ca.gov>; Ryan_olah@few.gov; Jim Coda <jimcoda@gmail.com>; Lisa Levinson <lisa@idausa.org>; Liz Dodge - TSP <lizzarddodge6@gmail.com>; Jack Gescheidt <jack@treespiritproject.com>; Ketcham, Brannon <Brannon_Ketcham@nps.gov>
Subject: Re: [EXTERNAL] Point Reyes National Seashore Water Quality Concerns

Dear Ms. Cunningham,

I'm confirming receipt of your organization's letter and report.

Thank you.

Craig Kenkel
Superintendent
Point Reyes National Seashore
1 Bear Valley Road
Point Reyes Station, CA 94956
440-668-2230 mobile

Please consider the environment before printing this e-mail

Laura Cunningham
California Director
Western Watersheds Project
102551 Cedar Canyon Rd., Cima CA 92323
Mailing: PO Box 70, Beatty, NV 89003
tel: (775) 513-1280
email: lcunningham@westernwatersheds.org
web site: www.westernwatersheds.org *Working to protect and restore Western Watersheds and Wildlife*

Superintendent Craig Kenkel
Point Reyes National Seashore
1 Bear Valley Road
Point Reyes Station, CA 94956
Craig_Kenkel@nps.gov

Larry Simon
Manager, Federal Consistency Unit
Energy, Ocean Resources and
Federal Consistency Division
California Coastal Commission
455 Market Street, Suite 228
San Francisco, CA 94105-2219
(415) 904-5288
larry.simon@coastal.ca.gov

San Francisco Bay Regional Water Quality Control Board
1515 Clay St
Suite 1400
Oakland, CA 94612
info2@waterboards.ca.gov

State Water Resources Control Board
P.O. Box 100
Sacramento, CA 95812-0100
OPA@waterboards.ca.gov

Marin County Health and Human Services
Via web portal: https://www.marinhhs.org/form/email-health-human-services

Via email: Craig_Kenkel@nps.gov
CC: Melanie_Gunn@nps.gov
Dave_Press@nps.gov
PointReyesManagementPlan@coastal.ca.gov
John.Weber@coastal.ca.gov
info2@waterboards.ca.gov
OPA@waterboards.ca.gov

Edward.Ortiz@waterboards.ca.gov
Ryan_olah@few.gov

Via US mail with letter and enclosed thumb-drive with report and references to the above addresses.

March 4, 2021

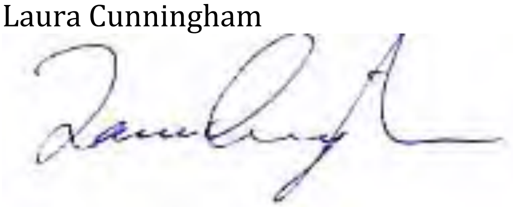
RE: Point Reyes National Seashore Water Quality

Dear Superintendent Kenkel,

Please find attached a report made for Western Watersheds Project and In Defense of Animals of water quality testing undertaken by our groups in late January 2021 in water bodies within the Seashore. We found levels of bacterial surface water pollution at hazardous levels in Kehoe Creek and Abbotts Lagoon, and therefore request that the park service place appropriate warning signs at locations where human direct contact water recreation occurs.

Please enter this Report into the administrative record for the General Management Plan Amendment/EIS.

Thank you,

Laura Cunningham

California Director
Western Watersheds Project
102551 Cedar Canyon Rd., Cima CA 92323
Mailing: PO Box 70
Beatty NV 89003
775-513-1280
lcunningham@westernwatersheds.org

encl.

Douglas W Lovell
1514 Hearst Avenue
Berkeley CA 94703
doug.streamborn@gmail.com

3 March 2021

VIA EMAIL
Laura Cunningham
Western Watersheds Project
PO Box 70
Beatty NV 89003 CA

Report
Surface Water Monitoring Conducted 27 and 28 January 2021
Point Reyes National Seashore
Marin County CA

Dear Ms. Cunningham:

The subject report is attached.

Because the monitoring identified imminent risks human health, the report should be forwarded to appropriate regulatory agencies.

Please contact me with any questions or comments.

Sincerely,

Douglas W Lovell
Geoenvironmental Engineer

Attachment

Report
Surface Water Monitoring Conducted 27 and 28 January 2021
Point Reyes National Seashore
Marin County CA

Expires 31 December 2022

Prepared for
Laura Cunningham
Western Watersheds Project
PO Box 70
Beatty NV 89003 CA

Prepared by
Douglas W Lovell
1514 Hearst Avenue
Berkeley CA 94703
doug.streamborn@gmail.com

3 March 2021

CONTENTS

INTRODUCTION

This report documents surface water monitoring conducted 27 and 28 January 2021 at selected locations within Point Reyes National Seashore, Marin County CA. Five locations were monitored (Figures 1 and 2, Appendix A):

- PAC1S (South Kehoe Creek)
- PAC3 (Kehoe Lagoon)
- ABB2/3 (Unnamed Northern Tributary to Upper Abbotts Lagoon)
- DES2 (East Schooner Creek)
- DES4 (Main Stem Schooner Creek, downstream of the confluence with East Schooner Creek)

The January 2021 monitoring locations are within drainages with dairy cattle and beef cattle operations that "contribute to poor water quality through bacteria and nutrient loading from animal waste and runoff" (Pawley and Lay 2013). The drainages monitored in January 2021 had not been monitored since 2013, despite documented exceedances of surface water thresholds of concern for coliform bacteria in 2013 (Voller et al. 2020a).

BACKGROUND

Field parameters were measured at each location, including temperature, pH, specific conductivity, salinity, oxidation/reduction potential, dissolved oxygen, quantitative turbidity, qualitative turbidity, qualitative color, and flowrate.

For each location, samples were analyzed in the laboratory for coliform bacteria (total, fecal, E coli), enterococci bacteria, and macronutrients (nitrogen and phosphorus). The North Coast Regional Water Quality Control Board prepared a protocol to study bacteria in coastal watersheds, including freshwater lagoons and contributory freshwater feeder streams/rivers (North Coast RWQCB 2015). The bacteria analyses for the January 2021 monitoring were patterned after the North Coast's protocol, including (1) analysis of coliform bacteria, (2) analysis of enterococci bacteria, and (3) the use of analytical methods that employ whole sample aliquots, reported as most probable number (mpn), instead of filtering, reported as colony forming units (cfu).

Enterococci and E coli are generally considered the most reliable fecal indicator bacteria for evaluating human health risks in fresh, brackish, and marine recreational waters (US Environmental Protection Agency 2012). Enterococci bacteria, instead of E coli bacteria, have been suggested to more reliably predict gastrointestinal illness (North Coast 2015). Enterococci bacteria, instead of E coli bacteria, have been suggested to more reliably predict human health risks in brackish and marine waters because enterococci bacteria are more persistent in these saline environments (Jin et al. 2004, Boehm and Sassoubre 2014). However, enterococci bacteria have not been historically analyzed in the drainages that were monitored in January 2021. The lack of enterococci bacteria analyses may specifically impact conclusions regarding human health risks in Lower Abbotts Lagoon (represented by historical monitoring location

ABB4, Figures 1 and 2) because Lower Abbotts Lagoon is a brackish water environment (Kratzer et al. 2006).

Approximately 1.5 to 1.9 inches of precipitation were recorded for the 48 hours that preceded January 2021 monitoring (Table 1, Figure 3, Appendix D). Detailed hydrologic studies of Abbotts Creek immediately upstream of Upper Abbots Lagoon (Kratzer et al. 2006) revealed that peak instream flow occurred approximately 2.5-4 hours after peak precipitation. The January 2021 monitoring was performed more than 9 hours after peak precipitation (Figure 3), with monitoring performed on the falling portion of the hydrograph (decreasing flowrate with time). Had monitoring been performed sooner, relative to peak precipitation, greater bacteria and micronutrient concentrations would likely have been measured.

Monitoring locations PAC1S, PAC3, and DES2 coincide with historical monitoring locations; locations ABB2/3 and DES4 are new. Location ABB2/3 accounts for the combined input of historical monitoring locations T2 (also named ABB2) and T3 (also named ABB3), which are positioned upstream in separate forks of the drainage (Figures 1 and 2). Compared to historical locations T2 and T3, location ABB2/3 is closer to Upper Abbotts Lagoon and more accurately evaluates the impacts of cattle waste pollution on Upper Abbotts Lagoon. Location DES4 is characterized by brackish water of variable salinity.

Monitoring locations PAC1S, PAC3, and ABB2/3 coincide with drainages generally subject to "medium" and "high" use by dairy cattle (Pawley and Lay 2013, National Park Service 2020). Additionally, these three monitoring locations coincide with drainages subject to land application of cattle manure and composted cattle wastes (National Park Service 2020). Cattle waste management actions have reportedly been implemented in these drainages and temporal analyses of historical data showed (1) a significant decrease in the frequency of exceeding coliform bacteria thresholds of concern, and (2) "little evidence for any global or station level temporal trends" for turbidity due to temporal increases in "algal growth" (Voller et al. 2020a).

Monitoring locations DES2 and DES4 coincide with drainages generally subject to "medium" use by beef cattle (Pawley and Lay 2013, National Park Service 2020).

Special status/at-risk species and critical habitat are associated with the monitoring locations; the species include Central California Coast Steelhead and the California Red-Legged Frog (Appendices M, N, and O of National Park Service 2020) whose lifecycles directly depend on surface water quality.

- Steelhead have been observed in Abbotts Creek, a tributary to Upper Abbotts Lagoon (Figures 1 and 2) (National Park Service 2019).
- East Schooner Creek and downstream reaches of the main stem of Schooner Creek (to Drakes Estero) have been designated critical habitat for Central California Coast Steelhead (monitoring locations DES2 and DES4). Steelhead passage enhancements have been completed on East Schooner Creek and are planned on the main stem of Schooner Creek (National Park Service 2009, Federal Highway Administration 2018). Cattle waste management actions have not been implemented in the East Schooner Creek drainage and temporal analyses of historical data revealed an increase in the frequency of coliform bacteria exceeding thresholds of concern (Voller et al. 2020a).

- Populations of the California Red-Legged Frog are documented in drainages that feed Abbotts Lagoon (monitoring location ABB2/3), Kehoe Creek (monitoring locations PAC1S and PAC3), and Schooner Creek (monitoring location DES4). Cattle exclusion fencing has been installed in the West Schooner Creek drainage and Abbotts Creek drainage for protection of frog habitat (National Park Service 2020).

Depending on hydrologic conditions, time of year (season), and water temperature (which are interrelated); excess phytoplankton growth (leading to Harmful Algal Blooms) has been observed in Upper Abbots Lagoon, Middle Abbotts Lagoon, South Kehoe Creek, Kehoe Marsh, and Kehoe Lagoon (Pawley and Lay 2013; Kratzer et al. 2006; undocumented review of historical aerial photographs that are available on Google Earth; undocumented observations by me, and other undocumented first-person observations). Algal growth was suggested as the reason why turbidity had not decreased in drainages that received cattle waste management actions (Voller et al. 2020a). The National Park Service's Environmental Impact Statement (National Park Service 2020, Voller et al. 2020a, Voller et al. 2020b) did not compile and analyze historical macronutrient data. The link between excess phytoplankton growth, Harmful Algal Blooms, and macronutrient loading is well-established in the scientific literature, as is the expectation that climate change will exacerbate the excess growth.

In 1999-2000, the US Geological Survey performed investigations to evaluate eutrophication in the Abbotts Lagoon system; the investigations evaluated phytoplankton growth a result of nutrient loading (Kratzer et al. 2006). The investigations revealed that approximately 70% of the phosphorus loading and approximately 50% of the nitrogen loading to Upper Abbotts Lagoon originated from the unnamed northern tributary where ABB2/3 is located, whereas the unnamed northern tributary contributed (only) about 20% of the surface water inflow to Upper Abbotts Lagoon. The investigations also revealed that phytoplankton growth was nitrogen-limited as opposed to phosphorus-limited, indicating that reducing nitrogen loading to Upper Abbotts Lagoon would be most effective in limiting excess phytoplankton growth.

At the time of monitoring in January 2021, the cumulative precipitation for water year 2020-2021 was approximately 30-35% of normal (https://www.cnrfc.noaa.gov/monthly_precip.php). Had water year precipitation been normal (or above), a rainfall event similar to that in January 2021 would have likely revealed greater bacterial and macronutrient concentrations at the monitoring locations.

Stock ponds exist upstream of the five monitoring locations. These ponds are associated with historical and ongoing cattle watering (National Park Service 2020). During drier periods of the year, the ponds store precipitation; the ponds release water (spill) given sufficient precipitation. The ponds upstream of the five monitoring locations had not spilled for several months prior to the January 2021 monitoring, nor were the ponds spilling during monitoring. Had the ponds been spilling at the time of monitoring, it is likely that greater bacterial and macronutrient concentrations would have been measured - the increase relatively more for bacteria, which themselves are "particulates" (for example, E coli bacteria are rod-shaped particles, diameter = ±0.5 µm, length =±2 µm) – the increase relatively less for macronutrient because macronutrients continue to be released from the ponds via seepage of dissolved nitrogen and phosphorus, even when the ponds do not spill.

DISCUSSION OF THE MONITORING RESULTS

Table 1 contains the field observations and field parameter measurements. The elevated specific conductance measured at location DES4 reflects the monitoring of brackish water (monitoring was performed about halfway through an ebbing tide and the monitoring location was impacted by brackish water in the adjacent Drakes Estero). Specific conductance measurements at locations PAC1S, PAC3, and ABB2/3 (indicative of dairy cattle impacts) were greater than the measurement at the location DES2 (indicative of beef cattle impacts); the difference is partially due to greater nitrogen and phosphorus concentrations in the dairy cattle-impacted drainages.

Table 2 contains the bacteria laboratory results, along with potentially applicable criteria/thresholds of concern (listed in the rows at the bottom of Table 2).

Table 3 provides a comparison of measured bacteria concentrations to specifically-applicable criteria at each monitoring location. General note "(a)" at the bottom of Table 3 explains the selection of specifically-applicable criteria. The human health risk at each location is characterized by the ratio of (1) measured concentration to (2) specifically-applicable criterion. Locations PAC1S, PAC3, and ABB2/3 (indicative of dairy cattle impacts) exhibit exceedances of all specifically-applicable criteria. The human health risks characterized for locations PAC1S, PAC3, and ABB2/3 (indicative of dairy cattle impacts) significantly and consistently exceed the risks characterized for locations DES2 and DES4 (indicative of beef cattle impacts). The drainages characterized by PAC1S, PAC3, and ABB2/3 have reportedly received more cattle waste management actions than other drainages; the actions have reportedly included fencing, infrastructure improvement, livestock water supply, manure management, and pond restoration (Voller et al. 2020a). The January 2021 data indicate that, despite these reported actions, significant bacterial water quality pollution persists, resulting in continued risk to human health. At the lower water temperatures present during wintertime, coliform and enterococci bacteria will likely persist longer - compared to warmer periods (Korajkic et al. 2019, Dipankar et al. 2013).

For the drainages monitored in January 2021, enterococci bacteria posed greater risks to human health than coliform bacteria and enterococci may serve as a more accurate fecal indicator bacterium. However, only coliform bacteria were historically analyzed, and the National Park Service's conclusions drawn solely from coliform concentrations (National Park Service 2020, Voller et al. 20201) may be inaccurate.

Table 4 contains the macronutrient (nitrogen and phosphorus) laboratory results. Macronutrient concentrations at locations PAC1S, PAC3, and ABB2/3 (indicative of dairy cattle impacts) were more than twice the concentrations at locations DES2 and DES4 (indicative of beef cattle impacts).

Reliable general macronutrient criteria are not available to protect surface waters from excess phytoplankton growth and Harmful Algal Blooms; waterbody-specific analysis is required. The US Geological Survey study of eutrophication in Abbotts Lagoon (Kratzer et al. 2006) provides such an analysis. The US Geological Survey study concluded that phytoplankton growth in Upper Abbotts Lagoon was predominantly influenced by the macronutrient loading from the Unnamed Northern Tributary to Upper Lagoon (corresponding to historical monitoring locations T2 and T3 and January 2021 monitoring location ABB2/3, Figures 1 and 2). The US Geological

Survey study also concluded that phytoplankton growth was nitrogen-limited as opposed to phosphorus-limited. The total inorganic nitrogen/orthophosphate ratio measured in January 2021 at monitoring location ABB2/3 (Table 4) also suggests nitrogen-limiting conditions.

Table 5 provides a comparison of the historical (1999) and January 2021 nitrogen concentrations in the Unnamed Northern Tributary to Upper Abbotts Lagoon. Had location ABB2/3 been monitored in 1999, (1) the approximate flowrate at ABB2/3 would have been the sum of the flowrates at T2 and T3 and (2) the approximate nitrogen concentrations at ABB2/3 would have been the flow-weighted average of nitrogen concentrations at T2 and T3. The flowrates during the 1999 monitoring were approximately two to four times those in January 2021, which would be expected to have caused higher concentrations of nitrogen in 1999. In light of the flowrate differences, the nitrogen concentrations measured in January 2021 are remarkably similar to those measured in 1999; however, the data set for this comparison is small. Between 2000 and January 2012, cattle waste management actions were reportedly implemented in the Unnamed Northern Tributary to Upper Abbotts Lagoon drainage, including fencing, infrastructure improvements, livestock water supply, and manure management (Voller et al. 2020a). Despite these reported actions, nitrogen loads to Upper Abbotts Lagoon appear similar to those measured in 1999 and concerns regarding excess phytoplankton growth persist.

CONCLUSIONS

On the basis of the monitoring results and documented cattle operations, the following conclusions have a high level of confidence, particularly in the context of the meteorologic and hydrological conditions that existed immediately prior to and during monitoring:

- Bacteria contamination of surface water significantly exceeds applicable water quality criteria despite the reported implementation of cattle waste management actions. An increase of the frequency/extent of these same reported actions will likely further reduce bacteria contamination; however, it is likely that exceedances of applicable criteria will persist.
- Imminent human health risks exist regarding exposure to bacterial contamination in surface water, particularly for locations with documented or likely direct water contact.
- Macronutrient pollution of surface water, which causes excess phytoplankton growth, appears to persist at concentrations similar to those that predated the reported implementation of cattle waste management actions. Global warming will exacerbate excess phytoplankton growth.
- Reductions in the localized abundance of cattle waste will likely be necessary to adequately protect surface water quality.

Table 1

Field Observations and Field Parameter Measurements

Point Reyes National Seashore
Marin County CA

Location	Date	Time	Sample Type	Temp (˚C)	pH	Specific Conductance (µS/cm)	Salinity (o/oo) (ppt)	Oxidation-Reduction Potential (mV)	Dissolved Oxygen (mg/L) (3)	Turbidity (NTU) (4)	Visual Turbidity and Color	Estimated Flowrate (cfs)	Cumulative Precipitation for 6, 12, 24, 48 hours Preceding Monitoring (inches)	Hydrologic Conditions	Comments
PAC1S	27 Jan 21	9:40 am	Grab	9.9	7.0	650	0.3	230	9.6	22	translucent/light brown (with dozens of colloid-size black particles in ±12 fluid ounces)	4 (1) (2)	0.07/0.10/1.48/1.48	1.48" precipitation over the 48-hours preceding monitoring, which was the first precipitation event with more than 1" for water year 2020-2021. Upstream stock ponds had not spilled for at least 7 months preceding monitoring and the recent precipitation did not cause the ponds to spill. As of the date of monitoring, cumulative precipitation has been ±30-35% of normal for water year 2020-2021.	Monitoring was performed in a marshy area with prevalent aquatic vegetation. A well-mixed, reasonably well-defined flow channel existed within the vegetation. Monitoring was performed in this channel.
	28 Jan 21	9:00 am	Grab	9.6	7.4	630	0.3	210	9.4	18	translucent/light brown (with dozens of colloid-size black particles in ±12 fluid ounces)	4 (1) (2)	0.03/0.05/0.38/1.86	1.86" precipitation over the 48-hours preceding monitoring, which was the first precipitation event with more than 1" for water year 2020-2021. Upstream stock ponds had not spilled for at least 7 months preceding monitoring and the recent precipitation did not cause the ponds to spill. As of the date of monitoring, cumulative precipitation has been ±30-35% of normal for water year 2020-2021.	Monitoring was performed in a marshy area with prevalent aquatic vegetation. A well-mixed, reasonably well-defined flow channel existed within the vegetation. Monitoring was performed in this channel.
PAC3	28 Jan 21	9:47 am	Grab	10.8	7.5	990	0.5	90	11.8	14	translucent/light brown (with dozens of colloid-size black particles in ±12 fluid ounces)	Not estimated (2)	0.03/0.05/0.38/1.86	1.86" precipitation over the 48-hours preceding monitoring, which was the first precipitation event with more than 1" for water year 2020-2021. Upstream stock ponds had not spilled for at least 7 months preceding monitoring and the recent precipitation did not cause the ponds to spill. As of the date of monitoring, cumulative precipitation has been ±30-35% of normal for water year 2020-2021.	Monitoring of quiescent water was performed within a freshwater lagoon without observable flow. The monitored water was collected approximately 8 feet from shore at a depth of approximately 1 foot (below water surface). The total water depth at the monitoring location was approximately 6 feet.
ABB2/3	27 Jan 21	10:10 am	Grab	10.6	7.0	650	0.3	190	10.9	12	translucent/light brown (with dozens of colloid-size black particles in ±12 fluid ounces)	3 (1) (2)	0.07/0.10/1.48/1.48	1.48" precipitation over the 48-hours preceding monitoring, which was the first precipitation event with more than 1" for water year 2020-2021. Upstream stock ponds had not spilled for at least 7 months preceding monitoring and the recent precipitation did not cause the ponds to spill. As of the date of monitoring, cumulative precipitation has been ±30-35% of normal for water year 2020-2021.	Representative monitoring was performed within a well-defined, well-mixed channel.
	28 Jan 21	10:38 am	Grab	11.3	7.7	610	0.3	50	10.8	10	translucent/light brown (with dozens of colloid-size black particles in ±12 fluid ounces)	3 (1) (2)	0.03/0.07/0.38/1.86	1.86" precipitation over the 48-hours preceding monitoring, which was the first precipitation event with more than 1" for water year 2020-2021. Upstream stock ponds had not spilled for at least 7 months preceding monitoring and the recent precipitation did not cause the ponds to spill. As of the date of monitoring, cumulative precipitation has been ±30-35% of normal for water year 2020-2021.	Representative monitoring was performed within a well-defined, well-mixed channel.
DES2	28 Jan 21	11:22 pm	Grab	10.6	7.9	370	0.2	340	11.6	12	clear/slight brownish tint	4 (2)	0.03/0.07/0.38/1.86	1.86" precipitation over the 48-hours preceding monitoring, which was the first precipitation event with more than 1" for water year 2020-2021. Upstream stock ponds had not spilled for at least 7 months preceding monitoring and the recent precipitation did not cause the ponds to spill. As of the date of monitoring, cumulative precipitation has been ±30-35% of normal for water year 2020-2021.	Representative monitoring was performed within a well-defined, well-mixed channel.
DES4	28 Jan 21	2:40 pm	Grab	12.3	7.1	12,100	14	50	9.6	10	clear/none	20 (2)	0.01/0.04/0.33/1.87	1.87" precipitation over the 48-hours preceding monitoring, which was the first precipitation event with more than 1" for water year 2020-2021. Upstream stock ponds had not spilled for at least 7 months preceding monitoring and the recent precipitation did not cause the ponds to spill. As of the date of monitoring, cumulative precipitation has been ±30-35% of normal for water year 2020-2021.	Representative monitoring was performed within a well-defined, well-mixed channel. The monitoring location is impacted by saltwater and tidal fluctuations in Drakes Estero. Monitoring was performed on an ebb tide, approximately half-way between high tide and low tide, with the water in well-defined marsh channels, below the lowest level of channel-side vegetation. Brackish water was monitored, which explains the elevated specific conductance and salinity.

General Notes

(a) Monitoring was performed by Douglas Lovell (Berkeley CA).

(b) Visual turbidity classified as either clear, translucent, or opaque.

(c) Precipitation measurements from the nearby "Pt. Reyes RCA" meteorological station (https://wrcc.dri.edu/cgi-bin/wea_daysum.pl?nvprca).

(d) Comparison to "normal precipitation" based on actual accumulated rainfall for water year 1 October 2020-30 September 2021 (https://www.cnrfc.noaa.gov/monthly_precip.php).

(e) Estimated Flowrate = volumetric discharge of the entire water flow, rounded to one significant digit. The estimate is approximate, based on visual observations and rudimentary estimates of flow velocity and channel dimensions. The estimate is likely accurate within ±50%.

Footnotes

(1) = The flowrate on 28 January 2021 was less than the flowrate on 27 January 2021.

(2) = Monitoring was performed on the falling portion of the hydrograph – flowrate was decreasing at the time of monitoring.

(3) = A calibration check was performed after returning from the field; the calibration check revealed that the reported dissolved oxygen measurements were 0.1 to 0.2 mg/L high.

(4) = A calibration check was performed after returning from the field; the calibration check revealed that the reported turbidity measurements were low (the magnitude of the error was not estimated).

Table 2

Laboratory Analytical Results for Bacteria

Point Reyes National Seashore
Marin County CA

Location	Date	Sample Type	Estimated Flowrate (cfs)	Hydrologic Conditions	Total Coliform Bacteria (mpn/100 ml)	Fecal Coliform Bacteria (mpn/100 ml)	E Coli Bacteria (mpn/100 ml)	Enterococci Bacteria (mpn/100 ml)	Comments
PAC1S	27 Jan 21	Grab	4 (1) (2)	1.48" precipitation over the 48-hours preceding monitoring, which was the first precipitation event with more than 1" for water year 2020-2021. Upstream stock ponds had not spilled for at least 7 months preceding monitoring and the recent precipitation did not cause the ponds to spill. As of the date of monitoring, cumulative precipitation has been ±30-35% of normal for water year 2020-2021.	54,000	22,000	17,000	12,000	
	28 Jan 21	Grab	4 (1) (2)	1.86" precipitation over the 48-hours preceding monitoring, which was the first precipitation event with more than 1" for water year 2020-2021. Upstream stock ponds had not spilled for at least 7 months preceding monitoring and the recent precipitation did not cause the ponds to spill. As of the date of monitoring, cumulative precipitation has been ±30-35% of normal for water year 2020-2021.	22,000	14,000	11,000	14,000	
PAC3	28 Jan 21	Grab	not estimated (2)	1.86" precipitation over the 48-hours preceding monitoring, which was the first precipitation event with more than 1" for water year 2020-2021. Upstream stock ponds had not spilled for at least 7 months preceding monitoring and the recent precipitation did not cause the ponds to spill. As of the date of monitoring, cumulative precipitation has been ±30-35% of normal for water year 2020-2021.	17,000	11,000	9,400	17,000	
ABB2/3	27 Jan 21	Grab	3 (1) (2)	1.48" precipitation over the 48-hours preceding monitoring, which was the first precipitation event with more than 1" for water year 2020-2021. Upstream stock ponds had not spilled for at least 7 months preceding monitoring and the recent precipitation did not cause the ponds to spill. As of the date of monitoring, cumulative precipitation has been ±30-35% of normal for water year 2020-2021.	35,000	17,000	13,000	8,700	
	28 Jan 21	Grab	3 (1) (2)	1.86" precipitation over the 48-hours preceding monitoring, which was the first precipitation event with more than 1" for water year 2020-2021. Upstream stock ponds had not spilled for at least 7 months preceding monitoring and the recent precipitation did not cause the ponds to spill. As of the date of monitoring, cumulative precipitation has been ±30-35% of normal for water year 2020-2021.	17,000	7,000	920	11,000	
DES2	28 Jan 21	Grab	4 (2)	1.86" precipitation over the 48-hours preceding monitoring, which was the first precipitation event with more than 1" for water year 2020-2021. Upstream stock ponds had not spilled for at least 7 months preceding monitoring and the recent precipitation did not cause the ponds to spill. As of the date of monitoring, cumulative precipitation has been ±30-35% of normal for water year 2020-2021.	1,600	920	540	550	
DES4	28 Jan 21	Grab	20 (2)	1.87" precipitation over the 48-hours preceding monitoring, which was the first precipitation event with more than 1" for water year 2020-2021. Upstream stock ponds had not spilled for at least 7 months preceding monitoring and the recent precipitation did not cause the ponds to spill. As of the date of monitoring, cumulative precipitation has been ±30-35% of normal for water year 2020-2021.	5,400 (H)	1,700 (H)	1,100 (H)	1,400 (H)	Brackish water was monitored.

Candidate Criteria/Thresholds of Concern (RWQCB 2019)

Criterion	Total Coliform Bacteria	Fecal Coliform Bacteria	E Coli Bacteria	Enterococci Bacteria	Comments
Geometric mean concentration for "Water Contact Recreation"		200			
90th percentile concentration for "Water Contact Recreation"		400			
Median concentration for "Water Contact Recreation"	240				
Maximum concentration of any sample for "Water Contact Recreation"	10,000				
Median concentration for "Shellfish Harvesting" (mpn/100 mL)	70	14			
90th percentile concentration for "Shellfish Harvesting" (mpn/100 mL)	230	43			
Maximum concentration for a "designed beach" in freshwater (cfu/100 mL)			235	61	
Maximum concentration for a "moderately used area" in freshwater (cfu/100 mL)			298	89	
Maximum concentration for a "lightly used area" in freshwater (cfu/100 mL)			406	108	
Maximum concentration for a "infrequently used area" in freshwater (cfu/100 mL)			576	151	
Maximum concentration for a "designated beach" in saltwater (cfu/100 mL)				104	
Maximum concentration for a "moderately used area" in saltwater (cfu/100 mL)				124	
Maximum concentration for a "lightly used area" in saltwater (cfu/100 mL)				276	
Maximum concentration for a "infrequently used area" in saltwater (cfu/100 mL)				500	
Geometric mean concentration for REC1 beneficial use in freshwater (cfu/100 mL)			100	30	
90th percentile concentration for REC1 beneficial use in freshwater (cfu/100 mL)			320	110	

General Notes

(a) Samples were collected by Douglas Lovell (Berkeley CA). Samples were analyzed by McCampbell Analytical (Pittsburg CA).

(b) Precipitation measurements from the nearby "Pt. Reyes RCA" meteorological station (https://wrcc.dri.edu/cgi-bin/wea_daysum.pl?nvprca).

(c) Comparison to "normal precipitation" based on actual accumulated rainfall for water year 1 October 2020-30 September 2021 (https://www.cnrfc.noaa.gov/monthly_precip.php).

(d) Estimated Flowrate = volumetric discharge of the entire water flow, rounded to one significant digit. The estimate is approximate, based on visual observations and rudimentary estimates of flow velocity and channel dimensions. The estimate is likely accurate within ±50%.

(e) mpn = most probable number. cfu = colony forming units. Common practice treats these as equivalent units although they are not equivalent under certain conditions.

(f) REC1 beneficial use includes direct contact recreation (swimming, wading, etc.).

Footnotes

(H) = sample prepared/analyzed beyond the accepted holding time; however, the measured concentrations are believed accurate.

(1) = The flowrate on 28 January 2021 was less than the flowrate on 27 January 2021.

(2) = Monitoring was performed on the falling portion of the hydrograph – flowrate was decreasing at the time of monitoring.

Table 3

Comparisons of Measured Bacteria Concentrations to Applicable Criteria

Point Reyes National Seashore
Marin County CA

Location	Date	Measured Total Coliform Bacteria (mpn/100 ml)	Applicable Total Coliform Criterion (mpn/100 ml)	Ratio of Measured Total Coliform to Applicable Criterion [(1)]	Measured E Coli Bacteria (mpn/100 ml)	Applicable E Coli Criterion (cfu/100 ml)	Ratio of Measured E Coli to Applicable Criterion [(1)]	Measured Enterococci Bacteria (mpn/100 ml)	Applicable Enterococci Criterion (cfu/100 ml)	Ratio of Measured Enterococci to Applicable Criterion [(1)]
PAC1S	27 Jan 21	54,000	10,000	5	17,000	576	30	12,000	151	80
	28 Jan 21	22,000	10,000	2	11,000	576	20	14,000	151	90
PAC3	28 Jan 21	17,000	10,000	2	9,400	235	40	17,000	61	300
ABB2/3	27 Jan 21	35,000	10,000	3	13,000	576	20	8,700	151	60
	28 Jan 21	17,000	10,000	2	920	576	2	11,000	151	70
DES2	28 Jan 21	1,600	10,000	<1	540	576	<1	550	151	4
DES4 [(2)]	28 Jan 21	5,400 [(H)]	10,000	<1	1,100 [(H)]			1,400 [(H)]	276-500	3-5

General Notes

(a) Potentially applicable criteria are compiled in the bottom rows of Table 2. Because the January 2021 monitoring consisted of either one or two samples at each location, the data set is too small to calculate meaningful median values, geometric mean values, or 90th percentile values. Accordingly, "maximum concentration" criteria have been employed for comparison purposes. For E Coli and Enterococci bacteria, maximum concentration criteria are segregated according to frequency of use, with the choices being "designated beach," "moderately used area," "lightly used area," and "infrequently used area."

Kehoe Beach, including Kehoe Beach Lagoon (PAC3), receives frequent use that includes wading and swimming – the area is supported by nearby parking that accommodates more than a dozen vehicles, along with restrooms – this location is properly classified as a "designated beach."

The main stem of Schooner Creek at Sir Frances Drake Boulevard (DES4) is supported by adjacent parking and accommodates the launching of personal watercraft – this location is properly classified as either a "lightly used area" or an "infrequently used area."

Each of the remaining locations is properly classified as an "infrequently used area."

(b) mpn = most probable number. cfu = colony forming units. Common practice treats these as equivalent units although they are not equivalent under certain conditions.

Footnotes

[(H)] = sample prepared/analyzed beyond the accepted holding time; however, the measured concentrations are believed accurate.

[(1)] = rounded to one significant digit.

[(2)] = brackish water was monitored at DES4 and saltwater criteria are applicable; an E coli maximum concentration is not available for saltwater.

Table 4

Laboratory Analytical Results for Nitrogen and Phosphorus

Point Reyes National Seashore
Marin County CA

Location	Date	Sample Type	Estimated Flowrate (cfs)	Hydrologic Conditions	Ammonia as Nitrogen (mg N/L)	Unionized Ammonia (calculation) (mg NH_3/L)	Nitrate as Nitrogen (mg N/L)	Nitrite as Nitrogen (mg N/L)	Total Inorganic Nitrogen (calculation) (mg N/L)	Total Kjeldahl Nitrogen (mg N/L)	Total Organic Nitrogen (calculation) (mg N/L)	Total Nitrogen (calculation) (mg N/L)	Ortho-phosphate (PO_4) as Phosphorus (mg P/L)	Total Phosphorus (mg P/L) [FB]	Ratio of Total Inorganic Nitrogen to Ortho-phosphate as P	Comments
PAC1S	27 Jan 21	Grab	4 [1][2]	1.48" precipitation over the 48-hours preceding monitoring, which was the first precipitation event with more than 1" for water year 2020-2021. Upstream stock ponds had not spilled for at least 7 months preceding monitoring and the recent precipitation did not cause the ponds to spill. As of the date of monitoring, cumulative precipitation has been ±30-35% of normal for water year 2020-2021.	0.18	<0.001	4.1	<0.10	4.2	3.1	2.9	7.1	0.48	0.83	9	
	28 Jan 21	Grab	4 [1][2]	1.86" precipitation over the 48-hours preceding monitoring, which was the first precipitation event with more than 1" for water year 2020-2021. Upstream stock ponds had not spilled for at least 7 months preceding monitoring and the recent precipitation did not cause the ponds to spill. As of the date of monitoring, cumulative precipitation has been ±30-35% of normal for water year 2020-2021.	0.14	0.001	3.3	<0.10	3.4	2.4	2.3	5.7	0.20	0.37	17	
PAC3	28 Jan 21	Grab	not estimated [2]	1.86" precipitation over the 48-hours preceding monitoring, which was the first precipitation event with more than 1" for water year 2020-2021. Upstream stock ponds had not spilled for at least 7 months preceding monitoring and the recent precipitation did not cause the ponds to spill. As of the date of monitoring, cumulative precipitation has been ±30-35% of normal for water year 2020-2021.	0.14	0.001	2.5	<0.10	2.6	3.0	2.9	5.5	0.59	0.87	4	
ABB2/3	27 Jan 21	Grab	3 [1][2]	1.48" precipitation over the 48-hours preceding monitoring, which was the first precipitation event with more than 1" for water year 2020-2021. Upstream stock ponds had not spilled for at least 7 months preceding monitoring and the recent precipitation did not cause the ponds to spill. As of the date of monitoring, cumulative precipitation has been ±30-35% of normal for water year 2020-2021.	0.24	<0.001	5.2	<0.10	5.4	3.4	3.2	8.6	0.51	0.83	11	
	28 Jan 21	Grab	3 [1][2]	1.86" precipitation over the 48-hours preceding monitoring, which was the first precipitation event with more than 1" for water year 2020-2021. Upstream stock ponds had not spilled for at least 7 months preceding monitoring and the recent precipitation did not cause the ponds to spill. As of the date of monitoring, cumulative precipitation has been ±30-35% of normal for water year 2020-2021.	0.18	0.002	3.9	<0.10	4.1	2.9	2.7	6.8	0.45	0.70	9	
DES2	28 Jan 21	Grab	4 [2]	1.86" precipitation over the 48-hours preceding monitoring, which was the first precipitation event with more than 1" for water year 2020-2021. Upstream stock ponds had not spilled for at least 7 months preceding monitoring and the recent precipitation did not cause the ponds to spill. As of the date of monitoring, cumulative precipitation has been ±30-35% of normal for water year 2020-2021.	0.12	0.002	1.9	<0.10	2.0	0.76	0.64	2.6	<0.10	0.14	>20	
DES4	28 Jan 21	Grab	20 [2]	1.87" precipitation over the 48-hours preceding monitoring, which was the first precipitation event with more than 1" for water year 2020-2021. Upstream stock ponds had not spilled for at least 7 months preceding monitoring and the recent precipitation did not cause the ponds to spill. As of the date of monitoring, cumulative precipitation has been ±30-35% of normal for water year 2020-2021.	<0.10	<0.001	<2.0 [3]	<2.0 [3]	<2.0	0.90	>0.90	<2.8	<2.0 [3]	0.20	Not calculated	Brackish water was monitored.

General Notes

(a) Samples were collected by Douglas Lovell (Berkeley CA). Samples were analyzed by McCampbell Analytical (Pittsburg CA).

(b) Precipitation measurements from the nearby "Pt. Reyes RCA" meteorological station (https://wrcc.dri.edu/cgi-bin/wea_daysum.pl?nvprca).

(c) Comparison to "normal precipitation" based on actual accumulated rainfall for water year 1 October 2020-30 September 2021 (https://www.cnrfc.noaa.gov/monthly_precip.php).

(d) Estimated Flowrate = volumetric discharge of the entire water flow, rounded to one significant digit. The estimate is approximate, based on visual observations and rudimentary estimates of flow velocity and channel dimensions. The estimate is likely accurate within ±50%.

(e) "<" indicates the result was below the cited laboratory reporting limit.

(g) Calculation of Unionized Ammonia as N from https://www.svl.net/unionized-amonia-calculator/. The calculation is specific to freshwater.

(h) Total Organic Nitrogen = Total Kjeldahl Nitrogen - Ammonia as Nitrogen. Total Inorganic Nitrogen = Ammonia as Nitrogen + Nitrate as Nitrogen + Nitrite as Nitrogen. Total Nitrogen = Organic Nitrogen + Inorganic Nitrogen. For the purposes of calculation, results below the laboratory detection limit have been taken as zero.

Footnotes

[1] = The flowrate on 28 January 2021 was less than the flowrate on 27 January 2021.

[2] = Monitoring was performed on the falling portion of the hydrograph – flowrate was decreasing at the time of monitoring.

[3] = For Nitrate, Nitrite, and Orthophosphate analyses of the sample from location DES4, the reporting limit was raised (the sample was diluted) due to the physical nature (salinity) of the sample; consequently, the surrogate recovery was outside accepted limits. Nitrogen and phosphorus measurements at DES4 were not employed to interpret macronutrient impacts on surface water quality.

[FB] = Total Phosphorus was measured in the field blank at a concentration of 0.083 mg/L (negligible concentration).

Table 5

Nitrogen Concentrations in the Unnamed Northern Tributary to Upper Abbotts Lagoon

Point Reyes National Seashore
Marin County CA

Location	Date	Time	Estimated Flowrate (cfs)	Hydrologic Conditions	Ammonia as Nitrogen (mg N/L)	Nitrate as Nitrogen (mg N/L)	Nitrite as Nitrogen (mg N/L)	Total Inorganic Nitrogen (mg N/L)	Total Kjeldahl Nitrogen (mg N/L)	Total Organic Nitrogen (mg N/L)	Total Nitrogen (mg N/L)
T2 (also named ABB2)	6 Feb 99	6:50 pm	5 [3]	Approximately 3” precipitation over the 48-hours preceding monitoring. Approximately 6” precipitation over the month preceding monitoring.	1.00	3.33	0.076	4.41	5.2	4.2	9.6
	6 Feb 99	9:50 pm	5 [3]	Approximately 3” precipitation over the 48-hours preceding monitoring. Approximately 6” precipitation over the month preceding monitoring.	1.27	2.87	0.058	4.20	6.4	5.1	11.5
	7 Feb 99	10:30 am	5 [3]	Approximately 3” precipitation over the 48-hours preceding monitoring. Approximately 6” precipitation over the month preceding monitoring.	0.83	3.25	0.067	4.15	4.5	3.7	8.2
	7 Feb 99	2:40 pm	3 [3]	Approximately 3” precipitation over the 48-hours preceding monitoring. Approximately 6” precipitation over the month preceding monitoring.	0.72	4.52	0.085	5.33	3.0	2.3	5.3
	11 Apr 99	6:00 am	5 [3]	Approximately 2” precipitation over the 48-hours preceding monitoring. Approximately 3” precipitation over the month preceding monitoring.	0.79	4.91	0.096	5.80	7.8	7.0	14.8
T3 (also named ABB3	7 Feb 99	1:00 pm	7 [3]	Approximately 3” precipitation over the 48-hours preceding monitoring. Approximately 6” precipitation over the month preceding monitoring.	3.46	8.34	0.223	12.12	9.9	6.4	16.3
	11 Apr 99	7:15 am	1.5 [3]	Approximately 2” precipitation over the 48-hours preceding monitoring. Approximately 3” precipitation over the month preceding monitoring.	1.68	3.39	0.085	5.16	13	11.3	24.3
ABB2/3	27 Jan 21	10:10 am	3 [1] [2]	1.48” precipitation over the 48-hours preceding monitoring, which was the first precipitation event with more than 1” for water year 2020-2021. Upstream stock ponds had not spilled for at least 7 months preceding monitoring and the recent precipitation did not cause the ponds to spill. As of the date of monitoring, cumulative precipitation has been ±30-35% of normal for water year 2020-2021.	0.24	5.2	<0.10	5.4	3.4	3.2	8.6
	28 Jan 21	10:38 am	3 [1] [2]	1.86” precipitation over the 48-hours preceding monitoring, which was the first precipitation event with more than 1” for water year 2020-2021. Upstream stock ponds had not spilled for at least 7 months preceding monitoring and the recent precipitation did not cause the ponds to spill. As of the date of monitoring, cumulative precipitation has been ±30-35% of normal for water year 2020-2021.	0.18	3.9	<0.10	4.1	2.9	2.7	6.8

General Notes

(a) The US Geological Survey performed the monitoring in 1999 (Kratzer et al. 2006).

(b) “<” indicates the result was below the cited laboratory reporting limit.

(c) Total Organic Nitrogen = Total Kjeldahl Nitrogen - Ammonia as Nitrogen. Total Inorganic Nitrogen = Ammonia as Nitrogen + Nitrate as Nitrogen + Nitrite as Nitrogen. Total Nitrogen = Organic Nitrogen + Inorganic Nitrogen. For the purposes of calculation, results below the laboratory detection limit have been taken as zero.

Footnotes

[1] = The flowrate on 28 January 2021 was less than the flowrate on 27 January 2021.

[2] = Monitoring was performed on the falling portion of the hydrograph – flowrate was decreasing at the time of monitoring.

[3] = Monitoring was performed near peak flowrate.

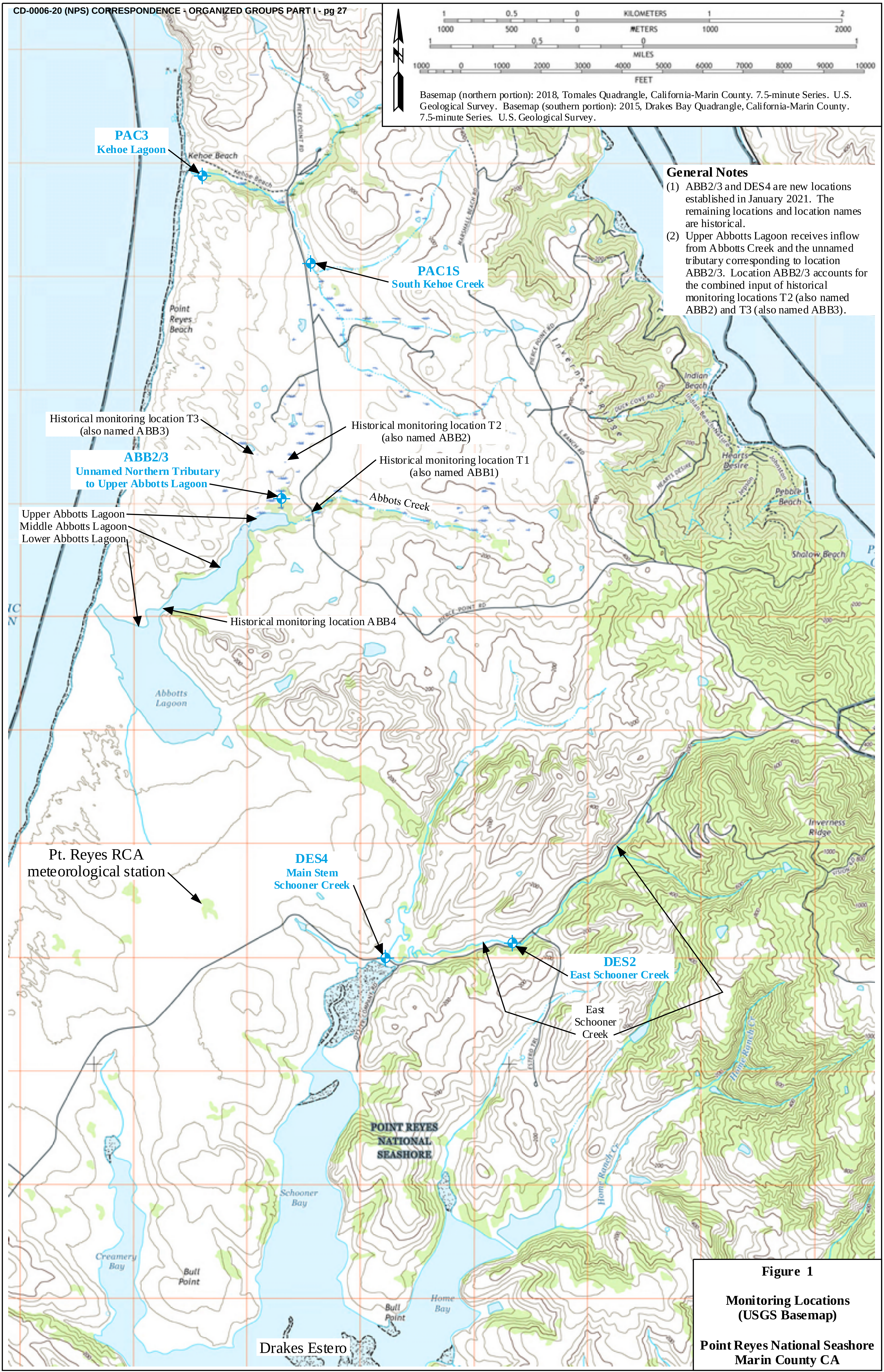
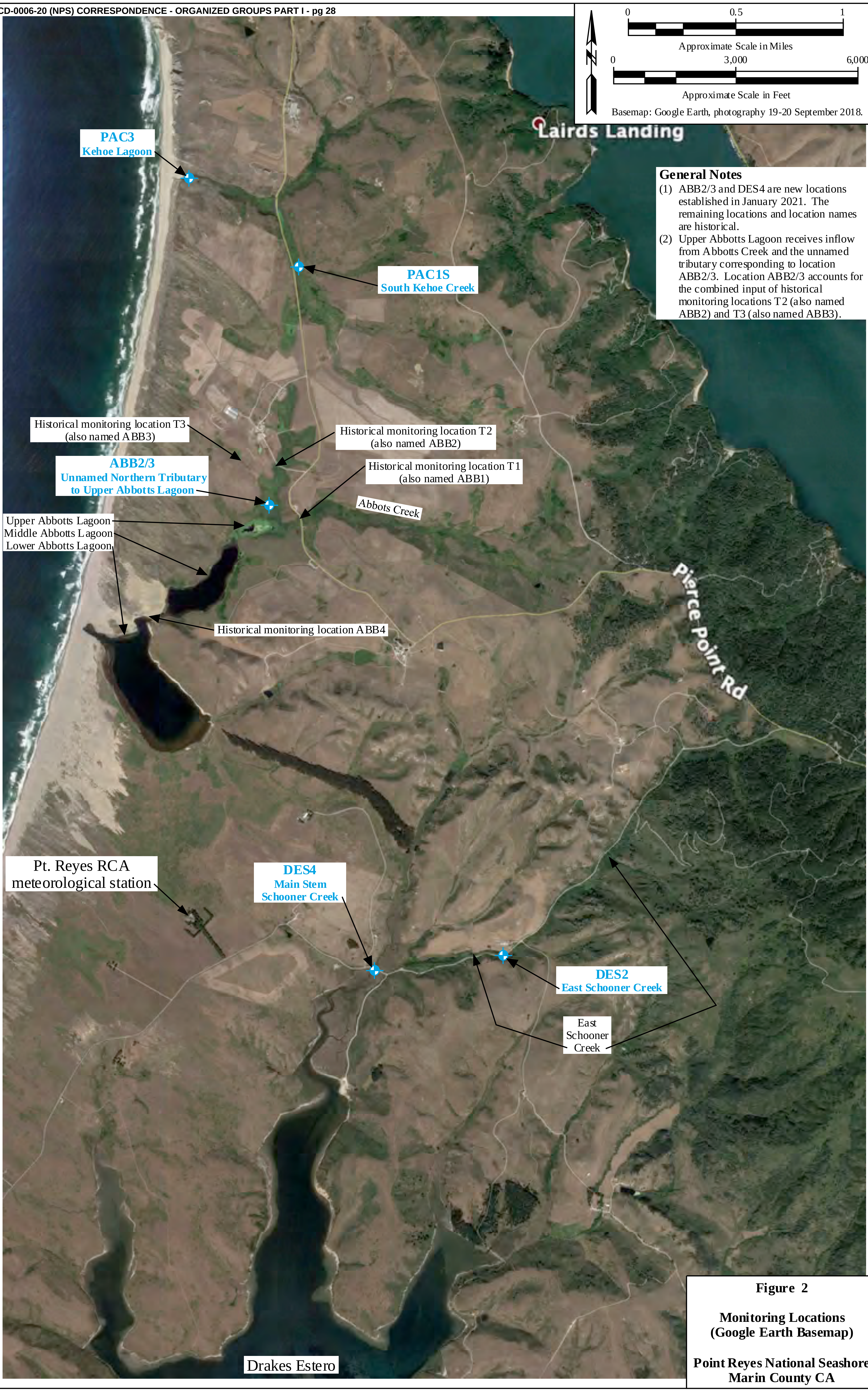


Figure 1

Monitoring Locations (USGS Basemap)

Point Reyes National Seashore Marin County CA



General Notes

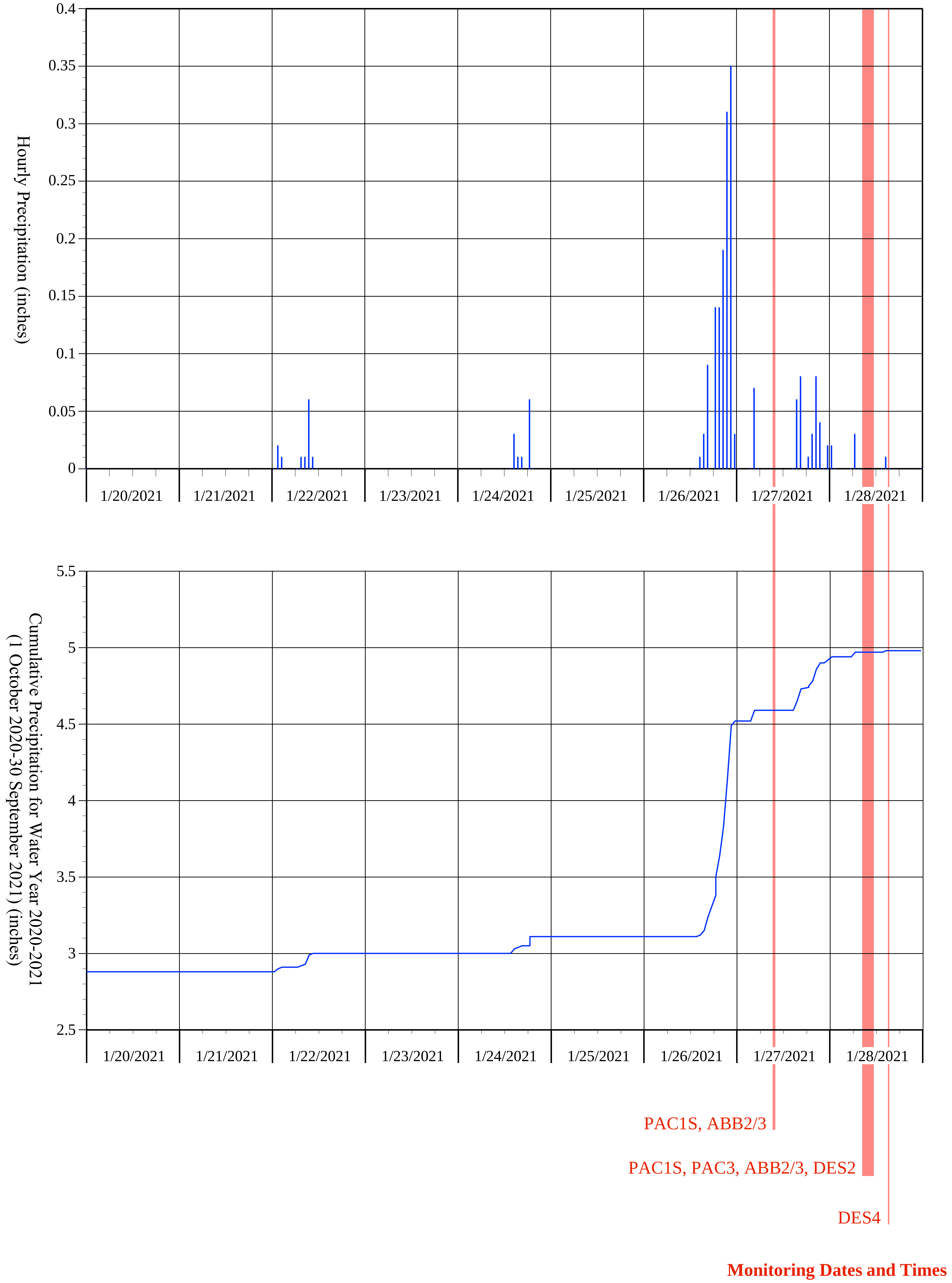
(1) ABB2/3 and DES4 are new locations established in January 2021. The remaining locations and location names are historical.

(2) Upper Abbotts Lagoon receives inflow from Abbotts Creek and the unnamed tributary corresponding to location ABB2/3. Location ABB2/3 accounts for the combined input of historical monitoring locations T2 (also named ABB2) and T3 (also named ABB3).

Figure 2

Monitoring Locations (Google Earth Basemap)

Point Reyes National Seashore
Marin County CA



Detailed hydrologic studies of Abbotts Creek immediately upstream of Upper Abbots Lagoon revealed that peak instream flow occurred approximately 2.5-4 hours after peak precipitation [Kratzer, CR, Saleh, DK, and Celia Zamora (2006). *Assessment of Hydrologic and Water Quality Data Collected in Abbotts Lagoon Watershed, Point Reyes National Seashore, California during Water Years 1999 and 2000. Scientific Investigations Report 2005-5261, Prepared in cooperation with the National Park Service.* Prepared by United States Geological Survey, Sacramento CA. 2006. https://pubs.usgs.gov/sir/2005/5261/sir_2005-5261.pdf]

Precipitation data from the nearby Pt Reyes RCA meterological station
https://wrcc.dri.edu/cgi-bin/rawMAIN.pl?nvprca

Figure 3

Precipitation Measurements from the Pt. Reyes RCA Meteorological Station

Point Reyes National Seashore Marin County CA

APPENDIX A

Monitoring Locations

MONITORING LOCATIONS

PAC1S (South Kehoe Creek)

- Historical monitoring location with historical water quality data.
- Primarily reflects dairy cattle impacts.
- Located in a marshy area with abundant terrestrial and aquatic vegetation. Flow at the monitoring location was somewhat diffuse. At the monitoring location, the total width of the flow channel was approximately 8 feet; the depth varied up to approximately 0.7 feet. Some of the water flow occurred around stems and leaves of the aquatic vegetation. Monitoring was performed at a location with visible flow and without vegetation.
- The substrate at the monitoring location was black, organic sandy silt.
- [a] Water was collected from the upper ±2 inches of flow without disturbing the substrate.
- Immediately downstream of PAC1S, Pierce Point Road creates a flow restriction, resulting in standing/quiescent water (on the upstream side of Piercy Point Road). Floating algae have been observed in the standing/quiescent water.
- Visitors have direct access to South Kehoe Creek, particularly the standing/quiescent water upstream of Pierce Pont Road. Restrooms and parking are near the monitoring location.

PAC3 (Kehoe Lagoon)

- Historical monitoring location with historical water quality data.
- Primarily reflects dairy cattle impacts.
- The monitoring location was at the downstream end of Kehoe Marsh, ±8 feet from the northern shore of the lagoon. The water depth at the monitoring location was ±6 feet.
- Quiescent/standing water existed at the monitoring location.
- The substrate at the monitoring locations was brown sand.
- Water was collected at a depth of ±1 foot below the water surface without disturbing the substrate.
- Filamentous algae and floating algae have been observed in Kehoe Lagoon.
- Visitors frequent Kehoe Lagoon. Visitors wade and swim in Kehoe Lagoon. Restrooms and parking are near the monitoring location.

ABB2/3 (Unnamed Northern Tributary to Upper Abbotts Lagoon)

- This new monitoring location is downstream of historical monitoring locations T2 (also named ABB2) and T3 (also named ABB3). Location ABB2/3 accounts for the combined flow from historical monitoring locations T2 and T3. ABB2/3 represents a more accurate location to determine water quality impacts on Upper Abbotts Lagoon.
- Primarily reflects dairy cattle impacts.
- Monitoring was performed in a well-defined flow channel. Monitoring was performed of well-mixed flow.
- The substrate at the monitoring location was brown sand and gravel.

- [a] Water was collected from the upper ±2 inches of flow without disturbing the substrate.
- Upper Abbots Lagoon is located immediately downstream of ABB2/3. Floating algae have been observed in Upper Abbotts Lagoon.
- Parking is located near the monitoring location and lightly-used footpaths to the unnamed tributary were observed during monitoring.

DES2 (East Schooner Creek)

- Historical monitoring location with historical water quality data.
- Primarily reflects beef cattle impacts.
- Located where Sir Frances Drake Boulevard crosses the creek.
- Prior to monitoring, the former corrugated-metal-pipe culvert crossing had been replaced with a reinforced-concrete bottomless culvert crossing (Federal Highway Administration 2018). The replacement crossing at DES2 had been constructed in a manner similar to previous side-road crossings of East Schooner Creek (National Park Service 2006).
- Monitoring was performed immediately upstream of the bottomless culvert, within a well-defined flow channel. Monitoring was performed approximately 5 feet upstream of pooled water that existed on the upstream side of the bottomless culvert. Monitoring was performed of well-mixed flow.
- The substrate at the monitoring locations was brown sand and gravel.
- [a] Water was collected from the upper ±2 inches of flow without disturbing the substrate.
- East Schooner Creek is designated critical habitat for the Central California Coast Steelhead.
- Parking exists immediately adjacent to the monitoring location. Creek access upstream of the bottomless culvert is limited by fencing; direct access exists on the downstream side of the bottomless culvert.

DES4 (Main Stem Schooner Creek)

- Not a historical monitoring location.
- Primarily reflects beef cattle impacts.
- Located where Sir Frances Drake Boulevard crosses the creek.
- At the time of the January 2021 monitoring, the crossing consisted of twin 84-inch corrugated-metal-pipes. The crossing has been slated for replacement with a single-span bridge (Federal Highway Administration 2018); barricades, silt fence, and sandbags were observed on the downstream side of the crossing, indicating construction of the replacement bridge had commenced.
- Monitoring was performed within the westerly culvert, at the downstream end. Monitoring was performed of well-mixed flow.
- The “substrate” at the monitoring locate was the metal culvert.
- [a] Water was collected from the upper ±2 inches of flow.
- Parking exists immediately adjacent to the monitoring location. Visitors can launch personal watercraft at the monitoring location, although the “advertised” personal watercraft launch for Drakes Estero is ±1 mile to the south.

Location PAC1S. View looking east. 28 January 2021.

Kehoe Lagoon. View looking southwest. Location PAC3 was at the outside edge of the tules that are visible on the left side of the photograph. 28 January 2021.

Location PAC3. View looking south. 28 January 2021.

Location ABB2/3. View looking south (downstream towards Upper Abbotts Lagoon). 28 January 2021.

Location ABB2/3. View looking south (downstream towards Upper Abbotts Lagoon). 28 January 2021.

Location DES2 located upstream of the bottomless culvert where Sir Frances Drake Boulevard crosses East Schooner Creek. View looking northeast. 28 January 2021.

Location DES4 at the downstream end of the twin corrugated metal pipes where Sir Frances Drake Boulevard crosses the main stem of Schooner Creek. Monitoring was performed at the westerly (closest pipe). View looking east. 28 January 2021.

View of the tidal marsh upstream of the twin corrugated metal pipes where Sir Frances Drake Boulevard crosses the main stem of Schooner Creek. East Schooner Creek enters on the lower right-hand corner of the photograph. View looking north (upstream). 28 January 2021.

APPENDIX B

Laboratory Analytical Reports

McCampbell Analytical, Inc.

"When Quality Counts"

Analytical Report

WorkOrder: 2101C81

Report Created for: Douglas Lovell

1514 Hearst Avenue
Berkeley, CA 94703

Project Contact: Douglas Lovell
Project P.O.:
Project: P2021.1; Pt Reys Surface Water Monitoring

Project Received: 01/27/2021

Analytical Report reviewed & approved for release on 02/05/2021 by:

Yen Cao

Yen Cao
Project Manager

The report shall not be reproduced except in full, without the written approval of the laboratory. The analytical results relate only to the items tested. Results reported conform to the most current NELAP standards, where applicable, unless otherwise stated in a case narrative.

NELAP ACCREDITED TNI LABORATORY

1534 Willow Pass Rd. Pittsburg, CA 94565 ♦ TEL: (877) 252-9262 ♦ FAX: (925) 252-9269 ♦ www.mccampbell.com
CA ELAP 1644 ♦ NELAP 4033 ORELAP

McCampbell Analytical, Inc.
"When Quality Counts"
1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Glossary of Terms & Qualifier Definitions

Client: Douglas Lovell
Project: P2021.1; Pt Reys Surface Water Monitoring
WorkOrder: 2101C81

Glossary Abbreviation

%D	Serial Dilution Percent Difference
95% Interval	95% Confident Interval
CPT	Consumer Product Testing not NELAP Accredited
DF	Dilution Factor
DI WET	(DISTLC) Waste Extraction Test using DI water
DISS	Dissolved (direct analysis of 0.45 μm filtered and acidified water sample)
DLT	Dilution Test (Serial Dilution)
DUP	Duplicate
EDL	Estimated Detection Limit
ERS	External reference sample. Second source calibration verification.
ITEF	International Toxicity Equivalence Factor
LCS	Laboratory Control Sample
LQL	Lowest Quantitation Level
MB	Method Blank
MB % Rec	% Recovery of Surrogate in Method Blank, if applicable
MDL	Method Detection Limit
ML	Minimum Level of Quantitation
MS	Matrix Spike
MSD	Matrix Spike Duplicate
N/A	Not Applicable
ND	Not detected at or above the indicated MDL or RL
NR	Data Not Reported due to matrix interference or insufficient sample amount.
PDS	Post Digestion Spike
PDSD	Post Digestion Spike Duplicate
PF	Prep Factor
RD	Relative Difference
RL	Reporting Limit (The RL is the lowest calibration standard in a multipoint calibration.)
RPD	Relative Percent Deviation
RRT	Relative Retention Time
SPK Val	Spike Value
SPKRef Val	Spike Reference Value
SPLP	Synthetic Precipitation Leachate Procedure
ST	Sorbent Tube
TCLP	Toxicity Characteristic Leachate Procedure
TEQ	Toxicity Equivalents
TZA	TimeZone Net Adjustment for sample collected outside of MAI's UTC.
WET (STLC)	Waste Extraction Test (Soluble Threshold Limit Concentration)

McCampbell Analytical, Inc.
"When Quality Counts"
1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Glossary of Terms & Qualifier Definitions

Client: Douglas Lovell
Project: P2021.1; Pt Reys Surface Water Monitoring
WorkOrder: 2101C81

Analytical Qualifiers

b1	Aqueous sample that contains greater than ~1 vol. % sediment

McCampbell Analytical, Inc.
"When Quality Counts"

1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Analytical Report

Client:	Douglas Lovell	**WorkOrder:**	2101C81
Date Received:	01/27/2021 13:34	**Extraction Method:**	E300.1
Date Prepared:	01/27/2021-01/28/2021	**Analytical Method:**	E300.1
Project:	P2021.1; Pt Reys Surface Water Monitoring	**Unit:**	mg/L

Inorganic Anions by IC

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
PAC 1S	**2101C81-001C**	**Water**	**01/27/2021 09:40**	**IC4 01292166.D**	**213976**

Analytes	Result	RL	DF	Date Analyzed
Nitrate as N	**4.1**	0.10	1	01/27/2021 19:34
Nitrate as $NO3^-$	**18**	0.44	1	01/27/2021 19:34
Nitrite as N	ND	0.10	1	01/27/2021 19:34
Nitrite as $NO2^-$	ND	0.33	1	01/27/2021 19:34
Nitrate & Nitrite as N	**4.1**	0.10	1	01/27/2021 19:34
ortho-Phosphate as P	**0.48**	0.10	1	01/27/2021 19:34
ortho-Phosphate as PO4	**1.5**	0.31	1	01/27/2021 19:34

Surrogates	REC (%)	Limits	Date Analyzed
Malonate	97	90-115	01/27/2021 19:34

Analyst(s): AO   Analytical Comments: b1

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
ABB2/3	**2101C81-002C**	**Water**	**01/27/2021 10:10**	**IC4 01292175.D**	**213976**

Analytes	Result	RL	DF	Date Analyzed
Nitrate as N	**5.2**	0.20	2	01/28/2021 00:13
Nitrate as $NO3^-$	**23**	0.88	2	01/28/2021 00:13
Nitrite as N	ND	0.10	1	01/27/2021 19:50
Nitrite as $NO2^-$	ND	0.33	1	01/27/2021 19:50
Nitrate & Nitrite as N	**5.2**	0.20	2	01/28/2021 00:13
ortho-Phosphate as P	**0.51**	0.10	1	01/27/2021 19:50
ortho-Phosphate as PO4	**1.6**	0.31	1	01/27/2021 19:50

Surrogates	REC (%)	Limits	Date Analyzed
Malonate	98	90-115	01/27/2021 19:50

Analyst(s): AO

McCampbell Analytical, Inc.
"When Quality Counts"

1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Analytical Report

Client:	Douglas Lovell	**WorkOrder:**	2101C81
Date Received:	01/27/2021 13:34	**Extraction Method:**	E350.1
Date Prepared:	01/30/2021	**Analytical Method:**	E350.1
Project:	P2021.1; Pt Reys Surface Water Monitoring	**Unit:**	mg/L

Ammonia as N

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
PAC 1S	**2101C81-001B**	**Water**	**01/27/2021 09:40**	**WC_SKALAR 013021A1_114**	**214180**

Analytes	Result	MDL	RL	DF	Date Analyzed
Ammonia, total as N	**0.18**	0.092	0.10	1	01/30/2021 14:07

Analyst(s): RB

Analytical Comments: b1

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
ABB2/3	**2101C81-002B**	**Water**	**01/27/2021 10:10**	**WC_SKALAR 013021A1_115**	**214180**

Analytes	Result	MDL	RL	DF	Date Analyzed
Ammonia, total as N	**0.24**	0.092	0.10	1	01/30/2021 14:09

Analyst(s): RB

McCampbell Analytical, Inc.
"When Quality Counts"

1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Analytical Report

Client:	Douglas Lovell	**WorkOrder:**	2101C81
Date Received:	01/27/2021 13:34	**Extraction Method:**	IDEXX Enterolert
Date Prepared:	01/27/2021 14:00	**Analytical Method:**	9230D.3b
Project:	P2021.1; Pt Reys Surface Water Monitoring	**Unit:**	MPN/100ml

Enterococci, Enumeration

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
PAC 1S	**2101C81-001D**	**Water**	**01/27/2021 09:40**	**MICROBIOLOGY**	**213973**

Analytes	Result	RL	DF	95% Interval	Date Analyzed
Enterococci	**12,000**	10	10	8k - 18k	01/28/2021 14:34

Analyst(s): AB

Analytical Comments: b1

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
ABB2/3	**2101C81-002D**	**Water**	**01/27/2021 10:10**	**MICROBIOLOGY**	**213973**

Analytes	Result	RL	DF	95% Interval	Date Analyzed
Enterococci	**8700**	10	10	6k - 12k	01/28/2021 14:40

Analyst(s): AB

McCampbell Analytical, Inc.
"When Quality Counts"
1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Analytical Report

Client:	Douglas Lovell	**WorkOrder:**	2101C81
Date Received:	01/27/2021 13:34	**Extraction Method:**	E365.1
Date Prepared:	02/04/2021	**Analytical Method:**	E365.1
Project:	P2021.1; Pt Reys Surface Water Monitoring	**Unit:**	mg/L

Total Phosphorous as P

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
PAC 1S	**2101C81-001A**	**Water**	**01/27/2021 09:40**	**WC_SKALAR 020521C1_28**	**214580**

Analytes	Result	RL	DF	Date Analyzed
Total Phosphorous as P	**0.83**	0.050	1	02/05/2021 11:38

Analyst(s): RB

Analytical Comments: b1

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
ABB2/3	**2101C81-002A**	**Water**	**01/27/2021 10:10**	**WC_SKALAR 020521C1_29**	**214580**

Analytes	Result	RL	DF	Date Analyzed
Total Phosphorous as P	**0.83**	0.050	1	02/05/2021 11:40

Analyst(s): RB

McCampbell Analytical, Inc.
"When Quality Counts"

1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Analytical Report

Client:	Douglas Lovell	**WorkOrder:**	2101C81
Date Received:	01/27/2021 13:34	**Extraction Method:**	SM9221B2B3CE1F
Date Prepared:	01/27/2021 14:00	**Analytical Method:**	SM9221B2B3CE1F
Project:	P2021.1; Pt Reys Surface Water Monitoring	**Unit:**	MPN/100ml

Fecal Coliform, Total Coliform, & E. Coli, Enumeration

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
PAC 1S	2101C81-001E	Water	01/27/2021 09:40	MICROBIOLOGY	213969

Analytes	Result	RL	DF	95% Interval	Date Analyzed
Fecal Coliform	**22,000**	180	100	7k - 44k	01/31/2021 13:15
Total Coliform	**54,000**	180	100	15k - 170k	01/31/2021 13:15
E. Coli	**17,000**	180	100	6k - 40k	01/31/2021 13:15

Analyst(s): AB

Analytical Comments: b1

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
ABB2/3	2101C81-002E	Water	01/27/2021 10:10	MICROBIOLOGY	213969

Analytes	Result	RL	DF	95% Interval	Date Analyzed
Fecal Coliform	**17,000**	180	100	6k - 40k	01/31/2021 13:21
Total Coliform	**35,000**	180	100	10k - 100k	01/31/2021 13:21
E. Coli	**13,000**	180	100	4k - 40k	01/31/2021 13:21

Analyst(s): AB

McCampbell Analytical, Inc.
"When Quality Counts"

1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Analytical Report

Client:	Douglas Lovell	**WorkOrder:**	2101C81
Date Received:	01/27/2021 13:34	**Extraction Method:**	E351.2
Date Prepared:	01/29/2021	**Analytical Method:**	E351.2
Project:	P2021.1; Pt Reys Surface Water Monitoring	**Unit:**	mg/L

Total Kjeldahl Nitrogen

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
PAC 1S	**2101C81-001B**	**Water**	**01/27/2021 09:40**	**WC_SKALAR 013021A1_159**	**214113**

Analytes	Result	RL	DF	Date Analyzed
TKN as N	**3.1**	0.40	1	01/30/2021 15:59

Analyst(s): RB

Analytical Comments: b1

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
ABB2/3	**2101C81-002B**	**Water**	**01/27/2021 10:10**	**WC_SKALAR 013021A1_160**	**214113**

Analytes	Result	RL	DF	Date Analyzed
TKN as N	**3.4**	0.40	1	01/30/2021 16:02

Analyst(s): RB

McCampbell Analytical, Inc.
"When Quality Counts"
1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Quality Control Report

Client:	Douglas Lovell	**WorkOrder:**	2101C81
Date Prepared:	01/27/2021 - 01/28/2021	**BatchID:**	213976
Date Analyzed:	01/27/2021 - 01/28/2021	**Extraction Method:**	E300.1
Instrument:	IC4	**Analytical Method:**	E300.1
Matrix:	Water	**Unit:**	mg/L
Project:	P2021.1; Pt Reys Surface Water Monitoring	**Sample ID:**	MB/LCS/LCSD-213976

QC Summary Report for E300.1

Analyte	MB Result	MDL	RL	SPK Val	MB SS %REC	MB SS Limits
Nitrate as N	ND	0.0170	0.100	-	-	-
Nitrate as NO3¯	ND	0.0740	0.440	-	-	-
Nitrite as N	ND	0.0190	0.100	-	-	-
Nitrite as NO2¯	ND	0.0630	0.330	-	-	-
ortho-Phosphate as P	ND	0.0560	0.100	-	-	-
ortho-Phosphate as PO4	ND	0.170	0.310	-	-	-
Surrogate Recovery						
Malonate	0.0995			0.1	99	90-115

Analyte	LCS Result	LCSD Result	SPK Val	LCS %REC	LCSD %REC	LCS/LCSD Limits	RPD	RPD Limit
Nitrate as N	0.973	0.960	1	97	96	85-115	1.35	20
Nitrate as NO3¯	4.31	4.25	4.4	98	97	85-115	1.35	20
Nitrite as N	0.966	0.956	1	97	96	85-115	0.947	20
Nitrite as NO2¯	3.17	3.14	3.3	96	95	85-115	0.947	20
ortho-Phosphate as P	1.00	0.969	1	100	97	85-115	3.36	20
ortho-Phosphate as PO4	3.07	2.97	3.06	100	97	85-115	3.36	20
Surrogate Recovery								
Malonate	0.0987	0.0972	0.10	99	97	90-115	1.54	20

McCampbell Analytical, Inc.
"When Quality Counts"
1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Quality Control Report

Client:	Douglas Lovell	**WorkOrder:**	2101C81
Date Prepared:	01/30/2021	**BatchID:**	214180
Date Analyzed:	01/30/2021	**Extraction Method:**	E350.1
Instrument:	WC_SKALAR	**Analytical Method:**	E350.1
Matrix:	Water	**Unit:**	mg/L
Project:	P2021.1; Pt Reys Surface Water Monitoring	**Sample ID:**	MB/LCS/LCSD-214180

QC Summary Report for E350.1

Analyte	MB Result	MDL	RL			
Ammonia, total as N	ND	0.0920	0.100	-	-	-

Analyte	LCS Result	LCSD Result	SPK Val	LCS %REC	LCSD %REC	LCS/LCSD Limits	RPD	RPD Limit
Ammonia, total as N	4.08	4.15	4	102	104	88-113	1.60	20

McCampbell Analytical, Inc.
"When Quality Counts"
1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Quality Control Report

Client:	Douglas Lovell	**WorkOrder:**	2101C81
Date Prepared:	01/27/2021	**BatchID:**	213973
Date Analyzed:	01/28/2021	**Extraction Method:**	IDEXX Enterolert
Instrument:	MICROBIOLOGY	**Analytical Method:**	9230D.3b
Matrix:	Water	**Unit:**	MPN/100ml
Project:	P2021.1; Pt Reys Surface Water Monitoring	**Sample ID:**	MB-213973 2101C81-001D

QC Summary Report for Enterococci

Analyte	RL	Blank	Control	Sample Result	Dup / Serial Dilution Result	RPD	RPD Limit
Enterococci	1.00	ND	-	12,000	11,200	7.18	70
Enterococcus faecalis (Ent POS Control)	1.00	-	866	-	-	-	-
E. coli (Ent NEG Control)	1.00	-	ND	-	-	-	-

McCampbell Analytical, Inc.
"When Quality Counts"

1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Quality Control Report

Client:	Douglas Lovell	**WorkOrder:**	2101C81
Date Prepared:	02/05/2021	**BatchID:**	214580
Date Analyzed:	02/05/2021	**Extraction Method:**	E365.1
Instrument:	WC_SKALAR	**Analytical Method:**	E365.1
Matrix:	Water	**Unit:**	mg/L
Project:	P2021.1; Pt Reys Surface Water Monitoring	**Sample ID:**	MB/LCS/LCSD-214580

QC Summary Report for E365.1

Analyte	MB Result	MDL	RL			
Total Phosphorous as P	ND	0.0350	0.0500	-	-	-

Analyte	LCS Result	LCSD Result	SPK Val	LCS %REC	LCSD %REC	LCS/LCSD Limits	RPD	RPD Limit
Total Phosphorous as P	0.835	0.819	0.80	104	102	90-110	1.91	20

McCampbell Analytical, Inc.
"When Quality Counts"
1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Quality Control Report

Client:	Douglas Lovell	**WorkOrder:**	2101C81
Date Prepared:	01/27/2021	**BatchID:**	213969
Date Analyzed:	01/31/2021	**Extraction Method:**	SM9221B2B3CE1F
Instrument:	MICROBIOLOGY	**Analytical Method:**	SM9221B2B3CE1F
Matrix:	Water	**Unit:**	MPN/100ml
Project:	P2021.1; Pt Reys Surface Water Monitoring	**Sample ID:**	MB-213969

QC Summary Report for SM9221B2B3CE1F

Analyte	RL	Blank	Control	Sample Result	Dup / Serial Dilution Result	RPD	RPD Limit
Fecal Coliform	1.80	ND	-	-	-	-	-
E. coli (FC POS Control)	1.80	-	220	-	-	-	-
Enterobacter aerogenes (FC NEG Control)	1.80	-	ND	-	-	-	-
Total Coliform	1.80	ND	-	-	-	-	-
Enterobacter aerogenes (TC POS Control)	1.80	-	110	-	-	-	-
Pseudomonas aeruginosa (TC NEG Control)	1.80	-	ND	-	-	-	-
E. Coli	1.80	ND	-	-	-	-	-
E. coli (EC POS Control)	1.80	-	220	-	-	-	-
Enterobacter aerogenes (EC NEG Control)	1.80	-	ND	-	-	-	-

McCampbell Analytical, Inc.
"When Quality Counts"
1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Quality Control Report

Client:	Douglas Lovell	**WorkOrder:**	2101C81
Date Prepared:	01/29/2021	**BatchID:**	214113
Date Analyzed:	01/30/2021	**Extraction Method:**	E351.2
Instrument:	WC_SKALAR	**Analytical Method:**	E351.2
Matrix:	Water	**Unit:**	mg/L
Project:	P2021.1; Pt Reys Surface Water Monitoring	**Sample ID:**	MB/LCS/LCSD-214113 2101C81-001BMS/MSD

QC Summary Report for E351.2 (TKN as N)

Analyte	MB Result	MDL	RL			
TKN as N	ND	0.310	0.400	-	-	-

Analyte	LCS Result	LCSD Result	SPK Val	LCS %REC	LCSD %REC	LCS/LCSD Limits	RPD	RPD Limit
TKN as N	12.0	12.1	12	100	101	73-119	0	20

Analyte	MS DF	MS Result	MSD Result	SPK Val	SPKRef Val	MS %REC	MSD %REC	MS/MSD Limits	RPD	RPD Limit
TKN as N		NR	NR		3.1	NR	NR	-	NR	-

McCampbell Analytical, Inc.
1534 Willow Pass Rd
Pittsburg, CA 94565-1701
(925) 252-9262

CHAIN-OF-CUSTODY RECORD

Page 1 of 1

WorkOrder: 2101C81 **ClientCode: DLBC** **QuoteID: 212277**

☐ WaterTrax ☐ WriteOn ☐ EDF ☐ EQuIS ☒ Dry-Weight ☐ Email ☐ HardCopy ☐ ThirdParty ☒ J-flag
☐ Detection Summary ☐ Excel

Report to:
Douglas Lovell
Douglas Lovell
1514 Hearst Avenue
Berkeley, CA 94703
(510) 520-3146 FAX:

Email: doug.streamborn@gmail.com
cc/3rd Party:
PO:
Project: P2021.1; Pt Reys Surface Water Monitoring

Bill to:
Douglas Lovell
Douglas Lovell
1514 Hearst Avenue
Berkeley, CA 94703
doug.streamborn@gmail.com

Requested TAT: **5 days;**

Date Received: **01/27/2021**
Date Logged: **01/27/2021**

Lab ID	Client ID	Matrix	Collection Date	Hold	1	2	3	4	5	6	7	8	9	10	11	12
					Requested Tests (See legend below)											
2101C81-001	PAC 1S	Water	1/27/2021 09:40	☐	C	B	D	A	A	E	B					
2101C81-002	ABB2/3	Water	1/27/2021 10:10	☐	C	B	D	A	A	E	B					

Test Legend:

1	300_1_W	2	AMMONIA_NPDES_W [J]	3	ENTERO-EST_W	4	PhosTot_W
5	PRDisposal Fee	6	TC&EC&FC_9221_W	7	TKN_W	8	
9		10		11		12	

Project Manager: Angela Rydelius

Prepared by: Valerie Alfaro

Comments:

NOTE: Soil samples are discarded 60 days after results are reported unless other arrangements are made (Water samples are 30 days).
Hazardous samples will be returned to client or disposed of at client expense.

McCampbell Analytical, Inc.
"When Quality Counts"

1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

WORK ORDER SUMMARY

Client Name: DOUGLAS LOVELL
Client Contact: Douglas Lovell
Contact's Email: doug.streamborn@gmail.com

Project: P2021.1; Pt Reys Surface Water Monitoring
Comments:

Work Order: 2101C81
QC Level:
Date Logged: 1/27/2021

☐ WaterTrax ☐ WriteOn ☐ EDF ☐ Excel ☐ EQuIS ☐ Email ☐ HardCopy ☐ ThirdParty ☒ J-flag

LabID	ClientSampID	Matrix	Test Name	Containers /Composites	Bottle & Preservative	Head Space	Dry-Weight	Collection Date & Time	TAT	Test Due Date	Sediment Content	Hold	SubOut
001A	PAC 1S	Water	E365.1 (Total Phosphorous as P)	1	500mL aG w/ H_2SO_4	☐	☐	1/27/2021 9:40	5 days	2/3/2021	1%+	☐	
001B	PAC 1S	Water	E351.2 (TKN)	1	250mL aG w/ H_2SO_4	☐	☐	1/27/2021 9:40	5 days	2/3/2021	1%+	☐	
			E350.1 (Ammonia as N)			☐	☐		5 days	2/3/2021	1%+	☐	
001C	PAC 1S	Water	E300.1 (Inorganic Anions) <Nitrate & Nitrite as N, Nitrate as N, Nitrate as NO_3^-, Nitrite as N, Nitrite as NO_2^-, ortho-Phosphate as P, ortho-Phosphate as PO4>	1	125mL HDPE, unprsv.	☐	☐	1/27/2021 9:40	5 days	2/3/2021	1%+	☐	
001D	PAC 1S	Water	IDEXX Enterolert (Enterococci, Enumeration)	2	120ML Sterile w/ $Na_2S_2O_3$	☐	☐	1/27/2021 9:40	5 days	2/3/2021	1%+	☐	
001E	PAC 1S	Water	SM9221B2B3CE1F (FC, TC & E coli)	2	120ML Sterile w/ $Na_2S_2O_3$	☐	☐	1/27/2021 9:40	5 days	2/3/2021	1%+	☐	
002A	ABB2/3	Water	E365.1 (Total Phosphorous as P)	1	500mL aG w/ H_2SO_4	☐	☐	1/27/2021 10:10	5 days	2/3/2021	Trace	☐	
002B	ABB2/3	Water	E351.2 (TKN)	1	250mL aG w/ H_2SO_4	☐	☐	1/27/2021 10:10	5 days	2/3/2021	Trace	☐	
			E350.1 (Ammonia as N)			☐	☐		5 days	2/3/2021	Trace	☐	
002C	ABB2/3	Water	E300.1 (Inorganic Anions) <Nitrate & Nitrite as N, Nitrate as N, Nitrate as NO_3^-, Nitrite as N, Nitrite as NO_2^-, ortho-Phosphate as P, ortho-Phosphate as PO4>	1	125mL HDPE, unprsv.	☐	☐	1/27/2021 10:10	5 days	2/3/2021	Trace	☐	

NOTES: * STLC and TCLP extractions require 2 days to complete; therefore, all TATs begin after the extraction is completed (i.e., One-day TAT yields results in 3 days from sample submission).

- MAI assumes that all material present in the provided sampling container is considered part of the sample - MAI does not exclude any material from the sample prior to sample preparation unless requested in writing by the client.

McCampbell Analytical, Inc.
"When Quality Counts"

1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

WORK ORDER SUMMARY

Client Name: DOUGLAS LOVELL
Client Contact: Douglas Lovell
Contact's Email: doug.streamborn@gmail.com

Project: P2021.1; Pt Reys Surface Water Monitoring
Comments:

Work Order: 2101C81
QC Level:
Date Logged: 1/27/2021

☐ WaterTrax ☐ WriteOn ☐ EDF ☐ Excel ☐ EQuIS ☐ Email ☐ HardCopy ☐ ThirdParty ☒ J-flag

LabID	ClientSampID	Matrix	Test Name	Containers /Composites	Bottle & Preservative	Head Space	Dry-Weight	Collection Date & Time	TAT	Test Due Date	Sediment Content	Hold	SubOut
002D	ABB2/3	Water	IDEXX Enterolert (Enterococci, Enumeration)	2	120ML Sterile w/ Na2S2O3	☐	☐	1/27/2021 10:10	5 days	2/3/2021	Trace	☐	
002E	ABB2/3	Water	SM9221B2B3CE1F (FC, TC & E coli)	2	120ML Sterile w/ Na2S2O3	☐	☐	1/27/2021 10:10	5 days	2/3/2021	Trace	☐	

NOTES: * STLC and TCLP extractions require 2 days to complete; therefore, all TATs begin after the extraction is completed (i.e., One-day TAT yields results in 3 days from sample submission).

- MAI assumes that all material present in the provided sampling container is considered part of the sample - MAI does not exclude any material from the sample prior to sample preparation unless requested in writing by the client.

20VM.
2101C81

Quote ID = 212277

Chain-of-Custody Form

Project Name: Pt Reyes Surface Water Monitoring	Project Location: Pt Reyes National Seashore, Marin County CA	Project Number: P2021.1
Sampler: Douglas Lovell	Laboratory: McCampbell Analytical, 1534 Willow Pass Rd, Pittsburg CA 94565	Laboratory Number: (925) 252-9262

Sample Designation	Date	Time	Matrix			Type		Containers		Preservative (in addition to ice)	Field Filtration	Turnaround			Analyses								Sampler Comments	Laboratory Comments
				Surface Water		Grab		Quantity	Type					5-day (normal)	Total coliform, Fecal coliform, e coli (all enumeration, mpn)	Enterococci (enumeration, mpn)	Total Kjeldahl Nitrogen	Ammonia Nitrogen	Total Phosphorus	Inorganic Anions (Nitrate, Nitrite, Orthophosphate)				
PAC3	27-Jan-21			x		x		4	120 mL sterile plastic	Sodium Thiosulfate	None			x	x	x								
PAC3	27-Jan-21			x		x		1	500 mL amber glass	H2SO4	None			x			x	x	x					
PAC3	27-Jan-21			x		x		1	125 mL HDPE	None	None			x						x				
PAC1S	27-Jan-21	9:40		x		x		4	120 mL sterile plastic	Sodium Thiosulfate	None			x	x	x							High bacteria counts expected	
PAC1S	27-Jan-21			x		x		1	500 mL amber glass	H2SO4	None			x			x	x	x					
PAC1S	27-Jan-21			x		x		1	125 mL HDPE	None	None			x						x				
ABB2/3	27-Jan-21	10:10		x		x		4	120 mL sterile plastic	Sodium Thiosulfate	None			x	x	x							High bacteria counts expected	
ABB2/3	27-Jan-21			x		x		1	500 mL amber glass	H2SO4	None			x			x	x	x					
ABB2/3	27-Jan-21			x		x		1	125 mL HDPE	None	None			x						x				
DES2	27-Jan-21			x		x		4	120 mL sterile plastic	Sodium Thiosulfate	None			x	x	x								
DES2	27-Jan-21			x		x		1	500 mL amber glass	H2SO4	None			x			x	x	x					
DES2	27-Jan-21			x		x		1	125 mL HDPE	None	None			x						x				
DES4	27-Jan-21			x		x		4	120 mL sterile plastic	Sodium Thiosulfate	None			x	x	x								
DES4	27-Jan-21			x		x		1	500 mL amber glass	H2SO4	None			x			x	x	x					
DES4	27-Jan-21			x		x		1	125 mL HDPE	None	None			x						x				
FB2	27-Jan-21			x		x		4	120 mL sterile plastic	Sodium Thiosulfate	None			x	x	x								
FB2	27-Jan-21			x		x		1	500 mL amber glass	H2SO4	None			x			x	x	x					
FB2	27-Jan-21			x		x		1	125 mL HDPE	None	None			x						x				

+1

(+)

Note: Sampler and laboratory to observe preservative, condition, integrity, etc. of samples and record (under "Comments") any exceptions from standard protocols.

Relinquished By: D. Lovell	Received By: [illegible]	Date: 1/27/21	Time: 3:34
Relinquished By:	Received By:	Date:	Time: 4. [illegible]

Douglas Lovell, 1514 Hearst Avenue, Berkeley CA 94703 510-520-3146

Report results to doug.streamborn@gmail.com	Prepare EDF for Geotracker Upload? **No**	Log code:	Global ID:

McCampbell Analytical, Inc.
"When Quality Counts"

1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Sample Receipt Checklist

Client Name:	**Douglas Lovell**	Date and Time Received:	**1/27/2021 13:34**
Project:	**P2021.1; Pt Reys Surface Water Monitoring**	Date Logged:	**1/27/2021**
		Received by:	Lilly Ortiz
WorkOrder №:	**2101C81** Matrix: Water	Logged by:	Valerie Alfaro
Carrier:	Client Drop-In		

Chain of Custody (COC) Information

	Yes	No	NA
Chain of custody present?	☑	☐	
Chain of custody signed when relinquished and received?	☑	☐	
Chain of custody agrees with sample labels?	☑	☐	
Sample IDs noted by Client on COC?	☑	☐	
Date and Time of collection noted by Client on COC?	☑	☐	
Sampler's name noted on COC?	☑	☐	
COC agrees with Quote?	☑	☐	☐

Sample Receipt Information

	Yes	No	NA
Custody seals intact on shipping container/cooler?	☐	☐	☑
Shipping container/cooler in good condition?	☑	☐	
Samples in proper containers/bottles?	☑	☐	
Sample containers intact?	☑	☐	
Sufficient sample volume for indicated test?	☑	☐	

Sample Preservation and Hold Time (HT) Information

	Yes	No	NA
All samples received within holding time?	☑	☐	☐
Samples Received on Ice?	☑	☐	
(Ice Type: BLUE ICE)			
Sample/Temp Blank temperature	Temp: 4°C		☐
Water - VOA vials have zero headspace / no bubbles?	☐	☐	☑
Sample labels checked for correct preservation?	☑	☐	
pH acceptable upon receipt (Metal: <2; Nitrate 353.2/4500NO3: <2; 522: <4; 218.7: >8)?	☐	☐	☑

UCMR Samples:

	Yes	No	NA
pH tested and acceptable upon receipt (200.8: ≤2; 525.3: ≤4; 530: ≤7; 541: <3; 544: <6.5 & 7.5)?	☐	☐	☑
Free Chlorine tested and acceptable upon receipt (<0.1mg/L)?	☐	☐	☑

Comments:

McCampbell Analytical, Inc.

"When Quality Counts"

Analytical Report

WorkOrder: 2101D57

Report Created for: Douglas Lovell

1514 Hearst Avenue
Berkeley, CA 94703

Project Contact: Douglas Lovell
Project P.O.:
Project: P2021.1; Pt Reyes Surface Water Monitoring

Project Received: 01/28/2021

Analytical Report reviewed & approved for release on 02/05/2021 by:

Susan Thompson
Project Manager

The report shall not be reproduced except in full, without the written approval of the laboratory. The analytical results relate only to the items tested. Results reported conform to the most current NELAP standards, where applicable, unless otherwise stated in a case narrative.

NELAP ACCREDITED TNI LABORATORY

1534 Willow Pass Rd. Pittsburg, CA 94565 ♦ TEL: (877) 252-9262 ♦ FAX: (925) 252-9269 ♦ www.mccampbell.com
CA ELAP 1644 ♦ NELAP 4033 ORELAP

McCampbell Analytical, Inc.
"When Quality Counts"

1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Glossary of Terms & Qualifier Definitions

Client: Douglas Lovell
Project: P2021.1; Pt Reyes Surface Water Monitoring
WorkOrder: 2101D57

Glossary Abbreviation

%D	Serial Dilution Percent Difference
95% Interval	95% Confident Interval
CPT	Consumer Product Testing not NELAP Accredited
DF	Dilution Factor
DI WET	(DISTLC) Waste Extraction Test using DI water
DISS	Dissolved (direct analysis of 0.45 μm filtered and acidified water sample)
DLT	Dilution Test (Serial Dilution)
DUP	Duplicate
EDL	Estimated Detection Limit
ERS	External reference sample. Second source calibration verification.
ITEF	International Toxicity Equivalence Factor
LCS	Laboratory Control Sample
LQL	Lowest Quantitation Level
MB	Method Blank
MB % Rec	% Recovery of Surrogate in Method Blank, if applicable
MDL	Method Detection Limit
ML	Minimum Level of Quantitation
MS	Matrix Spike
MSD	Matrix Spike Duplicate
N/A	Not Applicable
ND	Not detected at or above the indicated MDL or RL
NR	Data Not Reported due to matrix interference or insufficient sample amount.
PDS	Post Digestion Spike
PDSD	Post Digestion Spike Duplicate
PF	Prep Factor
RD	Relative Difference
RL	Reporting Limit (The RL is the lowest calibration standard in a multipoint calibration.)
RPD	Relative Percent Deviation
RRT	Relative Retention Time
SPK Val	Spike Value
SPKRef Val	Spike Reference Value
SPLP	Synthetic Precipitation Leachate Procedure
ST	Sorbent Tube
TCLP	Toxicity Characteristic Leachate Procedure
TEQ	Toxicity Equivalents
TZA	TimeZone Net Adjustment for sample collected outside of MAI's UTC.
WET (STLC)	Waste Extraction Test (Soluble Threshold Limit Concentration)

McCampbell Analytical, Inc.
"When Quality Counts"

1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Analytical Report

Client:	Douglas Lovell	**WorkOrder:**	2101D57
Date Received:	01/28/2021 14:02	**Extraction Method:**	E300.1
Date Prepared:	01/28/2021-01/29/2021	**Analytical Method:**	E300.1
Project:	P2021.1; Pt Reyes Surface Water Monitoring	**Unit:**	mg/L

Inorganic Anions by IC

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
PAC3	**2101D57-001E**	**Water**	**01/28/2021 09:47**	**IC4 01292192.D**	**214065**

Analytes	Result	RL	DF	Date Analyzed
Nitrate as N	**2.5**	0.10	1	01/28/2021 22:37
Nitrate as $NO3^{-}$	**11**	0.44	1	01/28/2021 22:37
Nitrite as N	ND	0.10	1	01/28/2021 22:37
Nitrite as $NO2^{-}$	ND	0.33	1	01/28/2021 22:37
Nitrate & Nitrite as N	**2.5**	0.10	1	01/28/2021 22:37
ortho-Phosphate as P	**0.59**	0.10	1	01/28/2021 22:37
ortho-Phosphate as PO4	**1.8**	0.31	1	01/28/2021 22:37

Surrogates	REC (%)	Limits	
Malonate	98	90-115	01/28/2021 22:37

Analyst(s): AO

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
PAC1S	**2101D57-002E**	**Water**	**01/28/2021 09:00**	**IC4 01292193.D**	**214065**

Analytes	Result	RL	DF	Date Analyzed
Nitrate as N	**3.3**	0.10	1	01/28/2021 23:26
Nitrate as $NO3^{-}$	**14**	0.44	1	01/28/2021 23:26
Nitrite as N	ND	0.10	1	01/28/2021 23:26
Nitrite as $NO2^{-}$	ND	0.33	1	01/28/2021 23:26
Nitrate & Nitrite as N	**3.3**	0.10	1	01/28/2021 23:26
ortho-Phosphate as P	**0.20**	0.10	1	01/28/2021 23:26
ortho-Phosphate as PO4	**0.62**	0.31	1	01/28/2021 23:26

Surrogates	REC (%)	Limits	
Malonate	98	90-115	01/28/2021 23:26

Analyst(s): AO

(Cont.)

McCampbell Analytical, Inc.
"When Quality Counts"

1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Analytical Report

Client:	Douglas Lovell	**WorkOrder:**	2101D57
Date Received:	01/28/2021 14:02	**Extraction Method:**	E300.1
Date Prepared:	01/28/2021-01/29/2021	**Analytical Method:**	E300.1
Project:	P2021.1; Pt Reyes Surface Water Monitoring	**Unit:**	mg/L

Inorganic Anions by IC

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
ABB2/3	2101D57-003E	Water	01/28/2021 10:38	IC4 01292194.D	214065

Analytes	Result	RL	DF	Date Analyzed
Nitrate as N	**3.9**	0.10	1	01/28/2021 23:42
Nitrate as NO_3^-	**17**	0.44	1	01/28/2021 23:42
Nitrite as N	ND	0.10	1	01/28/2021 23:42
Nitrite as NO_2^-	ND	0.33	1	01/28/2021 23:42
Nitrate & Nitrite as N	**3.9**	0.10	1	01/28/2021 23:42
ortho-Phosphate as P	**0.45**	0.10	1	01/28/2021 23:42
ortho-Phosphate as PO4	**1.4**	0.31	1	01/28/2021 23:42

Surrogates	REC (%)	Limits	Date Analyzed
Malonate	98	90-115	01/28/2021 23:42

Analyst(s): AO

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
DES2	2101D57-004E	Water	01/28/2021 11:22	IC4 01292195.D	214065

Analytes	Result	RL	DF	Date Analyzed
Nitrate as N	**1.9**	0.10	1	01/28/2021 23:59
Nitrate as NO_3^-	**8.5**	0.44	1	01/28/2021 23:59
Nitrite as N	ND	0.10	1	01/28/2021 23:59
Nitrite as NO_2^-	ND	0.33	1	01/28/2021 23:59
Nitrate & Nitrite as N	**1.9**	0.10	1	01/28/2021 23:59
ortho-Phosphate as P	ND	0.10	1	01/28/2021 23:59
ortho-Phosphate as PO4	ND	0.31	1	01/28/2021 23:59

Surrogates	REC (%)	Limits	Date Analyzed
Malonate	99	90-115	01/28/2021 23:59

Analyst(s): AO

(Cont.)

McCampbell Analytical, Inc.
"When Quality Counts"

1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Analytical Report

Client:	Douglas Lovell	**WorkOrder:**	2101D57
Date Received:	01/28/2021 14:02	**Extraction Method:**	E300.1
Date Prepared:	01/28/2021-01/29/2021	**Analytical Method:**	E300.1
Project:	P2021.1; Pt Reyes Surface Water Monitoring	**Unit:**	mg/L

Inorganic Anions by IC

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
FB2	**2101D57-005E**	**Water**	**01/28/2021 11:38**	**IC4 01292196.D**	**214065**

Analytes	Result	RL	DF	Date Analyzed
Nitrate as N	ND	0.10	1	01/29/2021 00:15
Nitrate as $NO3^{-}$	ND	0.44	1	01/29/2021 00:15
Nitrite as N	ND	0.10	1	01/29/2021 00:15
Nitrite as $NO2^{-}$	ND	0.33	1	01/29/2021 00:15
Nitrate & Nitrite as N	ND	0.10	1	01/29/2021 00:15
ortho-Phosphate as P	ND	0.10	1	01/29/2021 00:15
ortho-Phosphate as PO4	ND	0.31	1	01/29/2021 00:15

Surrogates	REC (%)	Limits		
Malonate	100	90-115		01/29/2021 00:15

Analyst(s): AO

McCampbell Analytical, Inc.
"When Quality Counts"
1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Analytical Report

Client: Douglas Lovell
Date Received: 01/28/2021 14:02
Date Prepared: 01/30/2021
Project: P2021.1; Pt Reyes Surface Water Monitoring

WorkOrder: 2101D57
Extraction Method: E350.1
Analytical Method: E350.1
Unit: mg/L

Ammonia as N

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
PAC3	2101D57-001C	Water	01/28/2021 09:47	WC_SKALAR 013021A1_126	214181

Analytes	Result	MDL	RL	DF	Date Analyzed
Ammonia, total as N	**0.14**	0.092	0.10	1	01/30/2021 14:37

Analyst(s): RB

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
PAC1S	2101D57-002C	Water	01/28/2021 09:00	WC_SKALAR 013021A1_127	214181

Analytes	Result	MDL	RL	DF	Date Analyzed
Ammonia, total as N	**0.14**	0.092	0.10	1	01/30/2021 14:39

Analyst(s): RB

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
ABB2/3	2101D57-003C	Water	01/28/2021 10:38	WC_SKALAR 013021A1_128	214181

Analytes	Result	MDL	RL	DF	Date Analyzed
Ammonia, total as N	**0.18**	0.092	0.10	1	01/30/2021 14:42

Analyst(s): RB

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
DES2	2101D57-004C	Water	01/28/2021 11:22	WC_SKALAR 013021A1_129	214181

Analytes	Result	MDL	RL	DF	Date Analyzed
Ammonia, total as N	**0.12**	0.092	0.10	1	01/30/2021 14:44

Analyst(s): RB

(Cont.)

McCampbell Analytical, Inc.
"When Quality Counts"

1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Analytical Report

Client:	Douglas Lovell	**WorkOrder:**	2101D57
Date Received:	01/28/2021 14:02	**Extraction Method:**	E350.1
Date Prepared:	01/30/2021	**Analytical Method:**	E350.1
Project:	P2021.1; Pt Reyes Surface Water Monitoring	**Unit:**	mg/L

Ammonia as N

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
FB2	**2101D57-005C**	**Water**	**01/28/2021 11:38**	**WC_SKALAR 013021A1_130**	**214181**

Analytes	Result	MDL	RL	DF	Date Analyzed
Ammonia, total as N	ND	0.092	0.10	1	01/30/2021 14:47

Analyst(s): RB

McCampbell Analytical, Inc.
"When Quality Counts"
1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Analytical Report

Client:	Douglas Lovell	**WorkOrder:**	2101D57
Date Received:	01/28/2021 14:02	**Extraction Method:**	IDEXX Enterolert
Date Prepared:	01/28/2021 15:00	**Analytical Method:**	9230D.3b
Project:	P2021.1; Pt Reyes Surface Water Monitoring	**Unit:**	MPN/100ml

Enterococci, Enumeration

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
PAC3	**2101D57-001B**	**Water**	**01/28/2021 09:47**	**MICROBIOLOGY**	**214054**

Analytes	Result	RL	DF	95% Interval	Date Analyzed
Enterococci	**17,000**	10	10	12k - 27k	01/29/2021 15:24

Analyst(s): AB

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
PAC1S	**2101D57-002B**	**Water**	**01/28/2021 09:00**	**MICROBIOLOGY**	**214054**

Analytes	Result	RL	DF	95% Interval	Date Analyzed
Enterococci	**14,000**	10	10	9k - 21k	01/29/2021 15:27

Analyst(s): AB

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
ABB2/3	**2101D57-003B**	**Water**	**01/28/2021 10:38**	**MICROBIOLOGY**	**214054**

Analytes	Result	RL	DF	95% Interval	Date Analyzed
Enterococci	**11,000**	10	10	8k - 16k	01/29/2021 15:30

Analyst(s): AB

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
DES2	**2101D57-004B**	**Water**	**01/28/2021 11:22**	**MICROBIOLOGY**	**214054**

Analytes	Result	RL	DF	95% Interval	Date Analyzed
Enterococci	**550**	1.0	1	360 - 800	01/29/2021 15:32

Analyst(s): AB

(Cont.)

McCampbell Analytical, Inc.
"When Quality Counts"
1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Analytical Report

Client:	Douglas Lovell	**WorkOrder:**	2101D57
Date Received:	01/28/2021 14:02	**Extraction Method:**	IDEXX Enterolert
Date Prepared:	01/28/2021 15:00	**Analytical Method:**	9230D.3b
Project:	P2021.1; Pt Reyes Surface Water Monitoring	**Unit:**	MPN/100ml

Enterococci, Enumeration

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
FB2	2101D57-005B	Water	01/28/2021 11:38	MICROBIOLOGY	214054

Analytes	Result	RL	DF	95% Interval	Date Analyzed
Enterococci	ND	1.0	1	---	01/29/2021 15:35

Analyst(s): AB

McCampbell Analytical, Inc.
"When Quality Counts"

1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Analytical Report

Client:	Douglas Lovell	**WorkOrder:**	2101D57
Date Received:	01/28/2021 14:02	**Extraction Method:**	E365.1
Date Prepared:	02/04/2021	**Analytical Method:**	E365.1
Project:	P2021.1; Pt Reyes Surface Water Monitoring	**Unit:**	mg/L

Total Phosphorous as P

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
PAC3	**2101D57-001D**	**Water**	**01/28/2021 09:47**	**WC_SKALAR 020521C1_34**	**214580**

Analytes	Result	RL	DF	Date Analyzed
Total Phosphorous as P	**0.87**	0.050	1	02/05/2021 11:53

Analyst(s): RB

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
PAC1S	**2101D57-002D**	**Water**	**01/28/2021 09:00**	**WC_SKALAR 020521C1_35**	**214580**

Analytes	Result	RL	DF	Date Analyzed
Total Phosphorous as P	**0.37**	0.050	1	02/05/2021 11:55

Analyst(s): RB

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
ABB2/3	**2101D57-003D**	**Water**	**01/28/2021 10:38**	**WC_SKALAR 020521C1_36**	**214580**

Analytes	Result	RL	DF	Date Analyzed
Total Phosphorous as P	**0.70**	0.050	1	02/05/2021 11:58

Analyst(s): RB

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
DES2	**2101D57-004D**	**Water**	**01/28/2021 11:22**	**WC_SKALAR 020521C1_37**	**214580**

Analytes	Result	RL	DF	Date Analyzed
Total Phosphorous as P	**0.14**	0.050	1	02/05/2021 12:00

Analyst(s): RB

(Cont.)

McCampbell Analytical, Inc.
"When Quality Counts"

1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Analytical Report

Client:	Douglas Lovell	**WorkOrder:**	2101D57
Date Received:	01/28/2021 14:02	**Extraction Method:**	E365.1
Date Prepared:	02/04/2021	**Analytical Method:**	E365.1
Project:	P2021.1; Pt Reyes Surface Water Monitoring	**Unit:**	mg/L

Total Phosphorous as P

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
FB2	**2101D57-005D**	**Water**	**01/28/2021 11:38**	**WC_SKALAR 020521C1_49**	**214580**

Analytes	Result	RL	DF	Date Analyzed
Total Phosphorous as P	**0.083**	0.050	1	02/05/2021 12:30

Analyst(s): RB

McCampbell Analytical, Inc.
"When Quality Counts"
1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Analytical Report

Client:	Douglas Lovell	**WorkOrder:**	2101D57
Date Received:	01/28/2021 14:02	**Extraction Method:**	SM9221B2B3CE1F
Date Prepared:	01/28/2021 15:00	**Analytical Method:**	SM9221B2B3CE1F
Project:	Pt Reyes Surface Water Monitoring	**Unit:**	MPN/100ml

Fecal Coliform, Total Coliform, & E. Coli, Enumeration

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
PAC3	2101D57-001A	Water	01/28/2021 09:47	MICROBIOLOGY	214023

Analytes	Result	RL	DF	95% Interval	Date Analyzed
Fecal Coliform	**11,000**	180	100	3k - 25k	02/01/2021 12:15
Total Coliform	**17,000**	180	100	7k - 40k	02/01/2021 12:15
E. Coli	**9400**	180	100	3k - 23k	02/01/2021 12:15

Analyst(s): AB

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
PAC1S	2101D57-002A	Water	01/28/2021 09:00	MICROBIOLOGY	214023

Analytes	Result	RL	DF	95% Interval	Date Analyzed
Fecal Coliform	**14,000**	180	100	5k - 40k	02/01/2021 12:21
Total Coliform	**22,000**	180	100	7k - 44k	02/01/2021 12:21
E. Coli	**11,000**	180	100	3k - 25k	02/01/2021 12:21

Analyst(s): AB

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
ABB2/3	2101D57-003A	Water	01/28/2021 10:38	MICROBIOLOGY	214023

Analytes	Result	RL	DF	95% Interval	Date Analyzed
Fecal Coliform	**7000**	180	100	2k - 17k	02/01/2021 12:27
Total Coliform	**17,000**	180	100	6k - 40k	02/01/2021 12:27
E. Coli	**920**	180	100	340 - 2k	02/01/2021 12:27

Analyst(s): AB

(Cont.)

CA ELAP 1644

McCampbell Analytical, Inc.
"When Quality Counts"
1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Analytical Report

Client:	Douglas Lovell	**WorkOrder:**	2101D57
Date Received:	01/28/2021 14:02	**Extraction Method:**	SM9221B2B3CE1F
Date Prepared:	01/28/2021 15:00	**Analytical Method:**	SM9221B2B3CE1F
Project:	Pt Reyes Surface Water Monitoring	**Unit:**	MPN/100ml

Fecal Coliform, Total Coliform, & E. Coli, Enumeration

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
DES2	2101D57-004A	Water	01/28/2021 11:22	MICROBIOLOGY	214023

Analytes	Result	RL	DF	95% Interval	Date Analyzed
Fecal Coliform	**920**	1.8	1	220 - 4k	02/01/2021 12:31
Total Coliform	**1600**	1.8	1	400 - 5k	02/01/2021 12:31
E. Coli	**540**	1.8	1	150 - 2k	02/01/2021 12:31

Analyst(s): AB

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
FB2	2101D57-005A	Water	01/28/2021 11:38	MICROBIOLOGY	214023

Analytes	Result	RL	DF	95% Interval	Date Analyzed
Fecal Coliform	ND	1.8	1	---	02/01/2021 12:37
Total Coliform	ND	1.8	1	---	02/01/2021 12:37
E. Coli	ND	1.8	1	---	02/01/2021 12:37

Analyst(s): AB

McCampbell Analytical, Inc.
"When Quality Counts"
1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Analytical Report

Client:	Douglas Lovell	**WorkOrder:**	2101D57
Date Received:	01/28/2021 14:02	**Extraction Method:**	E351.2
Date Prepared:	01/29/2021	**Analytical Method:**	E351.2
Project:	P2021.1; Pt Reyes Surface Water Monitoring	**Unit:**	mg/L

Total Kjeldahl Nitrogen

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
PAC3	**2101D57-001C**	**Water**	**01/28/2021 09:47**	**WC_SKALAR 013021A1_56**	**214113**

Analytes	Result	RL	DF	Date Analyzed
TKN as N	**3.0**	0.40	1	01/30/2021 11:42

Analyst(s): RB

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
PAC1S	**2101D57-002C**	**Water**	**01/28/2021 09:00**	**WC_SKALAR 013021A1_57**	**214113**

Analytes	Result	RL	DF	Date Analyzed
TKN as N	**2.4**	0.40	1	01/30/2021 11:44

Analyst(s): RB

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
ABB2/3	**2101D57-003C**	**Water**	**01/28/2021 10:38**	**WC_SKALAR 013021A1_58**	**214113**

Analytes	Result	RL	DF	Date Analyzed
TKN as N	**2.9**	0.40	1	01/30/2021 11:47

Analyst(s): RB

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
DES2	**2101D57-004C**	**Water**	**01/28/2021 11:22**	**WC_SKALAR 013021A1_59**	**214113**

Analytes	Result	RL	DF	Date Analyzed
TKN as N	**0.76**	0.40	1	01/30/2021 11:49

Analyst(s): RB

(Cont.)

McCampbell Analytical, Inc.
"When Quality Counts"

1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Analytical Report

Client:	Douglas Lovell	**WorkOrder:**	2101D57
Date Received:	01/28/2021 14:02	**Extraction Method:**	E351.2
Date Prepared:	01/29/2021	**Analytical Method:**	E351.2
Project:	P2021.1; Pt Reyes Surface Water Monitoring	**Unit:**	mg/L

Total Kjeldahl Nitrogen

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
FB2	2101D57-005C	Water	01/28/2021 11:38	WC_SKALAR 013021A1_60	214113

Analytes	Result	RL	DF	Date Analyzed
TKN as N	ND	0.40	1	01/30/2021 11:52

Analyst(s): RB

McCampbell Analytical, Inc.
"When Quality Counts"
1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Quality Control Report

Client: Douglas Lovell
Date Prepared: 01/28/2021 - 01/29/2021
Date Analyzed: 01/28/2021 - 01/29/2021
Instrument: IC4
Matrix: Water
Project: P2021.1; Pt Reyes Surface Water Monitoring

WorkOrder: 2101D57
BatchID: 214065
Extraction Method: E300.1
Analytical Method: E300.1
Unit: mg/L
Sample ID: MB/LCS/LCSD-214065
2101D57-005EMS/MSD

QC Summary Report for E300.1

Analyte	MB Result	MDL	RL	SPK Val	MB SS %REC	MB SS Limits
Nitrate as N	ND	0.0170	0.100	-	-	-
Nitrate as NO3¯	ND	0.0740	0.440	-	-	-
Nitrite as N	ND	0.0190	0.100	-	-	-
Nitrite as NO2¯	ND	0.0630	0.330	-	-	-
ortho-Phosphate as P	ND	0.0560	0.100	-	-	-
ortho-Phosphate as PO4	ND	0.170	0.310	-	-	-
Surrogate Recovery						
Malonate	0.0972			0.1	97	90-115

Analyte	LCS Result	LCSD Result	SPK Val	LCS %REC	LCSD %REC	LCS/LCSD Limits	RPD	RPD Limit
Nitrate as N	0.969	0.977	1	97	98	85-115	0.750	20
Nitrate as NO3¯	4.29	4.32	4.4	98	98	85-115	0.750	20
Nitrite as N	0.966	0.972	1	97	97	85-115	0.635	20
Nitrite as NO2¯	3.18	3.20	3.3	96	97	85-115	0.635	20
ortho-Phosphate as P	1.03	1.01	1	102	101	85-115	1.89	20
ortho-Phosphate as PO4	3.14	3.08	3.06	103	101	85-115	1.89	20
Surrogate Recovery								
Malonate	0.0986	0.0991	0.10	99	99	90-115	0.538	20

Analyte	MS DF	MS Result	MSD Result	SPK Val	SPKRef Val	MS %REC	MSD %REC	MS/MSD Limits	RPD	RPD Limit
Nitrate as N	1	0.966	0.970	1	ND	91	92	85-115	0.421	20
Nitrate as NO3¯	1	4.28	4.30	4.4	ND	92	92	85-115	0.421	20
Nitrite as N	1	0.962	0.962	1	ND	96	96	85-115	0.0242	20
Nitrite as NO2¯	1	3.16	3.16	3.3	ND	96	96	85-115	0.0240	20
ortho-Phosphate as P	1	1.01	0.999	1	ND	101	100	85-115	1.42	20
ortho-Phosphate as PO4	1	3.10	3.06	3.06	ND	101	100	85-115	1.42	20
Surrogate Recovery										
Malonate	1	0.0982	0.0983	0.10		98	98	90-115	0.0254	20

McCampbell Analytical, Inc.
"When Quality Counts"
1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Quality Control Report

Client:	Douglas Lovell	**WorkOrder:**	2101D57
Date Prepared:	01/30/2021	**BatchID:**	214181
Date Analyzed:	01/30/2021	**Extraction Method:**	E350.1
Instrument:	WC_SKALAR	**Analytical Method:**	E350.1
Matrix:	Water	**Unit:**	mg/L
Project:	P2021.1; Pt Reyes Surface Water Monitoring	**Sample ID:**	MB/LCS/LCSD-214181

QC Summary Report for E350.1

Analyte	MB Result	MDL	RL			
Ammonia, total as N	ND	0.0920	0.100	-	-	-

Analyte	LCS Result	LCSD Result	SPK Val	LCS %REC	LCSD %REC	LCS/LCSD Limits	RPD	RPD Limit
Ammonia, total as N	4.13	4.15	4	103	104	88-113	0.585	20

McCampbell Analytical, Inc.
"When Quality Counts"

1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Quality Control Report

Client:	Douglas Lovell	**WorkOrder:**	2101D57
Date Prepared:	01/28/2021	**BatchID:**	214054
Date Analyzed:	01/29/2021	**Extraction Method:**	IDEXX Enterolert
Instrument:	MICROBIOLOGY	**Analytical Method:**	9230D.3b
Matrix:	Water	**Unit:**	MPN/100ml
Project:	P2021.1; Pt Reyes Surface Water Monitoring	**Sample ID:**	MB-214054

QC Summary Report for Enterococci

Analyte	RL	Blank	Control	Sample Result	Dup / Serial Dilution Result	RPD	RPD Limit
Enterococci	1.00	ND	-	-	-	-	-
Enterococcus faecalis (Ent POS Control)	1.00	-	548	-	-	-	-
E. coli (Ent NEG Control)	1.00	-	ND	-	-	-	-

McCampbell Analytical, Inc.
"When Quality Counts"

1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Quality Control Report

Client:	Douglas Lovell	**WorkOrder:**	2101D57
Date Prepared:	02/05/2021	**BatchID:**	214580
Date Analyzed:	02/05/2021	**Extraction Method:**	E365.1
Instrument:	WC_SKALAR	**Analytical Method:**	E365.1
Matrix:	Water	**Unit:**	mg/L
Project:	P2021.1; Pt Reyes Surface Water Monitoring	**Sample ID:**	MB/LCS/LCSD-214580

QC Summary Report for E365.1

Analyte	MB Result	MDL	RL			
Total Phosphorous as P	ND	0.0350	0.0500	-	-	-

Analyte	LCS Result	LCSD Result	SPK Val	LCS %REC	LCSD %REC	LCS/LCSD Limits	RPD	RPD Limit
Total Phosphorous as P	0.835	0.819	0.80	104	102	90-110	1.91	20

McCampbell Analytical, Inc.
"When Quality Counts"

1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Quality Control Report

Client:	Douglas Lovell	**WorkOrder:**	2101D57
Date Prepared:	01/28/2021	**BatchID:**	214023
Date Analyzed:	01/30/2021	**Extraction Method:**	SM9221B2B3CE1F
Instrument:	MICROBIOLOGY	**Analytical Method:**	SM9221B2B3CE1F
Matrix:	Water	**Unit:**	MPN/100ml
Project:	P2021.1; Pt Reyes Surface Water Monitoring	**Sample ID:**	MB-214023

QC Summary Report for SM9221B2B3CE1F

Analyte	RL	Blank	Control	Sample Result	Dup / Serial Dilution Result	RPD	RPD Limit
Total Coliform	1.80	ND	-	-	-	-	-
Enterobacter aerogenes (TC POS Control)	1.80	-	110	-	-	-	-
Pseudomonas aeruginosa (TC NEG Control)	1.80	-	0	-	-	-	-

McCampbell Analytical, Inc.
"When Quality Counts"
1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Quality Control Report

Client:	Douglas Lovell	**WorkOrder:**	2101D57
Date Prepared:	01/29/2021	**BatchID:**	214113
Date Analyzed:	01/30/2021	**Extraction Method:**	E351.2
Instrument:	WC_SKALAR	**Analytical Method:**	E351.2
Matrix:	Water	**Unit:**	mg/L
Project:	P2021.1; Pt Reyes Surface Water Monitoring	**Sample ID:**	MB/LCS/LCSD-214113

QC Summary Report for E351.2 (TKN as N)

Analyte	MB Result	MDL	RL			
TKN as N	ND	0.310	0.400	-	-	-

Analyte	LCS Result	LCSD Result	SPK Val	LCS %REC	LCSD %REC	LCS/LCSD Limits	RPD	RPD Limit
TKN as N	12.0	12.1	12	100	101	73-119	0	20

McCampbell Analytical, Inc.
1534 Willow Pass Rd
Pittsburg, CA 94565-1701
(925) 252-9262

CHAIN-OF-CUSTODY RECORD

WorkOrder: 2101D57 **ClientCode: DLBC** **QuoteID: 212277**

☐ WaterTrax ☐ WriteOn ☐ EDF ☐ EQuIS ☒ Dry-Weight ☐ Email ☐ HardCopy ☐ ThirdParty ☒ J-flag
☐ Detection Summary ☐ Excel

Report to:
Douglas Lovell
Douglas Lovell
1514 Hearst Avenue
Berkeley, CA 94703
(510) 520-3146 FAX:

Email: doug.streamborn@gmail.com
cc/3rd Party:
PO:
Project: P2021.1; Pt Reyes Surface Water Monitoring

Bill to:
Douglas Lovell
Douglas Lovell
1514 Hearst Avenue
Berkeley, CA 94703
doug.streamborn@gmail.com

Requested TAT: **5 days;**

Date Received: **01/28/2021**
Date Logged: **01/28/2021**

Lab ID	Client ID	Matrix	Collection Date	Hold	Requested Tests (See legend below) 1	2	3	4	5	6	7	8	9	10	11	12
2101D57-001	PAC3	Water	1/28/2021 09:47	☐	E	C	B	D	A	A	C					
2101D57-002	PAC1S	Water	1/28/2021 09:00	☐	E	C	B	D	A	A	C					
2101D57-003	ABB2/3	Water	1/28/2021 10:38	☐	E	C	B	D	A	A	C					
2101D57-004	DES2	Water	1/28/2021 11:22	☐	E	C	B	D	A	A	C					
2101D57-005	FB2	Water	1/28/2021 11:38	☐	E	C	B	D	A	A	C					

Test Legend:

1	300_1_W	2	AMMONIA_NPDES_W [J]	3	ENTERO-EST_W	4	PhosTot_W
5	PRDisposal Fee	6	TC&EC&FC_9221_W	7	TKN_W	8	
9		10		11		12	

Project Manager: Angela Rydelius **Prepared by: Lilly Ortiz**

Comments:

NOTE: Soil samples are discarded 60 days after results are reported unless other arrangements are made (Water samples are 30 days).
Hazardous samples will be returned to client or disposed of at client expense.

McCampbell Analytical, Inc.
"When Quality Counts"

1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

WORK ORDER SUMMARY

Client Name: DOUGLAS LOVELL **Project:** P2021.1; Pt Reyes Surface Water Monitoring **Work Order:** 2101D57
Client Contact: Douglas Lovell **QC Level:**
Contact's Email: doug.streamborn@gmail.com **Comments:** **Date Logged:** 1/28/2021

☐ WaterTrax ☐ WriteOn ☐ EDF ☐ Excel ☐ EQuIS ☐ Email ☐ HardCopy ☐ ThirdParty ☒ J-flag

LabID	ClientSampID	Matrix	Test Name	Containers /Composites	Bottle & Preservative	Head Space	Dry-Weight	Collection Date & Time	TAT	Test Due Date	Sediment Content	Hold	SubOut
001A	PAC3	Water	SM9221B2B3CE1F (FC, TC & E coli)	2	120mL w/Na2S2O3	☐	☐	1/28/2021 9:47	5 days	2/4/2021	Present	☐	
001B	PAC3	Water	IDEXX Enterolert (Enterococci, Enumeration)	2	120mL w/Na2S2O3	☐	☐	1/28/2021 9:47	5 days	2/4/2021	Present	☐	
001C	PAC3	Water	E351.2 (TKN)	1	250mL aG w/ H2SO4	☐	☐	1/28/2021 9:47	5 days	2/4/2021	Present	☐	
			E350.1 (Ammonia as N)			☐	☐		5 days	2/4/2021	Present	☐	
001D	PAC3	Water	E365.1 (Total Phosphorous as P)	1	500mL aG w/ H2SO4	☐	☐	1/28/2021 9:47	5 days	2/4/2021	Present	☐	
001E	PAC3	Water	E300.1 (Inorganic Anions) <Nitrate & Nitrite as N, Nitrate as N, Nitrate as $NO3^{-}$, Nitrite as N, Nitrite as $NO2^{-}$, ortho-Phosphate as P, ortho-Phosphate as PO4>	1	125mL HDPE, unprsv.	☐	☐	1/28/2021 9:47	5 days	2/4/2021	Present	☐	
002A	PAC1S	Water	SM9221B2B3CE1F (FC, TC & E coli)	2	120mL w/Na2S2O3	☐	☐	1/28/2021 9:00	5 days	2/4/2021	Present	☐	
002B	PAC1S	Water	IDEXX Enterolert (Enterococci, Enumeration)	2	120mL w/Na2S2O3	☐	☐	1/28/2021 9:00	5 days	2/5/2021	Present	☐	
002C	PAC1S	Water	E351.2 (TKN)	1	250mL aG w/ H2SO4	☐	☐	1/28/2021 9:00	5 days	2/4/2021	Present	☐	
			E350.1 (Ammonia as N)			☐	☐		5 days	2/4/2021	Present	☐	
002D	PAC1S	Water	E365.1 (Total Phosphorous as P)	1	500mL aG w/ H2SO4	☐	☐	1/28/2021 9:00	5 days	2/4/2021	Present	☐	

NOTES: * STLC and TCLP extractions require 2 days to complete; therefore, all TATs begin after the extraction is completed (i.e., One-day TAT yields results in 3 days from sample submission).

- MAI assumes that all material present in the provided sampling container is considered part of the sample - MAI does not exclude any material from the sample prior to sample preparation unless requested in writing by the client.

McCampbell Analytical, Inc.
"When Quality Counts"

1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

WORK ORDER SUMMARY

Client Name: DOUGLAS LOVELL **Project:** P2021.1; Pt Reyes Surface Water Monitoring **Work Order:** 2101D57
Client Contact: Douglas Lovell **QC Level:**
Contact's Email: doug.streamborn@gmail.com **Comments:** **Date Logged:** 1/28/2021

☐ WaterTrax ☐ WriteOn ☐ EDF ☐ Excel ☐ EQuIS ☐ Email ☐ HardCopy ☐ ThirdParty ☒ J-flag

LabID	ClientSampID	Matrix	Test Name	Containers /Composites	Bottle & Preservative	Head Space	Dry-Weight	Collection Date & Time	TAT	Test Due Date	Sediment Content	Hold	SubOut
002E	PAC1S	Water	E300.1 (Inorganic Anions) <Nitrate & Nitrite as N, Nitrate as N, Nitrate as NO3‾, Nitrite as N, Nitrite as NO2‾, ortho-Phosphate as P, ortho-Phosphate as PO4>	1	125mL HDPE, unprsv.	☐	☐	1/28/2021 9:00	5 days	2/4/2021	Present	☐	
003A	ABB2/3	Water	SM9221B2B3CE1F (FC, TC & E coli)	2	120mL w/Na2S2O3	☐	☐	1/28/2021 10:38	5 days	2/4/2021	Present	☐	
003B	ABB2/3	Water	IDEXX Enterolert (Enterococci, Enumeration)	2	120mL w/Na2S2O3	☐	☐	1/28/2021 10:38	5 days	2/4/2021	Present	☐	
003C	ABB2/3	Water	E351.2 (TKN)	1	250mL aG w/ H2SO4	☐	☐	1/28/2021 10:38	5 days	2/4/2021	Present	☐	
			E350.1 (Ammonia as N)			☐	☐		5 days	2/4/2021	Present	☐	
003D	ABB2/3	Water	E365.1 (Total Phosphorous as P)	1	500mL aG w/ H2SO4	☐	☐	1/28/2021 10:38	5 days	2/4/2021	Present	☐	
003E	ABB2/3	Water	E300.1 (Inorganic Anions) <Nitrate & Nitrite as N, Nitrate as N, Nitrate as NO3‾, Nitrite as N, Nitrite as NO2‾, ortho-Phosphate as P, ortho-Phosphate as PO4>	1	125mL HDPE, unprsv.	☐	☐	1/28/2021 10:38	5 days	2/4/2021	Present	☐	
004A	DES2	Water	SM9221B2B3CE1F (FC, TC & E coli)	2	120mL w/Na2S2O3	☐	☐	1/28/2021 11:22	5 days	2/4/2021	Present	☐	
004B	DES2	Water	IDEXX Enterolert (Enterococci, Enumeration)	2	120mL w/Na2S2O3	☐	☐	1/28/2021 11:22	5 days	2/4/2021	Present	☐	
004C	DES2	Water	E351.2 (TKN)	1	250mL aG w/ H2SO4	☐	☐	1/28/2021 11:22	5 days	2/4/2021	Present	☐	

NOTES: * STLC and TCLP extractions require 2 days to complete; therefore, all TATs begin after the extraction is completed (i.e., One-day TAT yields results in 3 days from sample submission).

- MAI assumes that all material present in the provided sampling container is considered part of the sample - MAI does not exclude any material from the sample prior to sample preparation unless requested in writing by the client.

McCampbell Analytical, Inc.
"When Quality Counts"

1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

WORK ORDER SUMMARY

Client Name: DOUGLAS LOVELL
Client Contact: Douglas Lovell
Contact's Email: doug.streamborn@gmail.com

Project: P2021.1; Pt Reyes Surface Water Monitoring
Comments:

Work Order: 2101D57
QC Level:
Date Logged: 1/28/2021

☐ WaterTrax ☐ WriteOn ☐ EDF ☐ Excel ☐ EQuIS ☐ Email ☐ HardCopy ☐ ThirdParty ☒ J-flag

LabID	ClientSampID	Matrix	Test Name	Containers /Composites	Bottle & Preservative	Head Space	Dry-Weight	Collection Date & Time	TAT	Test Due Date	Sediment Content	Hold	SubOut
004C	DES2	Water	E350.1 (Ammonia as N)	1	250mL aG w/ H2SO4	☐	☐	1/28/2021 11:22	5 days	2/4/2021	Present	☐	
004D	DES2	Water	E365.1 (Total Phosphorous as P)	1	500mL aG w/ H2SO4	☐	☐	1/28/2021 11:22	5 days	2/4/2021	Present	☐	
004E	DES2	Water	E300.1 (Inorganic Anions) <Nitrate & Nitrite as N, Nitrate as N, Nitrate as NO3¯, Nitrite as N, Nitrite as NO2¯, ortho-Phosphate as P, ortho-Phosphate as PO4>	1	125mL HDPE, unprsv.	☐	☐	1/28/2021 11:22	5 days	2/4/2021	Present	☐	
005A	FB2	Water	SM9221B2B3CE1F (FC, TC & E coli)	2	120mL w/Na2S2O3	☐	☐	1/28/2021 11:38	5 days	2/4/2021	None	☐	
005B	FB2	Water	IDEXX Enterolert (Enterococci, Enumeration)	2	120mL w/Na2S2O3	☐	☐	1/28/2021 11:38	5 days	2/4/2021	None	☐	
005C	FB2	Water	E351.2 (TKN)	1	250mL aG w/ H2SO4	☐	☐	1/28/2021 11:38	5 days	2/4/2021	None	☐	
			E350.1 (Ammonia as N)			☐	☐		5 days	2/4/2021	None	☐	
005D	FB2	Water	E365.1 (Total Phosphorous as P)	1	500mL aG w/ H2SO4	☐	☐	1/28/2021 11:38	5 days	2/4/2021	None	☐	
005E	FB2	Water	E300.1 (Inorganic Anions) <Nitrate & Nitrite as N, Nitrate as N, Nitrate as NO3¯, Nitrite as N, Nitrite as NO2¯, ortho-Phosphate as P, ortho-Phosphate as PO4>	1	125mL HDPE, unprsv.	☐	☐	1/28/2021 11:38	5 days	2/4/2021	None	☐	

NOTES: * STLC and TCLP extractions require 2 days to complete; therefore, all TATs begin after the extraction is completed (i.e., One-day TAT yields results in 3 days from sample submission).

- MAI assumes that all material present in the provided sampling container is considered part of the sample - MAI does not exclude any material from the sample prior to sample preparation unless requested in writing by the client.

Quote ID = 212277

Chain-of-Custody Form

2101057

Project Name: Pt Reyes Surface Water Monitoring	Project Location: Pt Reyes National Seashore, Marin County CA	Project Number: P2021.1
Sampler: Douglas Lovell	Laboratory: McCampbell Analytical, 1534 Willow Pass Rd, Pittsburg CA 94565	Laboratory Number: (925) 252-9262

All 28 Jan

			Matrix	Type	Containers				Turnaround	Analyses							
Sample Designation	Date	Time	Surface Water	Grab	Quantity	Type	Preservative (in addition to ice)	Field Filtration	5-day (normal)	Total coliform, Fecal coliform, e coli (all enumeration, mpn)	Enterococci (enumeration, mpn)	Total Kjeldahl Nitrogen	Ammonia Nitrogen	Total Phosphorus	Inorganic Anions (Nitrate, Nitrite, Orthophosphate)	Sampler Comments	Laboratory Comments
PAC3	28-Jan-21	9:47	x	x	4	120 mL sterile plastic	Sodium Thiosulfate	None	x	x	x						
PAC3	28-Jan-21	"	x	x	1	500 mL amber glass	H2SO4	None	x			x	x	x			
PAC3	28-Jan-21	"	x	x	1	125 mL HDPE	None	None	x						x		
PAC1S	28-Jan-21	9AM	x	x	4	120 mL sterile plastic	Sodium Thiosulfate	None	x	x	x					High bacteria counts expected	
PAC1S	28-Jan-21	"	x	x	1	500 mL amber glass	H2SO4	None	x			x	x	x			
PAC1S	28-Jan-21	"	x	x	1	125 mL HDPE	None	None	x						x		
ABB2/3	28-Jan-21	10:38	x	x	4	120 mL sterile plastic	Sodium Thiosulfate	None	x	x	x					High bacteria counts expected	
ABB2/3	28-Jan-21	"	x	x	1	500 mL amber glass	H2SO4	None	x			x	x	x			
ABB2/3	28-Jan-21	"	x	x	1	125 mL HDPE	None	None	x						x		
DES2	28-Jan-21	11:27	x	x	4	120 mL sterile plastic	Sodium Thiosulfate	None	x	x	x						
DES2	28-Jan-21	11:22	x	x	1	500 mL amber glass	H2SO4	None	x			x	x	x			
DES2	28-Jan-21	"	x	x	1	125 mL HDPE	None	None	x						x		
~~DES4~~	~~28-Jan-21~~	[illegible]	~~x~~	~~x~~	~~4~~	~~120 mL sterile plastic~~	~~Sodium Thiosulfate~~	~~None~~	~~x~~	~~x~~	~~x~~						
~~DES4~~	~~28-Jan-21~~	[illegible]	~~x~~	~~x~~	~~1~~	~~500 mL amber glass~~	~~H2SO4~~	~~None~~	~~x~~			~~x~~	~~x~~	~~x~~			
~~DES4~~	~~28-Jan-21~~		~~x~~	~~x~~	~~1~~	~~125 mL HDPE~~	~~None~~	~~None~~	~~x~~						~~x~~		
FB2	28-Jan-21	11:38	x	x	4	120 mL sterile plastic	Sodium Thiosulfate	None	x	x	x						
FB2	28-Jan-21	"	x	x	1	500 mL amber glass	H2SO4	None	x			x	x	x			
FB2	28-Jan-21	"	x	x	1	125 mL HDPE	None	None	x						x		

Note: Sampler and laboratory to observe preservative, condition, integrity, etc. of samples and record (under "Comments") any exceptions from standard protocols.

Relinquished By: D. Lovell	Received By: [illegible signature]	Date: 1/28/21	Time: 1402
Relinquished By:	Received By:	Date:	Time: 1.06

Douglas Lovell, 1514 Hearst Avenue, Berkeley CA 94703 510-520-3146

Report results to doug.streamborn@gmail.com

Prepare EDF for Geotracker Upload? **No**	Log code:	Global ID:

McCampbell Analytical, Inc.
"When Quality Counts"

1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Sample Receipt Checklist

Client Name:	**Douglas Lovell**	Date and Time Received:	**1/28/2021 14:02**
Project:	**P2021.1; Pt Reyes Surface Water Monitoring**	Date Logged:	**1/28/2021**
		Received by:	Lilly Ortiz
WorkOrder №:	**2101D57** Matrix: Water	Logged by:	Lilly Ortiz
Carrier:	Client Drop-In		

Chain of Custody (COC) Information

	Yes	No	NA
Chain of custody present?	✔		
Chain of custody signed when relinquished and received?	✔		
Chain of custody agrees with sample labels?	✔		
Sample IDs noted by Client on COC?	✔		
Date and Time of collection noted by Client on COC?	✔		
Sampler's name noted on COC?	✔		
COC agrees with Quote?	✔		☐

Sample Receipt Information

	Yes	No	NA
Custody seals intact on shipping container/cooler?			✔
Shipping container/cooler in good condition?	✔		
Samples in proper containers/bottles?	✔		
Sample containers intact?	✔		
Sufficient sample volume for indicated test?	✔		

Sample Preservation and Hold Time (HT) Information

	Yes	No	NA
All samples received within holding time?	✔		☐
Samples Received on Ice?	✔		
	(Ice Type: BLUE ICE)		
Sample/Temp Blank temperature	Temp: 4°C		☐
ZHS conditional analyses: VOA meets zero headspace requirement (VOCs, TPHg/BTEX, RSK)?			✔
Sample labels checked for correct preservation?	✔		
pH acceptable upon receipt (Metal: <2; Nitrate 353.2/4500NO3: <2; 522: <4; 218.7: >8)?			✔
UCMR Samples:			
pH tested and acceptable upon receipt (200.8: ≤2; 525.3: ≤4; 530: ≤7; 541: <3; 544: <6.5 & 7.5)?			✔
Free Chlorine tested and acceptable upon receipt (<0.1mg/L)?			✔

Comments:

McCampbell Analytical, Inc.

"When Quality Counts"

Analytical Report

WorkOrder:	2101E39
Report Created for:	Douglas Lovell
	1514 Hearst Avenue Berkeley, CA 94703
Project Contact:	Douglas Lovell
Project P.O.:	
Project:	P2021.1; Pt Reyes Surface Water Monitoring
Project Received:	01/29/2021

Analytical Report reviewed & approved for release on 02/05/2021 by:

Yen Cao

Yen Cao
Project Manager

The report shall not be reproduced except in full, without the written approval of the laboratory. The analytical results relate only to the items tested. Results reported conform to the most current NELAP standards, where applicable, unless otherwise stated in a case narrative.

NELAP ACCREDITED TNI LABORATORY

1534 Willow Pass Rd. Pittsburg, CA 94565 ♦ TEL: (877) 252-9262 ♦ FAX: (925) 252-9269 ♦ www.mccampbell.com
CA ELAP 1644 ♦ NELAP 4033 ORELAP

McCampbell Analytical, Inc.
"When Quality Counts"
1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Glossary of Terms & Qualifier Definitions

Client: Douglas Lovell
Project: P2021.1; Pt Reyes Surface Water Monitoring
WorkOrder: 2101E39

Glossary Abbreviation

%D	Serial Dilution Percent Difference
95% Interval	95% Confident Interval
CPT	Consumer Product Testing not NELAP Accredited
DF	Dilution Factor
DI WET	(DISTLC) Waste Extraction Test using DI water
DISS	Dissolved (direct analysis of 0.45 µm filtered and acidified water sample)
DLT	Dilution Test (Serial Dilution)
DUP	Duplicate
EDL	Estimated Detection Limit
ERS	External reference sample. Second source calibration verification.
ITEF	International Toxicity Equivalence Factor
LCS	Laboratory Control Sample
LQL	Lowest Quantitation Level
MB	Method Blank
MB % Rec	% Recovery of Surrogate in Method Blank, if applicable
MDL	Method Detection Limit
ML	Minimum Level of Quantitation
MS	Matrix Spike
MSD	Matrix Spike Duplicate
N/A	Not Applicable
ND	Not detected at or above the indicated MDL or RL
NR	Data Not Reported due to matrix interference or insufficient sample amount.
PDS	Post Digestion Spike
PDSD	Post Digestion Spike Duplicate
PF	Prep Factor
RD	Relative Difference
RL	Reporting Limit (The RL is the lowest calibration standard in a multipoint calibration.)
RPD	Relative Percent Deviation
RRT	Relative Retention Time
SPK Val	Spike Value
SPKRef Val	Spike Reference Value
SPLP	Synthetic Precipitation Leachate Procedure
ST	Sorbent Tube
TCLP	Toxicity Characteristic Leachate Procedure
TEQ	Toxicity Equivalents
TZA	TimeZone Net Adjustment for sample collected outside of MAI's UTC.
WET (STLC)	Waste Extraction Test (Soluble Threshold Limit Concentration)

McCampbell Analytical, Inc.
"When Quality Counts"

1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Glossary of Terms & Qualifier Definitions

Client: Douglas Lovell

Project: P2021.1; Pt Reyes Surface Water Monitoring

WorkOrder: 2101E39

Analytical Qualifiers

H	Samples were analyzed out of hold time.
S	Surrogate recovery outside accepted recovery limits.
a14	Reporting limit raised due to the physical nature of the sample.
c1	Surrogate recovery outside of the control limits due to the dilution of the sample.

McCampbell Analytical, Inc.
"When Quality Counts"
1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Analytical Report

Client:	Douglas Lovell	**WorkOrder:**	2101E39
Date Received:	01/29/2021 9:38	**Extraction Method:**	E300.1
Date Prepared:	01/29/2021	**Analytical Method:**	E300.1
Project:	P2021.1; Pt Reyes Surface Water Monitoring	**Unit:**	mg/L

Inorganic Anions by IC

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
DES4	**2101E39-001E**	**Water**	**01/28/2021**	**IC4 02012114.D**	**214140**

Analytes	Result	RL	DF	Date Analyzed
Nitrate as N	ND	2.0	20	01/29/2021 17:47
Nitrate as $NO3^{-}$	ND	8.8	20	01/29/2021 17:47
Nitrite as N	ND	2.0	20	01/29/2021 17:47
Nitrite as $NO2^{-}$	ND	6.6	20	01/29/2021 17:47
Nitrate & Nitrite as N	ND	2.0	20	01/29/2021 17:47
ortho-Phosphate as P	ND	2.0	20	01/29/2021 17:47
ortho-Phosphate as PO4	ND	6.2	20	01/29/2021 17:47

Surrogates	REC (%)	Qualifiers	Limits	
Malonate	0	S	90-115	01/29/2021 17:47

Analyst(s): AO Analytical Comments: a14,c1

McCampbell Analytical, Inc.
"When Quality Counts"

1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Analytical Report

Client:	Douglas Lovell	**WorkOrder:**	2101E39
Date Received:	01/29/2021 9:38	**Extraction Method:**	E350.1
Date Prepared:	01/30/2021	**Analytical Method:**	E350.1
Project:	P2021.1; Pt Reyes Surface Water Monitoring	**Unit:**	mg/L

Ammonia as N

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
DES4	2101E39-001C	Water	01/28/2021	WC_SKALAR 013021A1_149	214181

Analytes	Result	MDL	RL	DF	Date Analyzed
Ammonia, total as N	ND	0.092	0.10	1	01/30/2021 15:34

Analyst(s): RB

McCampbell Analytical, Inc.
"When Quality Counts"
1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Analytical Report

Client:	Douglas Lovell	**WorkOrder:**	2101E39
Date Received:	01/29/2021 9:38	**Extraction Method:**	IDEXX Enterolert
Date Prepared:	01/29/2021 10:20	**Analytical Method:**	9230D.3b
Project:	P2021.1; Pt Reyes Surface Water Monitoring	**Unit:**	MPN/100ml

Enterococci, Enumeration

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
DES4	**2101E39-001B**	**Water**	**01/28/2021**	**MICROBIOLOGY**	**214137**

Analytes	Result	Qualifiers	RL	DF	95% Interval	Date Analyzed
Enterococci	**1400**	H	1.0	1	920 - 2k	01/30/2021 11:03

Analyst(s): AB

McCampbell Analytical, Inc.
"When Quality Counts"

1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Analytical Report

Client:	Douglas Lovell	**WorkOrder:**	2101E39
Date Received:	01/29/2021 9:38	**Extraction Method:**	E365.1
Date Prepared:	02/04/2021	**Analytical Method:**	E365.1
Project:	P2021.1; Pt Reyes Surface Water Monitoring	**Unit:**	mg/L

Total Phosphorous as P

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
DES4	**2101E39-001D**	**Water**	**01/28/2021**	**WC_SKALAR 020521C1_50**	**214580**

Analytes	Result	RL	DF	Date Analyzed
Total Phosphorous as P	**0.20**	0.050	1	02/05/2021 12:33

Analyst(s): RB

McCampbell Analytical, Inc.
"When Quality Counts"
1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Analytical Report

Client: Douglas Lovell
Date Received: 01/29/2021 9:38
Date Prepared: 01/29/2021 10:20
Project: P2021.1; Pt Reyes Surface Water Monitoring

WorkOrder: 2101E39
Extraction Method: SM9221B2B3CE1F
Analytical Method: SM9221B2B3CE1F
Unit: MPN/100ml

Fecal Coliform, Total Coliform, & E. Coli, Enumeration

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
DES4	2101E39-001A	Water	01/28/2021	MICROBIOLOGY	214107

Analytes	Result	Qualifiers	RL	DF	95% Interval	Date Analyzed
Fecal Coliform	**1700**	H	18	10	580 - 4k	02/02/2021 09:44
Total Coliform	**5400**	H	18	10	2k - 17k	02/02/2021 09:44
E. Coli	**1100**	H	18	10	340 - 3k	02/02/2021 09:44

Analyst(s): AB

CA ELAP 1644

McCampbell Analytical, Inc.
"When Quality Counts"

1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Analytical Report

Client:	Douglas Lovell	**WorkOrder:**	2101E39
Date Received:	01/29/2021 9:38	**Extraction Method:**	E351.2
Date Prepared:	01/29/2021	**Analytical Method:**	E351.2
Project:	P2021.1; Pt Reyes Surface Water Monitoring	**Unit:**	mg/L

Total Kjeldahl Nitrogen

Client ID	Lab ID	Matrix	Date Collected	Instrument	Batch ID
DES4	**2101E39-001C**	**Water**	**01/28/2021**	**WC_SKALAR 013021A1_161**	**214113**

Analytes	Result	RL	DF	Date Analyzed
TKN as N	**0.90**	0.40	1	01/30/2021 16:04

Analyst(s): RB

McCampbell Analytical, Inc.
"When Quality Counts"
1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Quality Control Report

Client:	Douglas Lovell	**WorkOrder:**	2101E39
Date Prepared:	01/29/2021 - 01/30/2021	**BatchID:**	214140
Date Analyzed:	01/29/2021 - 01/30/2021	**Extraction Method:**	E300.1
Instrument:	IC4	**Analytical Method:**	E300.1
Matrix:	Water	**Unit:**	mg/L
Project:	P2021.1; Pt Reyes Surface Water Monitoring	**Sample ID:**	MB/LCS/LCSD-214140

QC Summary Report for E300.1

Analyte	MB Result	MDL	RL	SPK Val	MB SS %REC	MB SS Limits
Nitrate as N	ND	0.0170	0.100	-	-	-
Nitrate as $NO3^{-}$	ND	0.0740	0.440	-	-	-
Nitrite as N	ND	0.0190	0.100	-	-	-
Nitrite as $NO2^{-}$	ND	0.0630	0.330	-	-	-
ortho-Phosphate as P	ND	0.0560	0.100	-	-	-
ortho-Phosphate as PO4	ND	0.170	0.310	-	-	-
Surrogate Recovery						
Malonate	0.0988			0.1	99	90-115

Analyte	LCS Result	LCSD Result	SPK Val	LCS %REC	LCSD %REC	LCS/LCSD Limits	RPD	RPD Limit
Nitrate as N	0.969	0.966	1	97	97	85-115	0.331	20
Nitrate as $NO3^{-}$	4.29	4.28	4.4	98	97	85-115	0.332	20
Nitrite as N	0.959	0.955	1	96	95	85-115	0.466	20
Nitrite as $NO2^{-}$	3.15	3.14	3.3	96	95	85-115	0.466	20
ortho-Phosphate as P	0.985	0.962	1	98	96	85-115	2.32	20
ortho-Phosphate as PO4	3.02	2.95	3.06	99	96	85-115	2.32	20
Surrogate Recovery								
Malonate	0.0986	0.0981	0.10	99	98	90-115	0.581	20

McCampbell Analytical, Inc.
"When Quality Counts"
1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Quality Control Report

Client:	Douglas Lovell	**WorkOrder:**	2101E39
Date Prepared:	01/30/2021	**BatchID:**	214181
Date Analyzed:	01/30/2021	**Extraction Method:**	E350.1
Instrument:	WC_SKALAR	**Analytical Method:**	E350.1
Matrix:	Water	**Unit:**	mg/L
Project:	P2021.1; Pt Reyes Surface Water Monitoring	**Sample ID:**	MB/LCS/LCSD-214181

QC Summary Report for E350.1

Analyte	MB Result	MDL	RL			
Ammonia, total as N	ND	0.0920	0.100	-	-	-

Analyte	LCS Result	LCSD Result	SPK Val	LCS %REC	LCSD %REC	LCS/LCSD Limits	RPD	RPD Limit
Ammonia, total as N	4.13	4.15	4	103	104	88-113	0.585	20

McCampbell Analytical, Inc.
"When Quality Counts"
1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Quality Control Report

Client:	Douglas Lovell	**WorkOrder:**	2101E39
Date Prepared:	01/29/2021	**BatchID:**	214137
Date Analyzed:	01/30/2021	**Extraction Method:**	IDEXX Enterolert
Instrument:	MICROBIOLOGY	**Analytical Method:**	9230D.3b
Matrix:	Water	**Unit:**	MPN/100ml
Project:	P2021.1; Pt Reyes Surface Water Monitoring	**Sample ID:**	MB-214137

QC Summary Report for Enterococci

Analyte	RL	Blank	Control	Sample Result	Dup / Serial Dilution Result	RPD	RPD Limit
Enterococci	1.00	ND	-	-	-	-	-
Enterococcus faecalis (Ent POS Control)	1.00	-	687	-	-	-	-
E. coli (Ent NEG Control)	1.00	-	ND	-	-	-	-

McCampbell Analytical, Inc.
"When Quality Counts"
1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Quality Control Report

Client:	Douglas Lovell	**WorkOrder:**	2101E39
Date Prepared:	02/05/2021	**BatchID:**	214580
Date Analyzed:	02/05/2021	**Extraction Method:**	E365.1
Instrument:	WC_SKALAR	**Analytical Method:**	E365.1
Matrix:	Water	**Unit:**	mg/L
Project:	P2021.1; Pt Reyes Surface Water Monitoring	**Sample ID:**	MB/LCS/LCSD-214580

QC Summary Report for E365.1

Analyte	MB Result	MDL	RL			
Total Phosphorous as P	ND	0.0350	0.0500	-	-	-

Analyte	LCS Result	LCSD Result	SPK Val	LCS %REC	LCSD %REC	LCS/LCSD Limits	RPD	RPD Limit
Total Phosphorous as P	0.835	0.819	0.80	104	102	90-110	1.91	20

McCampbell Analytical, Inc.
"When Quality Counts"

1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Quality Control Report

Client:	Douglas Lovell	**WorkOrder:**	2101E39
Date Prepared:	01/29/2021	**BatchID:**	214107
Date Analyzed:	02/02/2021	**Extraction Method:**	SM9221B2B3CE1F
Instrument:	MICROBIOLOGY	**Analytical Method:**	SM9221B2B3CE1F
Matrix:	Water	**Unit:**	MPN/100ml
Project:	P2021.1; Pt Reyes Surface Water Monitoring	**Sample ID:**	MB-214107

QC Summary Report for SM9221B2B3CE1F

Analyte	RL	Blank	Control	Sample Result	Dup / Serial Dilution Result	RPD	RPD Limit
Fecal Coliform	1.80	ND	-	-	-	-	-
E. coli (FC POS Control)	1.80	-	220	-	-	-	-
Enterobacter aerogenes (FC NEG Control)	1.80	-	ND	-	-	-	-
Total Coliform	1.80	ND	-	-	-	-	-
Enterobacter aerogenes (TC POS Control)	1.80	-	110	-	-	-	-
Pseudomonas aeruginosa (TC NEG Control)	1.80	-	ND	-	-	-	-
E. Coli	1.80	ND	-	-	-	-	-
E. coli (EC POS Control)	1.80	-	220	-	-	-	-
Enterobacter aerogenes (EC NEG Control)	1.80	-	ND	-	-	-	-

McCampbell Analytical, Inc.
"When Quality Counts"

1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Quality Control Report

Client:	Douglas Lovell	**WorkOrder:**	2101E39
Date Prepared:	01/29/2021	**BatchID:**	214113
Date Analyzed:	01/30/2021	**Extraction Method:**	E351.2
Instrument:	WC_SKALAR	**Analytical Method:**	E351.2
Matrix:	Water	**Unit:**	mg/L
Project:	P2021.1; Pt Reyes Surface Water Monitoring	**Sample ID:**	MB/LCS/LCSD-214113

QC Summary Report for E351.2 (TKN as N)

Analyte	MB Result	MDL	RL			
TKN as N	ND	0.310	0.400	-	-	-

Analyte	LCS Result	LCSD Result	SPK Val	LCS %REC	LCSD %REC	LCS/LCSD Limits	RPD	RPD Limit
TKN as N	12.0	12.1	12	100	101	73-119	0	20

McCampbell Analytical, Inc.
1534 Willow Pass Rd
Pittsburg, CA 94565-1701
(925) 252-9262

CHAIN-OF-CUSTODY RECORD

Page 1 of 1

WorkOrder: 2101E39 **ClientCode:** DLBC **QuoteID:** 212277

☐ WaterTrax ☐ WriteOn ☐ EDF ☐ EQuIS ☒ Dry-Weight ☐ Email ☐ HardCopy ☐ ThirdParty ☒ J-flag
☐ Detection Summary ☐ Excel

Report to:
Douglas Lovell
Douglas Lovell
1514 Hearst Avenue
Berkeley, CA 94703
(510) 520-3146 FAX:

Email: doug.streamborn@gmail.com
cc/3rd Party:
PO:
Project: P2021.1; Pt Reyes Surface Water Monitoring

Bill to:
Douglas Lovell
Douglas Lovell
1514 Hearst Avenue
Berkeley, CA 94703
doug.streamborn@gmail.com

Requested TAT: 5 days;

Date Received: 01/29/2021
Date Logged: 01/29/2021

Lab ID	Client ID	Matrix	Collection Date	Hold	1	2	3	4	5	6	7	8	9	10	11	12
					Requested Tests (See legend below)											
2101E39-001	DES4	Water	1/28/2021 00:00	☐	E	C	B	D	A	A	C					

Test Legend:

1	300_1_W	2	AMMONIA_NPDES_W [J]	3	ENTERO_9230B_W	4	PhosTot_W
5	PRDisposal Fee	6	TC&EC&FC_9221_W	7	TKN_W	8	
9		10		11		12	

Project Manager: Angela Rydelius

Prepared by: Tina Perez

Comments:

NOTE: Soil samples are discarded 60 days after results are reported unless other arrangements are made (Water samples are 30 days).
Hazardous samples will be returned to client or disposed of at client expense.

McCampbell Analytical, Inc.
"When Quality Counts"

1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

WORK ORDER SUMMARY

Client Name: DOUGLAS LOVELL **Project:** P2021.1; Pt Reyes Surface Water Monitoring **Work Order:** 2101E39

Client Contact: Douglas Lovell **QC Level:**

Contact's Email: doug.streamborn@gmail.com **Comments** **Date Logged:** 1/29/2021

☐ WaterTrax ☐ WriteOn ☐ EDF ☐ Excel ☐ EQuIS ☐ Email ☐ HardCopy ☐ ThirdParty ☒ J-flag

LabID	ClientSampID	Matrix	Test Name	Containers /Composites	Bottle & Preservative	Head Space	Dry-Weight	Collection Date & Time	TAT	Test Due Date	Sediment Content	Hold	SubOut
001A	DES4	Water	SM9221B2B3CE1F (FC, TC & E coli)	2	120ML Sterile w/ Na2S2O3	☐	☐	1/28/2021	5 days	2/5/2021	Trace	☐	
001B	DES4	Water	SM9230B (Enterococci, Enumeration)	2	120ML Sterile w/ Na2S2O3	☐	☐	1/28/2021	5 days	2/5/2021	Trace	☐	
001C	DES4	Water	E351.2 (TKN)	1	250mL aG w/ H2SO4	☐	☐	1/28/2021	5 days	2/5/2021	Trace	☐	
			E350.1 (Ammonia as N)			☐	☐		5 days	2/5/2021	Trace	☐	
001D	DES4	Water	E365.1 (Total Phosphorous as P)	1	500mL aG w/ H2SO4	☐	☐	1/28/2021	5 days	2/5/2021	Trace	☐	
001E	DES4	Water	E300.1 (Inorganic Anions) <Nitrate & Nitrite as N, Nitrate as N, Nitrate as NO3^{-}, Nitrite as N, Nitrite as NO2^{-}, ortho-Phosphate as P, ortho-Phosphate as PO4>	1	125mL HDPE, unprsv.	☐	☐	1/28/2021	5 days	2/5/2021	Trace	☐	

NOTES: * STLC and TCLP extractions require 2 days to complete; therefore, all TATs begin after the extraction is completed (i.e., One-day TAT yields results in 3 days from sample submission).

- MAI assumes that all material present in the provided sampling container is considered part of the sample - MAI does not exclude any material from the sample prior to sample preparation unless requested in writing by the client.

2101E39

Quote ID = 212277

Chain-of-Custody Form

Project Name: Pt Reyes Surface Water Monitoring	Project Location: Pt Reyes National Seashore, Marin County CA	Project Number: P2021.1
Sampler: Douglas Lovell	Laboratory: McCampbell Analytical, 1534 Willow Pass Rd, Pittsburg CA 94565	Laboratory Number: (925) 252-9262

			Matrix			Type		Containers				Turnaround			Analyses									
Sample Designation	Date	Time		Surface Water		Grab		Quantity	Type	Preservative (in addition to ice)	Field Filtration			5-day (normal)	Total coliform, Fecal coliform, e coli (all enumeration, mpn)	Enterococci (enumeration, mpn)	Total Kjeldahl Nitrogen	Ammonia Nitrogen	Total Phosphorus	Inorganic Anions (Nitrate, Nitrite, Orthophosphate)			Sampler Comments	Laboratory Comments
DES4	28-Jan-21			x		x		4	120 mL sterile plastic	Sodium Thiosulfate	None			x	x	x								
DES4	28-Jan-21			x		x		1	500 mL amber glass	H2SO4	None			x			x	x	x					
DES4	28-Jan-21			x		x		1	125 mL HDPE	None	None			x						x				

(+)

Note: Sampler and laboratory to observe preservative, condition, integrity, etc. of samples and record (under "Comments") any exceptions from standard protocols.

Relinquished By:	Received By:	Date: 1/29/21 @ 0938	Time:
Relinquished By:	Received By:	Date:	Time:

Douglas Lovell, 1514 Hearst Avenue, Berkeley CA 94703 510-520-3146

Report results to doug.streamborn@gmail.com

Prepare EDF for Geotracker Upload? **No**	Log code:	Global ID:

3.9 °C wet

McCampbell Analytical, Inc.
"When Quality Counts"
1534 Willow Pass Road, Pittsburg, CA 94565-1701
Toll Free Telephone: (877) 252-9262 / Fax: (925) 252-9269
http://www.mccampbell.com / E-mail: main@mccampbell.com

Sample Receipt Checklist

Client Name:	**Douglas Lovell**	Date and Time Received	**1/29/2021 09:38**
Project:	**P2021.1; Pt Reyes Surface Water Monitoring**	Date Logged:	**1/29/2021**
		Received by:	Tina Perez
WorkOrder №:	**2101E39** Matrix: Water	Logged by:	Tina Perez
Carrier:	Client Drop-In		

Chain of Custody (COC) Information

	Yes	No	NA
Chain of custody present?	☑	☐	
Chain of custody signed when relinquished and received?	☑	☐	
Chain of custody agrees with sample labels?	☑	☐	
Sample IDs noted by Client on COC?	☑	☐	
Date and Time of collection noted by Client on COC?	☑	☐	
Sampler's name noted on COC?	☑	☐	
COC agrees with Quote?	☑	☐	☐

Sample Receipt Information

	Yes	No	NA
Custody seals intact on shipping container/cooler?	☐	☐	☑
Shipping container/cooler in good condition?	☑	☐	
Samples in proper containers/bottles?	☑	☐	
Sample containers intact?	☑	☐	
Sufficient sample volume for indicated test?	☑	☐	

Sample Preservation and Hold Time (HT) Information

	Yes	No	NA
All samples received within holding time?	☐	☑	☐
Samples Received on Ice?	☑	☐	
	(Ice Type: WET ICE)		
Sample/Temp Blank temperature	Temp: 3.9°C		☐
ZHS conditional analyses: VOA meets zero headspace requirement (VOCs, TPHg/BTEX, RSK)?	☐	☐	☑
Sample labels checked for correct preservation?	☑	☐	
pH acceptable upon receipt (Metal: <2; Nitrate 353.2/4500NO3: <2; 522: <4; 218.7: >8)?	☐	☐	☑
UCMR Samples:			
pH tested and acceptable upon receipt (200.8: ≤2; 525.3: ≤4; 530: ≤7; 541: <3; 544: <6.5 & 7.5)?	☐	☐	☑
Free Chlorine tested and acceptable upon receipt (<0.1mg/L)?	☐	☐	☑

Comments Method SM9221B2B3CE1F (FC, TC & E coli) was received past its 0.333-day holding time. Method SM9230B (Enterococci, Enumeration) was received past its 0.333-day holding time.

APPENDIX C

Quality Assurance/Quality Control

QUALITY ASSURANCE/QUALITY CONTROL

Field Meters

- Prior to traveling to the field, the meters were calibrated using reference/standard solutions (brought to a temperature of ±25˚ C).
- During monitoring, each of the meters read within 0.1 ˚C of each other.
- Upon return from the field, meters were checked against reference/standard solutions (brought to a temperature of ±25˚ C) with the following results:
  - pH reference solution = 7.00 Meter = 7.05
  - Specific conductance reference solution = 1,413 µS/cm Meter = 1,429 µS/cm
  - Meter dedicated to salinity: specific conductance reference solution = 1,413 µS/cm Meter = 1,379 µS/cm
  - ORP reference solution = 231 mV Meter = 225 mV
  - Dissolved oxygen reference solution = 0.00 mg/L Meter = 0.15 mg/L
  - Dissolved oxygen reference solution = 100% Meter = 109%
  - Turbidity reference solution = 1.00 NTU Meter = 0.82 NTU
- Except for dissolved oxygen and turbidity, no significant QA/QC issues were noted with the field meters.
  - Dissolved oxygen measurements in mg/L were about 0.1 to 0.2 high. Dissolved oxygen measurements in % saturation were about 9% high
  - Turbidity measurements were higher than measured although the magnitude cannot be reliably estimated

Field Blank

- A field blank (sample ID = FB2) was prepared at monitoring location DES2. The blank was prepared (the sample containers were filled in the field) using deionized water that had been provided by the laboratory.
- Phosphorus was measured in the field blank at a concentration of 0.083 mg/L (negligible concentration). No other analytes were detected in the field blank.

Laboratory Data

- For Nitrate, Nitrite, and Orthophosphate analyses of the sample from location DES4, the reporting limit was raised (the sample was diluted) due to the physical nature (salinity) of the sample; consequently, the surrogate recovery was outside accepted limits. Nitrogen and phosphorus measurements at DES4 were not employed to interpret macronutrient impacts on surface water quality.
- For bacterial analyses of the sample from location DES4, the time between sample collection and laboratory preparation (hold time) was approximately 20 hours, whereas the accepted time is 8 hours. In general, (1) decreased concentrations result from extended hold times and maintenance of the sample at 4˚C minimizes the decrease, and (2) the relatively short hold time of 8 hours is designed to limit reporting nondetect or lower-than-actual concentrations (Pope et al. 2003, Ahammed 2003, Selvakumar et al. 2004, US Environmental Protection Agency 2006, Aulenbach 2009). The sample at DES4 was maintained at a temperature of ±4˚C (on ice) from the time of sample collection until submittal to the laboratory; accordingly, the measured bacteria concentrations at location DES4 are believed accurate.

APPENDIX D

Weather Data from the
Pt. Reyes RCA Meteorological Station
(https://wrcc.dri.edu/cgi-bin/rawMAIN.pl?nvprca)

January 21, 2021

Hour	Total			Air	Soil		Soil	Relative												
of Day	Solar	Wind		Temperature	Temperature		Moisture	Humidity		Dew	Wet		Baro.		Total					
Ending at	Rad.	Ave.	V. Dir.	Max.	Mean	Max	Min	Mean	Max	Min		Mean		Mean	Max	Min	Point	Bulb	Press.	Precip.
L.S.T.	° ly.	mph	Deg	mph	Deg. F.		Deg. F.	cBars		Percent		Deg. F.		in. Hg.		inches				
1:00 AM	0.0	2.2	6	5.2	42.4			46.9	47	46.8		-28.9		100			42	42	29.97	0
2:00 AM	0.0	2.3	55	4.7	39.3			47	47.1	46.8		-28.8		100			39	39	29.97	0
3:00 AM	0.0	1.7	67	3.9	39.7			47	47.1	46.9		-28.9		100			40	40	29.97	0
4:00 AM	0.0	2.2	81	3.6	39.7			47	47.1	46.9		-29		100			40	40	29.97	0
5:00 AM	0.0	2.8	54	4.6	39.7			47.1	47.2	47		-29		100			40	40	29.96	0
6:00 AM	0.0	2.3	119	4.7	38.1			47.1	47.2	47		-29		100			38	38	29.95	0
7:00 AM	0.0	2.4	151	5.2	33.5			47.1	47.2	46.9		-29.3		100			33	33	29.95	0
8:00 AM	1.0	1.5	175	3.4	34.2			46.6	46.9	46.3		-29.2		100			34	34	29.96	0
9:00 AM	6.6	3.9	136	5.7	37			46.2	46.4	46.1		-29.1		100			37	37	29.97	0
10:00 AM	13.9	3	189	7.3	41			46.4	46.6	46.2		-29.1		100			41	41	29.99	0
11:00 AM	24.0	4.9	190	9.1	43.2			47	47.6	46.5		-29.1		100			43	43	29.99	0
12:00 PM	25.7	5.9	208	11.8	44.4			48.1	48.7	47.5		-29.1		100			44	44	29.98	0
1:00 PM	32.7	10.1	191	14.7	45.3			49.2	49.7	48.6		-29.2		100			45	45	29.95	0
2:00 PM	35.5	13.1	183	17.4	47.2			50.1	50.5	49.6		-29.2		94			46	46	29.92	0
3:00 PM	38.0	10.8	184	16.4	49.1			50.7	51	50.5		-29.2		87			45	47	29.91	0
4:00 PM	24.6	8.2	183	12.1	49.8			51	51.1	50.9		-29.4		85			46	47	29.91	0
5:00 PM	4.0	6.8	181	9.3	48			51	51.2	50.9		-29.6		91			45	47	29.9	0
6:00 PM	0.4	5.1	168	6.9	46.5			50.7	51	50.5		-29.7		94			45	46	29.9	0
7:00 PM	0.0	5	174	8.1	46.1			50.3	50.6	50		-29.9		96			45	45	29.89	0
8:00 PM	0.0	5.4	183	8.6	47.7			49.9	50.1	49.8		-30.1		95			46	47	29.89	0
9:00 PM	0.0	4.5	206	6.3	48.7			49.8	49.9	49.7		-30.1		92			47	47	29.89	0
10:00 PM	0.0	6.3	176	8.2	48.2			49.7	49.8	49.6		-30		91			46	47	29.88	0
11:00 PM	0.0	7.8	172	9.5	47.4			49.6	49.7	49.5		-30.2		94			46	46	29.85	0
12:00 AM	0.0	7.5	174	9.2	48.1			49.4	49.5	49.3		-30.3		95			47	47	29.85	0

DAILY STATISTICS

	Total			Air	Soil		Soil	Relative												
	Solar	Wind		Temperature	Temperature		Moisture	Humidity		Dew	Wet		Baro.		Total					
	Rad.	Ave.	V. Dir.	Max.	Mean	Max	Min	Mean	Max	Min		Mean		Mean	Max	Min	Point	Bulb	Press.	Precip.
	° ly.	mph	Deg	mph	Deg. F.		Deg. F.	cBars		Percent		Deg. F.		in. Hg.		inches				
Total	206.4																			0
Ave.		5.2	166		43.5			48.5				-29.4		96			43	43	29.93	
Max.				17.4		-147.8			51.2			-28.6			-100					
Min.							1831.8			46.1		-30.3				1000				

NOTES:
Daily averages might vary slightly from the average of the hourly values printed due to rounding of the hourly values.
Data are subject to further review and editing. Please refer any questions to the Western Regional Climate Center.
° 1 ly = 1 cal/cm² = 4.1855 J/cm² = 3.6855 BTU/ft² = .01163 KW-hr/m²

January 22, 2021

Hour	Total			Air	Soil		Soil	Relative												
of Day	Solar	Wind		Temperature	Temperature		Moisture	Humidity		Dew	Wet		Baro.		Total					
Ending at	Rad.	Ave.	V. Dir.	Max.	Mean	Max	Min	Mean	Max	Min		Mean		Mean	Max	Min	Point	Bulb	Press.	Precip.
L.S.T.	° ly.	mph	Deg	mph	Deg. F.		Deg. F.	cBars		Percent		Deg. F.		in. Hg.		inches				
1:00 AM	0.0	7.7	178	10.3	48.7			49.3	49.4	49.2		-30.2		96			48	48	29.82	0
2:00 AM	0.0	9.9	234	24.4	49.9			49.2	49.3	49.1		-30.4		97			49	49	29.81	0.02
3:00 AM	0.0	23.1	330	38.1	49			49.3	49.4	49.2		-30.3		94			47	48	29.8	0.01
4:00 AM	0.0	18.1	346	28.9	48.9			49.4	49.4	49.3		-30.4		89			46	47	29.8	0
5:00 AM	0.0	15.1	336	21.5	48.3			49.3	49.4	49.1		-30.3		88			45	46	29.8	0
6:00 AM	0.0	12.5	325	19.4	48.7			49	49.2	48.9		-30.5		84			44	46	29.8	0
7:00 AM	0.0	12	311	21	48.3			48.9	49	48.7		-30.4		91			46	47	29.79	0
8:00 AM	1.1	12.8	297	25.1	48.4			48.7	48.9	48.6		-30.4		89			45	47	29.79	0.01
9:00 AM	3.7	11.4	293	19.1	47.8			48.7	48.7	48.6		-30.4		92			46	47	29.79	0.01
10:00 AM	16.4	6.3	284	18.6	47.8			48.8	49	48.6		-30.3		90			45	46	29.79	0.06
11:00 AM	11.4	4.8	167	14.2	47.2			49.1	49.2	48.9		-30.4		94			46	46	29.78	0.01
12:00 PM	33.3	8.9	266	13.7	50.7			49.5	49.8	49.1		-30.2		86			46	48	29.76	0
1:00 PM	26.7	6.1	288	14.8	49.4			50.3	50.7	49.8		-30.1		89			46	48	29.75	0
2:00 PM	43.0	9.5	340	16	50.9			51.1	51.6	50.6		-30.1		82			46	48	29.74	0
3:00 PM	36.3	14.8	349	19.1	50.9			51.7	51.9	51.5		-30.1		83			46	48	29.75	0
4:00 PM	22.9	16.1	348	22.3	51.2			51.7	51.8	51.6		-30		83			46	48	29.74	0
5:00 PM	11.0	13	342	19.3	50.7			51.5	51.7	51.4		-30.2		84			46	48	29.74	0
6:00 PM	0.8	13	340	21.1	49.4			51.2	51.5	50.9		-30.1		86			46	47	29.75	0
7:00 PM	0.0	11.9	335	17.7	49			50.7	51	50.4		-30.1		89			46	47	29.76	0
8:00 PM	0.0	12.3	335	18	49			50.3	50.5	50		-30		85			45	47	29.76	0
9:00 PM	0.0	10.1	349	20.9	48.6			49.9	50.1	49.8		-30		88			45	47	29.76	0
10:00 PM	0.0	8.2	14	14.1	46.6			49.6	49.9	49.5		-30.1		89			44	45	29.76	0
11:00 PM	0.0	4.9	33	9.1	43.6			49.3	49.5	49		-29.9		96			43	43	29.78	0
12:00 AM	0.0	3.8	38	6.6	43.3			48.8	49	48.6		-29.9		98			43	43	29.78	0

DAILY STATISTICS

	Total			Air	Soil		Soil	Relative												
	Solar	Wind		Temperature	Temperature		Moisture	Humidity		Dew	Wet		Baro.		Total					
	Rad.	Ave.	V. Dir.	Max.	Mean	Max	Min	Mean	Max	Min		Mean		Mean	Max	Min	Point	Bulb	Press.	Precip.
	° ly.	mph	Deg	mph	Deg. F.		Deg. F.	cBars		Percent		Deg. F.		in. Hg.		inches				
Total	206.7																			0.12
Ave.		11.1	328		48.6			49.8				-30.2		89			46	47	29.77	
Max.				38.1		-147.8			51.9			-29.7			-100					
Min.							1831.8			48.6		-30.6				1000				

NOTES:
Daily averages might vary slightly from the average of the hourly values printed due to rounding of the hourly values.
Data are subject to further review and editing. Please refer any questions to the Western Regional Climate Center.
° 1 ly = 1 cal/cm² = 4.1855 J/cm² = 3.6855 BTU/ft² = .01163 KW-hr/m²

January 23, 2021

Hour of Day Ending at L.S.T.	Total Solar Rad. ° ly.	Wind Ave. mph	V. Dir. Deg	Air Temperature Max. mph	Soil Temperature Mean Deg. F.	Max	Soil Moisture Min Deg. F.	Relative Humidity Mean cBars	Max	Dew Min Percent	Wet	Mean Deg. F.	Baro.	Mean in. Hg.	Total Max	Min inches	Point	Bulb	Press.	Precip.
1:00 AM	0.0	1	39	3.4	42.1			48.4	48.7	48.1		-29.9		98			42	42	29.79	0
2:00 AM	0.0	3.3	72	8.3	42.3			47.8	48.2	47.4		-29.8		98			42	42	29.8	0
3:00 AM	0.0	2.4	49	5.3	42.7			47.3	47.5	47.1		-29.7		96			41	42	29.8	0
4:00 AM	0.0	4.4	57	8.8	42.4			47	47.2	46.8		-29.8		95			41	42	29.81	0
5:00 AM	0.0	4.2	37	6.9	40.4			46.6	46.8	46.4		-29.6		96			39	40	29.81	0
6:00 AM	0.0	3.7	10	5.6	39.9			46.2	46.5	46		-29.6		98			39	40	29.82	0
7:00 AM	0.0	3.6	23	7.1	40.4			45.8	46.1	45.6		-29.6		97			40	40	29.84	0
8:00 AM	1.5	3.9	354	7.7	40.5			45.5	45.6	45.3		-29.5		94			39	40	29.85	0
9:00 AM	13.6	4	56	7.4	43.8			45.2	45.3	45.1		-29.4		92			42	43	29.87	0
10:00 AM	26.6	4.3	27	6.9	48.2			45.4	45.8	45.1		-29.3		82			43	45	29.88	0
11:00 AM	37.7	4.1	354	8.8	50.5			46.3	46.9	45.8		-29.2		80			45	47	29.9	0
12:00 PM	44.8	5.3	331	10	51.2			47.6	48.2	46.9		-29		79			45	48	29.89	0
1:00 PM	47.4	8.3	334	13.6	51.3			48.9	49.5	48.2		-29.1		77			44	47	29.87	0
2:00 PM	44.4	13	334	16.8	52			49.9	50.3	49.5		-29.3		74			44	47	29.85	0
3:00 PM	36.6	13.3	333	17.6	52.1			50.4	50.6	50.3		-29.2		75			45	48	29.84	0
4:00 PM	24.8	12.7	331	16.7	51.6			50.6	50.7	50.5		-29.5		78			45	48	29.84	0
5:00 PM	11.2	11.1	339	15.9	50.6			50.5	50.7	50.4		-29.6		82			45	48	29.83	0
6:00 PM	1.0	11.7	339	18.2	49.2			50.3	50.5	50		-29.7		87			46	47	29.84	0
7:00 PM	0.0	12.6	345	19.6	49.2			49.8	50.1	49.5		-29.7		89			46	47	29.85	0
8:00 PM	0.0	10.4	356	17.5	48.7			49.4	49.6	49.2		-29.7		91			46	47	29.84	0
9:00 PM	0.0	9.1	355	14	48.3			49.1	49.3	48.9		-29.8		93			46	47	29.84	0
10:00 PM	0.0	8.4	356	13.2	47.2			48.8	49	48.6		-29.8		95			46	46	29.84	0
11:00 PM	0.0	11.2	344	15.6	47.9			48.5	48.7	48.3		-29.7		92			46	47	29.84	0
12:00 AM	0.0	10.2	345	14.1	47.4			48.3	48.5	48.2		-29.7		92			45	46	29.84	0

DAILY STATISTICS

	Total Solar Rad. ° ly.	Wind Ave. mph	V. Dir. Deg	Air Temperature Max. mph	Soil Temperature Mean Deg. F.	Max	Soil Moisture Min Deg. F.	Relative Humidity Mean cBars	Max	Dew Min Percent	Wet	Mean Deg. F.	Baro.	Mean in. Hg.	Total Max	Min inches	Point	Bulb	Press.	Precip.
Total	289.6																			0
Ave.		7.4	3		46.7			48.1				-29.5		89			43	45	29.84	
Max.				19.6		-147.8			50.7			-28.9			-100					
Min.							1831.8			45.1		-30.0				1000				

NOTES:
Daily averages might vary slightly from the average of the hourly values printed due to rounding of the hourly values.
Data are subject to further review and editing. Please refer any questions to the Western Regional Climate Center.
° 1 ly = 1 cal/cm² = 4.1855 J/cm² = 3.6855 BTU/ft² = .01163 KW-hr/m²

January 24, 2021

Hour of Day Ending at L.S.T.	Total Solar Rad. ° ly.	Wind Ave. mph	V. Dir. Deg	Air Temperature Max. mph	Soil Temperature Mean Deg. F.	Max	Soil Moisture Min Deg. F.	Relative Humidity Mean cBars	Max	Dew Min Percent	Wet	Mean Deg. F.	Baro.	Mean in. Hg.	Total Max	Min inches	Point	Bulb	Press.	Precip.
1:00 AM	0.0	13.5	338	19.5	47.8			48.1	48.3	48		-29.7		91			45	46	29.84	0
2:00 AM	0.0	14.6	340	20.7	47.6			48	48.1	47.9		-29.7		90			45	46	29.85	0
3:00 AM	0.0	14.4	334	21.9	47.5			47.9	48	47.7		-29.7		89			44	46	29.84	0
4:00 AM	0.0	15.9	335	23.8	47.3			47.7	47.8	47.7		-29.6		88			44	45	29.83	0
5:00 AM	0.0	18.8	332	25.8	47.3			47.6	47.8	47.6		-29.7		87			44	45	29.83	0
6:00 AM	0.0	18	332	25.3	46.9			47.6	47.7	47.5		-29.7		86			43	45	29.82	0
7:00 AM	0.0	16.5	333	26.4	47.1			47.5	47.6	47.4		-29.6		84			42	45	29.81	0
8:00 AM	1.1	15.3	333	21.9	47.1			47.4	47.5	47.4		-29.7		83			42	44	29.81	0
9:00 AM	6.3	17.3	332	25.3	47.8			47.4	47.6	47.4		-29.7		82			43	45	29.81	0
10:00 AM	13.2	16.2	335	22.5	48.8			47.6	47.7	47.4		-29.7		81			43	46	29.81	0
11:00 AM	8.2	16.2	334	21.6	48.8			47.9	48.1	47.6		-29.7		78			42	45	29.82	0
12:00 PM	14.5	9.2	329	14.8	49.3			48.2	48.4	48		-29.7		81			44	46	29.81	0
1:00 PM	18.1	10.9	308	16	50.3			48.6	48.9	48.3		-29.7		80			44	47	29.79	0
2:00 PM	17.6	10.6	309	14.9	50.4			49.2	49.7	48.9		-29.8		82			45	47	29.77	0
3:00 PM	6.5	9.1	292	15.9	47.8			49.8	49.9	49.6		-29.7		93			46	47	29.75	0.03
4:00 PM	6.5	10.7	275	15.5	46.6			49.9	50	49.8		-29.7		96			46	46	29.74	0.01
5:00 PM	4.5	17.4	318	32.5	47.5			49.8	49.9	49.7		-29.7		92			45	46	29.72	0.01
6:00 PM	0.4	19.2	335	31	48.1			49.6	49.8	49.5		-29.8		92			46	47	29.69	0
7:00 PM	0.0	18.2	8	35.1	46.2			49.4	49.6	49.2		-29.7		92			44	45	29.73	0.06
8:00 PM	0.0	25.2	341	38.5	46.6			49	49.3	48.8		-29.7		82			41	44	29.74	0
9:00 PM	0.0	31.1	339	41.8	46.5			48.6	48.9	48.3		-29.5		78			40	43	29.73	0
10:00 PM	0.0	30.5	342	44.8	46.2			48.1	48.4	47.8		-29.3		75			39	42	29.73	0
11:00 PM	0.0	26.9	339	38.7	45.6			47.6	47.9	47.3		-29		74			38	42	29.74	0
12:00 AM	0.0	29.9	338	41.6	45.6			47.1	47.4	46.9		-28.7		75			38	42	29.74	0

DAILY STATISTICS

	Total Solar Rad. ° ly.	Wind Ave. mph	V. Dir. Deg	Air Temperature Max. mph	Soil Temperature Mean Deg. F.	Max	Soil Moisture Min Deg. F.	Relative Humidity Mean cBars	Max	Dew Min Percent	Wet	Mean Deg. F.	Baro.	Mean in. Hg.	Total Max	Min inches	Point	Bulb	Press.	Precip.
Total	96.9																			0.11
Ave.		17.7	330		47.5			48.3				-29.6		85			43	45	29.78	
Max.				44.8		-147.8			50.0			-28.7			-100					
Min.							1831.8			46.9		-30.0				1000				

NOTES:
Daily averages might vary slightly from the average of the hourly values printed due to rounding of the hourly values.
Data are subject to further review and editing. Please refer any questions to the Western Regional Climate Center.
° 1 ly = 1 cal/cm² = 4.1855 J/cm² = 3.6855 BTU/ft² = .01163 KW-hr/m²

January 25, 2021

Hour	Total			Air	Soil		Soil	Relative											
of Day	Solar	Wind		Temperature	Temperature		Moisture	Humidity		Dew	Wet	Baro.		Total					
Ending at	Rad.	Ave.	V. Dir.	Max.	Mean	Max	Min	Mean	Max	Min		Mean	Mean	Max	Min	Point	Bulb	Press.	Precip.
L.S.T.	° ly.	mph	Deg	mph	Deg. F.		Deg. F.	cBars		Percent		Deg. F.	in. Hg.		inches				
1:00 AM	0.0	27.5	341	40.2	45.2			46.8	47	46.6		-28.4	78			39	42	29.73	0
2:00 AM	0.0	27.5	339	38.1	44.7			46.5	46.7	46.4		-28.2	77			38	41	29.72	0
3:00 AM	0.0	26.1	340	38.2	44.9			46.3	46.5	46.1		-28	78			38	41	29.73	0
4:00 AM	0.0	26.6	344	36.9	44.8			46.1	46.2	45.9		-27.7	74			37	41	29.73	0
5:00 AM	0.0	26.9	340	38.7	44.4			45.9	46	45.7		-27.5	75			37	41	29.72	0
6:00 AM	0.0	27.8	342	37.4	44.4			45.6	45.8	45.5		-27.3	78			38	41	29.73	0
7:00 AM	0.0	22.8	349	30.9	43.5			45.5	45.6	45.3		-27	75			36	40	29.74	0
8:00 AM	2.4	23.7	352	37.1	44.2			45.3	45.4	45.1		-27	75			37	40	29.75	0
9:00 AM	14.9	26	348	37.6	45.2			45.1	45.2	45		-26.8	69			36	40	29.76	0
10:00 AM	28.8	26.3	342	34.9	46.6			45.2	45.3	45		-26.7	68			37	41	29.77	0
11:00 AM	40.1	26.4	340	35.7	47.9			45.6	46	45.3		-26.6	67			37	42	29.78	0
12:00 PM	47.1	26.7	333	36.5	48.7			46.3	46.6	45.9		-26.7	67			38	43	29.76	0
1:00 PM	49.3	29.2	331	38.1	48.9			47	47.4	46.6		-26.7	66			38	43	29.74	0
2:00 PM	45.8	28.8	330	38.6	48.8			47.6	47.9	47.3		-26.7	68			39	43	29.74	0
3:00 PM	37.8	30.6	331	40.9	48.3			48	48.1	47.8		-26.7	69			38	43	29.72	0
4:00 PM	25.8	29.9	331	39.2	47.9			48	48.1	47.9		-26.8	68			38	43	29.73	0
5:00 PM	11.4	29.2	331	40.9	46.9			47.9	48	47.7		-26.8	69			37	42	29.72	0
6:00 PM	0.9	28.4	334	38.4	46			47.5	47.8	47.2		-26.8	70			37	41	29.73	0
7:00 PM	0.0	25.8	338	35.8	45.8			47	47.2	46.8		-26.9	72			37	41	29.73	0
8:00 PM	0.0	24.1	339	32.4	45.5			46.6	46.8	46.4		-26.9	71			36	41	29.74	0
9:00 PM	0.0	22.3	342	31.6	45.1			46.3	46.5	46.1		-26.8	74			37	41	29.75	0
10:00 PM	0.0	22.5	337	30.7	44.9			46	46.1	45.8		-26.9	77			38	41	29.75	0
11:00 PM	0.0	18.8	346	28.2	44.3			45.8	45.9	45.6		-26.8	73			36	40	29.77	0
12:00 AM	0.0	19	345	27.1	44.1			45.5	45.7	45.3		-26.8	75			37	40	29.78	0

DAILY STATISTICS

	Total			Air	Soil		Soil	Relative											
	Solar	Wind		Temperature	Temperature		Moisture	Humidity		Dew	Wet	Baro.		Total					
	Rad.	Ave.	V. Dir.	Max.	Mean	Max	Min	Mean	Max	Min		Mean	Mean	Max	Min	Point	Bulb	Press.	Precip.
	° ly.	mph	Deg	mph	Deg. F.		Deg. F.	cBars		Percent		Deg. F.	in. Hg.		inches				
Total	304.3																		0
Ave.		25.9	339		45.9			46.4				-27.1	72			37	41	29.74	
Max.				40.9		-147.8			48.1			-26.6		-100					
Min.							1831.8			45.0		-28.5			1000				

NOTES:
Daily averages might vary slightly from the average of the hourly values printed due to rounding of the hourly values.
Data are subject to further review and editing. Please refer any questions to the Western Regional Climate Center.
° 1 ly = 1 cal/cm² = 4.1855 J/cm² = 3.6855 BTU/ft² = .01163 KW-hr/m²

January 26, 2021

Hour	Total			Air	Soil		Soil	Relative											
of Day	Solar	Wind		Temperature	Temperature		Moisture	Humidity		Dew	Wet	Baro.		Total					
Ending at	Rad.	Ave.	V. Dir.	Max.	Mean	Max	Min	Mean	Max	Min		Mean	Mean	Max	Min	Point	Bulb	Press.	Precip.
L.S.T.	° ly.	mph	Deg	mph	Deg. F.		Deg. F.	cBars		Percent		Deg. F.	in. Hg.		inches				
1:00 AM	0.0	17.4	347	24.5	43.7			45.3	45.4	45.1		-26.8	74			36	40	29.79	0
2:00 AM	0.0	15.4	347	21.4	43.1			45	45.2	44.8		-26.9	72			35	39	29.79	0
3:00 AM	0.0	13.1	343	17.5	42.6			44.8	45	44.6		-26.9	74			35	39	29.8	0
4:00 AM	0.0	12.4	343	17.4	42.5			44.5	44.7	44.4		-26.9	74			35	39	29.8	0
5:00 AM	0.0	13.7	345	19.1	42.6			44.3	44.4	44.2		-26.9	75			35	39	29.8	0
6:00 AM	0.0	12.1	344	18.3	42.3			44.1	44.2	44		-26.9	78			36	39	29.81	0
7:00 AM	0.0	7.1	337	11.8	40.6			43.9	44.1	43.8		-26.9	82			36	38	29.82	0
8:00 AM	2.4	2.4	49	5.9	35.8			43.7	43.9	43.4		-26.9	88			33	34	29.82	0
9:00 AM	14.8	3.2	137	5.1	40.2			43.2	43.5	43.1		-26.8	87			37	38	29.83	0
10:00 AM	27.7	7.1	164	12.1	46.1			43.5	43.9	43.2		-26.8	76			39	42	29.84	0
11:00 AM	24.3	11.5	173	16.5	47.4			44.4	45.1	43.8		-26.8	74			40	43	29.85	0
12:00 PM	17.0	14	171	20.6	47.2			45.6	46	45		-26.9	77			40	43	29.84	0
1:00 PM	15.5	15.9	171	21.9	47.8			46.2	46.6	45.9		-26.9	76			41	44	29.8	0
2:00 PM	16.7	18.5	187	29.1	47.3			46.7	47	46.5		-27.1	75			40	43	29.76	0
3:00 PM	8.6	20.3	176	32.1	46.5			47.1	47.2	46.9		-27.1	82			41	44	29.73	0.01
4:00 PM	3.8	26.1	172	37.5	45.7			47.2	47.3	47.1		-27.1	91			43	44	29.69	0.03
5:00 PM	0.9	29	169	41.4	45.5			47.1	47.2	47		-27.1	93			44	44	29.65	0.09
6:00 PM	0.1	32.3	167	44.6	45.4			46.9	47	46.7		-26.9	95			44	45	29.6	0.14
7:00 PM	0.0	34.8	174	50.9	45.6			46.6	46.8	46.5		-21.4	95			44	45	29.57	0.12
8:00 PM	0.0	37.5	175	54.1	46.1			46.5	46.6	46.4		-17.6	96			45	46	29.52	0.14
9:00 PM	0.0	41.5	176	60.4	46.4			46.4	46.5	46.3		-20.9	96			45	46	29.48	0.19
10:00 PM	0.0	37.2	178	56	46.9			46.4	46.5	46.3		-21.3	97			46	46	29.47	0.31
11:00 PM	0.0	29.5	191	49.3	48.1			46.5	46.6	46.3		-22.4	98			48	48	29.48	0.35
12:00 AM	0.0	15	193	24.2	48.9			46.7	46.9	46.5		-24	97			48	48	29.48	0.03

DAILY STATISTICS

	Total			Air	Soil		Soil	Relative											
	Solar	Wind		Temperature	Temperature		Moisture	Humidity		Dew	Wet	Baro.		Total					
	Rad.	Ave.	V. Dir.	Max.	Mean	Max	Min	Mean	Max	Min		Mean	Mean	Max	Min	Point	Bulb	Press.	Precip.
	° ly.	mph	Deg	mph	Deg. F.		Deg. F.	cBars		Percent		Deg. F.	in. Hg.		inches				
Total	131.8																		1.41
Ave.		19.5	177		44.8			45.5				-25.5	84			40	42	29.71	
Max.				60.4		-147.8			47.3			-17.2		-100					
Min.							1831.8			43.1		-27.3			1000				

NOTES:
Daily averages might vary slightly from the average of the hourly values printed due to rounding of the hourly values.
Data are subject to further review and editing. Please refer any questions to the Western Regional Climate Center.
° 1 ly = 1 cal/cm² = 4.1855 J/cm² = 3.6855 BTU/ft² = .01163 KW-hr/m²

January 27, 2021

Hour of Day Ending at L.S.T.	Total Solar Rad. ° ly.	Wind Ave. mph	V. Dir. Deg	Air Temperature Max. mph	Soil Temperature Mean Deg. F.	Max	Soil Moisture Min Deg. F.	Relative Humidity Mean cBars	Max	Dew Min Percent	Wet	Mean Deg. F.	Baro.	Mean in. Hg.	Total Max	Min inches	Point	Bulb	Press.	Precip.
1:00 AM	0.0	11.1	203	21.8	49			46.9	47.1	46.8		-24.8		98			48	49	29.5	0
2:00 AM	0.0	9.2	216	15.6	48.4			47.1	47.2	47		-23.8		97			48	48	29.52	0
3:00 AM	0.0	10.5	214	17.2	48.4			47.1	47.2	47		-23.6		96			47	48	29.54	0
4:00 AM	0.0	15	216	24.8	49.8			47	47.1	46.9		-23.7		93			48	49	29.56	0
5:00 AM	0.0	15.1	221	36.4	47.8			47	47.1	46.9		-23.9		91			45	46	29.56	0.07
6:00 AM	0.0	8.3	200	11.7	45.3			46.9	47.1	46.7		-24		94			44	44	29.59	0
7:00 AM	0.0	9	197	15.6	46.6			46.5	46.7	46.4		-23.8		93			45	46	29.62	0
8:00 AM	0.8	7.8	218	9.9	45.3			46.3	46.5	46.1		-23.8		93			43	44	29.64	0
9:00 AM	7.3	8.7	186	13.2	47.2			45.9	46.2	45.8		-23.6		94			45	46	29.65	0
10:00 AM	22.4	12.4	199	19.5	51.9			46	46.3	45.8		-23.7		89			49	50	29.66	0
11:00 AM	28.5	15.7	185	23.2	53.2			46.8	47.5	46.2		-23.7		89			50	51	29.67	0
12:00 PM	28.3	17.2	171	24.3	52.9			48	48.5	47.4		-23.6		90			50	51	29.67	0
1:00 PM	23.2	16.7	172	24.1	52.6			48.9	49.2	48.5		-23.5		93			50	51	29.65	0
2:00 PM	19.1	19.7	168	28	52.2			49.5	49.8	49.2		-23.6		92			50	51	29.6	0
3:00 PM	15.2	19.5	166	27.8	51.8			49.9	50.1	49.7		-23.6		90			49	50	29.59	0
4:00 PM	4.0	15.8	169	27	49.2			50.1	50.2	50		-23.4		96			48	49	29.59	0.06
5:00 PM	1.8	12.3	151	18.1	48.3			49.9	50.1	49.8		-23.2		96			47	48	29.58	0.08
6:00 PM	0.2	7.4	133	12.9	47.8			49.7	49.9	49.5		-22.8		96			47	47	29.56	0.01
7:00 PM	0.0	4.2	109	8.8	46.8			49.4	49.6	49.2		-22.5		96			46	46	29.56	0.01
8:00 PM	0.0	9	143	15.9	47.6			49.2	49.4	49		-22.5		95			46	47	29.55	0.03
9:00 PM	0.0	12.9	158	19.6	48			49	49.1	48.9		-22.3		96			47	47	29.55	0.08
10:00 PM	0.0	13.5	167	23.5	48			48.8	49	48.7		-21.3		97			47	47	29.55	0.04
11:00 PM	0.0	14.8	171	23.7	48.6			48.7	48.8	48.6		-21.2		97			48	48	29.55	0
12:00 AM	0.0	13.9	179	19.8	49.7			48.7	48.8	48.6		-21.5		98			49	49	29.56	0.02

DAILY STATISTICS

	Total Solar Rad. ° ly.	Wind Ave. mph	V. Dir. Deg	Air Temperature Max. mph	Soil Temperature Mean Deg. F.	Max	Soil Moisture Min Deg. F.	Relative Humidity Mean cBars	Max	Dew Min Percent	Wet	Mean Deg. F.	Baro.	Mean in. Hg.	Total Max	Min inches	Point	Bulb	Press.	Precip.
Total	151.1																			0.4
Ave.		12.5	180		49.0			48.1				-23.2		94			47	48	29.59	
Max.				36.4		-147.8			50.2			-21.0			-100					
Min.							1831.8			45.8		-25.1				1000				

NOTES:
Daily averages might vary slightly from the average of the hourly values printed due to rounding of the hourly values.
Data are subject to further review and editing. Please refer any questions to the Western Regional Climate Center.
° 1 ly = 1 cal/cm² = 4.1855 J/cm² = 3.6855 BTU/ft² = .01163 KW-hr/m²

January 28, 2021

Hour of Day Ending at L.S.T.	Total Solar Rad. ° ly.	Wind Ave. mph	V. Dir. Deg	Air Temperature Max. mph	Soil Temperature Mean Deg. F.	Max	Soil Moisture Min Deg. F.	Relative Humidity Mean cBars	Max	Dew Min Percent	Wet	Mean Deg. F.	Baro.	Mean in. Hg.	Total Max	Min inches	Point	Bulb	Press.	Precip.
1:00 AM	0.0	9.4	199	16.4	49.9			48.8	48.9	48.7		-21.7		99			50	50	29.56	0.02
2:00 AM	0.0	6.5	217	11.8	49.1			48.9	49	48.8		-21.8		99			49	49	29.56	0
3:00 AM	0.0	5.8	197	8.2	47.6			48.8	49	48.6		-21.9		99			47	47	29.57	0
4:00 AM	0.0	5.8	173	7.5	47.3			48.5	48.7	48.4		-22.1		99			47	47	29.58	0
5:00 AM	0.0	7.2	167	9.9	48.3			48.3	48.4	48.2		-22.4		99			48	48	29.59	0
6:00 AM	0.0	7.4	184	12	49.5			48.3	48.4	48.2		-22.5		99			49	49	29.59	0
7:00 AM	0.0	8.8	188	12.6	49.9			48.4	48.5	48.3		-22.6		100			50	50	29.6	0.03
8:00 AM	0.5	8.8	198	16.3	47.4			48.5	48.6	48.4		-22.5		98			47	47	29.61	0
9:00 AM	3.7	5.1	201	8.3	47.9			48.5	48.6	48.4		-22.5		97			47	47	29.62	0
10:00 AM	9.1	5.8	212	9.3	50			48.5	48.6	48.4		-22.5		96			49	49	29.63	0
11:00 AM	19.4	7.7	225	11.9	52.4			48.9	49.4	48.5		-22.5		91			50	51	29.65	0
12:00 PM	36.9	9.9	240	14.2	53.4			49.8	50.4	49.3		-22.7		83			48	50	29.64	0
1:00 PM	49.3	11.4	251	15.3	53.9			51.1	51.7	50.4		-22.6		82			48	51	29.63	0
2:00 PM	46.6	10.8	247	14.6	54.1			52.2	52.7	51.6		-22.6		79			48	50	29.61	0
3:00 PM	40.4	10.4	251	14.3	53.8			52.9	53.1	52.6		-22.6		82			48	51	29.62	0.01
4:00 PM	28.7	9.3	259	13	53.1			53	53.1	52.9		-22.8		81			48	50	29.62	0
5:00 PM	12.7	6.5	266	11.2	51.9			52.8	53	52.6		-22.8		82			47	49	29.62	0
6:00 PM	1.2	3.8	270	7.4	48.2			52.4	52.7	52		-23		91			46	47	29.61	0
7:00 PM	0.0	1.5	133	2.9	45.1			51.5	52.1	51		-23		96			44	45	29.62	0
8:00 PM	0.0	2.6	121	3.7	43.3			50.5	51	50.1		-23		99			43	43	29.62	0
9:00 PM	0.0	3.3	134	5.3	42			49.7	50.1	49.3		-23.1		100			42	42	29.62	0
10:00 PM	0.0	2.9	142	5.2	41.9			49.1	49.4	48.7		-23.1		100			42	42	29.63	0
11:00 PM	0.0	3	117	5.3	42.2			48.6	48.8	48.4		-23.2		100			42	42	29.64	0
12:00 AM	0.0	2.1	118	4.5	42.5			48.2	48.5	48		-23.1		100			42	42	29.65	0

DAILY STATISTICS

	Total Solar Rad. ° ly.	Wind Ave. mph	V. Dir. Deg	Air Temperature Max. mph	Soil Temperature Mean Deg. F.	Max	Soil Moisture Min Deg. F.	Relative Humidity Mean cBars	Max	Dew Min Percent	Wet	Mean Deg. F.	Baro.	Mean in. Hg.	Total Max	Min inches	Point	Bulb	Press.	Precip.
Total	248.6																			0.06
Ave.		6.5	199		48.5			49.8				-22.6		94			47	47	29.61	
Max.				16.4		-147.8			53.1			-21.6			-100					
Min.							1831.8			48.0		-23.2				1000				

NOTES:
Daily averages might vary slightly from the average of the hourly values printed due to rounding of the hourly values.
Data are subject to further review and editing. Please refer any questions to the Western Regional Climate Center.
° 1 ly = 1 cal/cm² = 4.1855 J/cm² = 3.6855 BTU/ft² = .01163 KW-hr/m²

October, 2020

Day of Month	Day of Year	Total Solar Rad. ly.	Wind Ave. mph	V. Dir. Deg	Air Temperature Max. mph	Soil Temperature Mean Deg. Fahrenheit	Max	Soil Moisture Min Deg. Fahrenheit	Humidity Mean cBars	Max	Dew Min Percent	Wet	Mean Deg. Fahrenheit	Baro. Max	Min in. HG.	Total	Mean inches	Max	Min	Point	Bulb	Press.	Precip.
1	275	297	3.0	282	9.4	57			62.7	66	60		-597	-578	-613		92			55	55	29.86	0.00
2	276	367	5.4	307	17.0	55			62.4	66	59		-579	-560	-600		97			54	55	29.85	0.00
3	277	345	7.1	331	16.0	54			62.5	65	61		-580	-562	-598		98			54	54	29.83	0.00
4	278	177	9.1	343	16.8	54			61.2	62	60		-576	-564	-588		100			53	54	29.88	0.00
5	279	319	4.3	340	11.8	52			61.4	64	60		-574	-558	-586		99			51	51	29.91	0.01
6	280	217	5.1	341	14.3	52			60.9	63	59		-577	-564	-592		100			52	52	29.89	0.00
7	281	142	6.2	338	15.5	56			60.9	62	60		-576	-563	-588		93			54	55	29.83	0.00
8	282	140	3.5	274	11.1	57			61.8	64	60		-569	-556	-586		91			54	55	29.84	0.00
9	283	336	4.9	179	16.4	57			62.7	65	61		-566	-550	-580		94			55	55	29.85	0.02
10	284	115	6.1	191	15.4	57			62.2	64	61		-564	-549	-578		99			57	57	29.87	0.00
11	285	409	8.7	358	20.8	56			61.3	63	59		-564	-544	-579		87			52	54	29.98	0.00
12	286	412	6.6	348	19.1	56			60.4	63	57		-561	-541	-576		88			53	54	29.98	0.00
13	287	404	7.0	343	16.9	57			60.3	63	57		-560	-541	-577		89			53	54	29.98	0.00
14	288	400	8.6	358	21.0	57			60.9	64	59		-558	-544	-572		86			53	54	29.98	0.00
15	289	399	3.3	327	10.7	61			61.0	65	57		-550	-526	-566		74			50	54	29.87	0.00
16	290	403	4.7	20	17.2	68			62.1	66	59		-542	-520	-565		47			43	53	29.84	0.00
17	291	399	3.3	294	10.4	62			61.9	66	58		-538	-516	-562		69			49	54	29.82	0.00
18	292	391	5.1	226	16.9	59			61.6	65	58		-533	-518	-550		79			52	54	29.88	0.00
19	293	345	5.9	248	20.5	53			61.3	64	60		-527	-515	-539		97			52	52	29.87	0.00
20	294	361	4.1	198	12.2	54			60.6	64	59		-520	-507	-538		95			52	53	29.78	0.00
21	295	373	5.9	343	18.3	54			59.2	62	57		-514	-500	-531		93			52	52	29.71	0.00
22	296	288	9.3	190	21.3	54			58.7	61	56		-504	-489	-521		95			52	53	29.75	0.00
23	297	330	5.0	188	15.0	55			60.1	63	58		-498	-485	-507		90			52	53	29.86	0.00
24	298	150	5.0	195	16.7	55			59.5	62	57		-489	-476	-503		91			52	53	29.86	0.00
25	299	307	6.1	349	18.6	54			60.0	62	58		-484	-472	-497		85			49	51	29.84	0.00
26	300	368	6.9	26	22.1	57			57.3	61	54		-474	-458	-494		38			25	43	30.00	0.00
27	301	365	4.1	232	11.5	55			57.5	62	54		-464	-448	-480		76			46	50	29.96	0.00
28	302	360	3.9	103	13.1	53			57.0	61	54		-457	-440	-472		77			45	49	29.96	0.00
29	303	348	4.3	352	12.2	50			56.5	59	54		-449	-434	-463		94			48	49	29.95	0.00
30	304	284	6.2	360	16.3	50			57.2	59	56		-441	-430	-450		95			49	49	29.95	0.00
31	305	321	5.0	6	12.2	50			56.6	59	54		-437	-425	-452		95			49	49	29.97	0.00

MONTHLY STATISTICS

		Total Solar Rad. ly.	Wind Ave. mph	V. Dir. Deg	Air Temperature Max. mph	Soil Temperature Mean Deg. Fahrenheit	Max	Soil Moisture Min Deg. Fahrenheit	Humidity Mean cBars	Max	Dew Min Percent	Wet	Mean Deg. Fahrenheit	Baro. Max	Min in. Hg.	Total	Mean inches	Max	Min	Point	Bulb	Press.	Precip.
Total	9874																						0.03
Ave.	319		5.6	328	15.7	55.5			60.3	63	57.9		-529.7	-514	-545.3		87			51	53	29.88	
Max.	412		9.3		22.1	68			63	66	61		-437	-425	-450		100			57	57	30	0.02
Min.	115		3		9.4	50			56	59	54		-597	-578	-613		38			25	43	29.71	0

Data are subject to further review and editing. Please refer any questions to the Western Regional Climate Center.
° 1 ly = 1 cal/cm² = 4.1855 J/cm² = 3.6855 BTU/ft² = .01163 KW-hr/m²

November, 2020

Day of Month	Day of Year	Total Solar Rad. ly.	Wind Ave. mph	V. Dir. Deg	Air Temperature Max. mph	Soil Temperature Mean Deg. Fahrenheit	Max	Soil Moisture Min Deg. Fahrenheit	Humidity Mean cBars	Max	Dew Min Percent	Wet	Mean Deg. Fahrenheit	Baro. Max	Min in. HG.	Total	Mean inches	Max	Min	Point	Bulb	Press.	Precip.
1	306				13.7					60	56			-423	-446								
2	307	302	5.7	348	18.9	51			57.3	59	55		-431	-421	-441		98			50	50	29.97	0.00
3	308	267	8.2	338	19.5	53			57.6	59	56		-429	-419	-441		94			51	51	29.98	0.00
4	309	256	5.7	337	17.0	55			59.2	61	58		-425	-414	-435		98			55	55	30.09	0.00
5	310	273	6.6	342	30.0	53			58.0	60	56		-427	-415	-436		98			53	53	29.96	0.00
6	311	278	15.2	327	40.3	53			57.4	59	56		-424	-413	-433		82			47	50	29.67	0.01
7	312	322	14.7	352	42.4	51			55.3	57	54		-418	-407	-430		79			44	47	29.61	0.00
8	313	296	21.2	346	43.4	49			54.5	56	52		-410	-398	-418		73			41	44	29.73	0.00
9	314	300	3.8	79	15.0	44			51.2	54	48		-404	-390	-418		68			34	39	30.05	0.00
10	315	266	3.8	219	14.9	47			51.5	55	48		-393	-380	-407		75			39	43	30.09	0.00
11	316	190	4.5	13	15.7	48			54.3	56	52		-387	-375	-396		95			46	47	29.97	0.00
12	317	309	5.4	341	16.6	47			51.3	54	48		-385	-375	-396		91			44	45	29.97	0.00
13	318	57	10.7	207	29.2	50			52.3	54	50		-383	-375	-393		98			49	50	29.99	0.24
14	319				15.4					53	49			-374	-396								
15	320	288	3.6	35	8.6	50			50.8	54	48		-384	-370	-397		84			45	47	30.14	0.00
16	321	294	6.1	111	21.5	60			52.8	56	50		-379	-365	-391		66			47	52	29.87	0.00
17	322	50	16.7	181	31.4	55			54.5	55	54		-163	-16	-391		93			53	53	29.76	0.65
18	323	213	7.9	201	20.1	54			56.2	58	54		-18	-17	-19		98			53	53	29.93	0.00
19	324	260	4.7	19	14.2	48			52.9	55	51		-20	-19	-22		96			47	47	30.16	0.01
20	325	287	4.6	14	12.0	47			50.4	53	48		-23	-22	-24		89			43	45	30.12	0.00
21	326	255	4.5	33	12.3	48			48.6	52	46		-24	-24	-25		75			40	44	30.06	0.00
22	327	169	7.3	1	24.5	48			49.2	52	47		-26	-25	-27		94			47	47	29.95	0.00
23	328	259	12.1	350	25.6	51			51.7	53	51		-27	-26	-28		91			49	50	29.92	0.00
24	329	269	7.1	307	25.0	49			50.7	53	48		-29	-28	-30		93			47	48	29.99	0.00
25	330	272	17.2	337	34.0	51			51.7	53	51		-30	-29	-32		86			47	49	30.10	0.00
26	331	276	7.8	24	21.9	47			49.2	51	47		-33	-32	-34		71			37	42	30.10	0.00
27	332				11.1					51	45			-34	-37								
28	333	266	4.3	38	17.0	46			47.0	50	44		-38	-36	-39		73			37	42	30.11	0.00
29	334	261	4.6	30	15.3	48			46.8	50	44		-40	-39	-42		78			40	44	30.08	0.00
30	335	255	8.4	353	19.3	49			49.4	51	48		-43	-41	-44		93			47	48	30.16	0.00

MONTHLY STATISTICS

		Total Solar Rad. ly.	Wind Ave. mph	V. Dir. Deg	Air Temperature Max. mph	Soil Temperature Mean Deg. Fahrenheit	Max	Soil Moisture Min Deg. Fahrenheit	Humidity Mean cBars	Max	Dew Min Percent	Wet	Mean Deg. Fahrenheit	Baro. Max	Min in. Hg.	Total	Mean inches	Max	Min	Point	Bulb	Press.	Precip.
Total	6791																						0.91
Ave.	252		8.2	357	21.5	50			52.6	54.8	50.4		-229.4	-223.4	-248.9		86			46	48	29.98	
Max.	322		21.2		43.4	60			59	61	58		-18	-16	-19		98			55	55	30.16	0.65
Min.	50		3.6		8.6	44			47	50	44		-431	-423	-446		66			34	39	29.61	0

Data are subject to further review and editing. Please refer any questions to the Western Regional Climate Center.
° 1 ly = 1 cal/cm² = 4.1855 J/cm² = 3.6855 BTU/ft² = .01163 KW-hr/m²

December, 2020

Day	Day	Total	Wind		Air Temperature	Soil Temperature		Soil Moisture	Humidity		Dew	Wet		Baro.		Total							
of	of	Solar Rad.	Ave.	V. Dir.	Max.	Mean	Max	Min	Mean	Max	Min		Mean	Max	Min		Mean	Max	Min	Point	Bulb	Press.	Precip.
Month	Year	ly.	mph	Deg	mph	Deg. Fahrenheit		Deg. Fahrenheit	cBars		Percent		Deg. Fahrenheit		in. HG.		inches						
1	336	235	4.4	346	15.9	46			50.8	53	49		-45	-44	-47		97			45	46	30.08	0.00
2	337	221	6.5	0	15.6	46			48.4	50	46		-48	-46	-49		96			45	45	30.01	0.00
3	338	206	4.4	7	12.5	49			49.9	52	48		-50	-49	-52		87			45	46	30.13	0.00
4	339	247	3.7	24	12.7	49			48.5	52	46		-52	-51	-54		76			41	45	30.12	0.00
5	340	157	4.0	163	14.1	49			48.3	51	46		-55	-54	-57		88			45	47	30.12	0.00
6	341	218	5.4	349	17.6	49			50.6	53	49		-57	-56	-59		96			48	48	30.17	0.00
7	342	257	9.0	31	35.3	57			50.0	53	47		-60	-58	-63		51			36	46	30.05	0.00
8	343	258	4.9	358	14.5	53			49.6	52	47		-65	-63	-68		68			40	46	30.03	0.00
9	344	223	4.1	22	18.7	47			49.8	52	48		-70	-68	-72		89			43	45	29.95	0.00
10	345	243	10.7	349	30.0	48			48.8	51	47		-72	-71	-74		91			46	47	29.94	0.00
11	346	100	10.4	324	27.0	49			50.0	51	49		-72	-24	-76		84			44	47	30.02	0.37
12	347	131	5.8	201	18.6	53			52.9	55	51		-19	-18	-22		93			51	51	30.00	0.07
13	348	56	10.7	233	24.5	51			52.8	54	51		-21	-17	-24		96			50	51	30.04	0.42
14	349	243	10.2	353	22.1	48			50.4	52	49		-23	-23	-24		90			45	47	30.16	0.00
15	350	204	3.0	28	9.8	48			49.5	52	48		-24	-24	-24		89			44	46	30.20	0.00
16	351	105	5.9	153	21.7	51			51.2	54	49		-24	-18	-24		90			48	49	30.05	0.44
17	352	241	15.1	341	34.4	50			51.7	53	49		-21	-19	-23		90			47	48	29.96	0.12
18	353	245	3.4	10	9.9	44			47.6	50	45		-23	-22	-23		88			40	42	30.17	0.00
19	354	246	4.2	36	18.0	46			46.6	50	44		-23	-22	-23		87			41	43	30.26	0.00
20	355	258	4.6	20	14.8	47			47.0	50	44		-23	-23	-24		93			45	45	30.16	0.00
21	356	217	5.9	5	23.4	47			46.9	49	44		-24	-23	-24		93			45	46	29.97	0.00
22	357	250	8.7	10	32.1	47			48.0	50	46		-24	-24	-25		88			43	45	30.06	0.00
23	358	251	4.6	73	19.4	47			45.3	48	43		-25	-25	-26		62			33	40	30.09	0.00
24	359	214	10.4	136	29.7	55			47.7	50	46		-26	-25	-26		51			36	45	30.07	0.00
25	360	53	16.9	181	34.3	53			50.1	52	49		-23	-17	-27		85			48	50	29.94	0.50
26	361	234	6.7	305	18.6	50			50.7	53	48		-22	-21	-22		95			48	49	30.07	0.00
27	362	217	4.8	118	18.8	47			48.1	51	46		-22	-22	-22		89			43	45	29.79	0.00
28	363	222	5.8	12	17.0	48			48.8	51	47		-22	-22	-23		82			42	45	29.74	0.00
29	364	256	3.2	27	11.2	45			46.6	50	44		-23	-23	-24		91			42	44	30.11	0.00
30	365	168	6.0	255	23.2	48			47.4	50	45		-24	-23	-24		95			46	47	30.18	0.03
31	366	246	10.2	356	25.1	49			49.3	51	47		-24	-23	-24		91			47	48	30.07	0.00

MONTHLY STATISTICS

		Total	Wind		Air Temperature	Soil Temperature		Soil Moisture	Humidity		Dew	Wet		Baro.		Total							
		Solar Rad.	Ave.	V. Dir.	Max.	Mean	Max	Min	Mean	Max	Min		Mean	Max	Min		Mean	Max	Min	Point	Bulb	Press.	Precip.
		ly.	mph	Deg	mph	Deg. Fahrenheit		Deg. Fahrenheit	cBars		Percent		Deg. Fahrenheit		in. Hg.		inches						
Total	6423																						1.95
Ave.	207		6.9	13	20.7	48.9			49.1	51.4	46.9		-35.6	-32.8	-37		86			44	46	30.05	
Max.	258		16.9		35.3	57			53	55	51		-19	-17	-22		97			51	51	30.26	0.5
Min.	53		3		9.8	44			45	48	43		-72	-71	-76		51			33	40	29.74	0

Data are subject to further review and editing. Please refer any questions to the Western Regional Climate Center.
° 1 ly = 1 cal/cm² = 4.1855 J/cm² = 3.6855 BTU/ft² = .01163 KW-hr/m²

January, 2021

Day	Day	Total	Wind		Air Temperature	Soil Temperature		Soil Moisture	Humidity		Dew	Wet		Baro.		Total							
of	of	Solar Rad.	Ave.	V. Dir.	Max.	Mean	Max	Min	Mean	Max	Min		Mean	Max	Min		Mean	Max	Min	Point	Bulb	Press.	Precip.
Month	Year	ly.	mph	Deg	mph	Deg. Fahrenheit		Deg. Fahrenheit	cBars		Percent		Deg. Fahrenheit		in. HG.		inches						
1	1	195	6.9	169	22.2	47			48.1	51	45		-24	-23	-24		95			46	46	30.04	0.01
2	2	61	5.5	158	18.7	50			51.0	53	50		-21	-20	-24		99			50	50	30.11	0.08
3	3	121	5.8	167	12.4	49			51.8	54	50		-20	-20	-21		100			49	49	30.10	0.01
4	4	142	13.2	194	34.8	51			52.0	54	49		-20	-16	-22		94			49	50	30.00	0.39
5	5	245	3.6	47	17.3	46			48.6	51	46		-21	-21	-22		94			44	45	30.14	0.00
6	6	101	5.0	145	20.4	47			48.1	50	45		-21	-20	-22		96			46	46	30.10	0.16
7	7	225	4.5	101	14.7	51			50.3	53	48		-21	-20	-21		87			46	48	30.08	0.00
8	8	118	4.2	19	20.6	48			50.8	53	49		-21	-20	-21		98			48	48	30.15	0.15
9	9	253	4.6	27	15.1	48			48.1	51	46		-21	-21	-22		86			43	45	30.14	0.00
10	10	153	4.0	92	13.4	48			48.9	53	46		-22	-21	-22		91			45	46	30.15	0.00
11	11	237	5.6	17	21.1	47			48.4	51	46		-23	-22	-23		96			45	46	30.13	0.00
12	12	125	5.7	164	14.2	51			50.3	53	48		-23	-23	-24		87			47	49	30.17	0.00
13	13	115	5.6	225	19.0	54			53.6	57	51		-24	-24	-25		95			53	53	30.24	0.00
14	14	243	6.5	35	17.6	51			53.2	56	51		-24	-24	-25		97			50	50	30.20	0.00
15	15	253	5.5	354	22.2	50			50.9	54	48		-24	-23	-24		94			48	49	30.17	0.00
16	16	95	7.1	350	15.9	49			51.4	53	50		-24	-23	-24		100			49	49	30.06	0.00
17	17	279	4.1	306	14.8	51			50.9	55	48		-23	-23	-24		92			49	50	29.96	0.00
18	18	294	9.9	18	39.3	56			50.7	53	48		-24	-24	-25		61			38	47	29.84	0.00
19	19	293	12.8	47	34.4	58			50.0	52	48		-26	-25	-27		21			18	41	29.89	0.00
20	20	289	3.8	34	10.7	51			48.9	52	46		-28	-27	-29		49			30	41	29.97	0.00
21	21	206	5.2	166	17.4	44			48.5	51	46		-29	-29	-30		96			43	43	29.93	0.00
22	22	207	11.1	328	38.1	49			49.8	52	49		-30	-30	-31		89			46	47	29.77	0.12
23	23	290	7.4	3	19.6	47			48.1	51	45		-30	-29	-30		89			43	45	29.84	0.00
24	24	97	17.7	330	44.8	48			48.3	50	47		-30	-29	-30		85			43	45	29.78	0.11
25	25	304	25.9	339	40.9	46			46.4	48	45		-27	-27	-28		72			37	41	29.74	0.00
26	26	132	19.5	177	60.4	45			45.5	47	43		-25	-17	-27		84			40	42	29.71	1.41
27	27	151	12.5	180	36.4	49			48.1	50	46		-23	-21	-25		94			47	48	29.59	0.40
28	28	249	6.5	199	16.4	49			49.8	53	48		-23	-22	-23		94			47	47	29.61	0.06
29	29	264	3.6	149	11.0	45			47.7	51	45		-23	-22	-23		92			42	43	29.81	0.00
30	30	215	9.5	158	19.0	50			49.2	53	47		-23	-23	-24		84			45	47	30.03	0.00
31	31	260	13.2	164	25.6	53			50.8	54	49		-25	-24	-26		72			44	48	30.00	0.00

MONTHLY STATISTICS

		Total	Wind		Air Temperature	Soil Temperature		Soil Moisture	Humidity		Dew	Wet		Baro.		Total							
		Solar Rad.	Ave.	V. Dir.	Max.	Mean	Max	Min	Mean	Max	Min		Mean	Max	Min		Mean	Max	Min	Point	Bulb	Press.	Precip.
		ly.	mph	Deg	mph	Deg. Fahrenheit		Deg. Fahrenheit	cBars		Percent		Deg. Fahrenheit		in. Hg.		inches						
Total	6211																						2.9
Ave.	200		8.3	90	23.5	49.2			49.6	52.3	47.3		-23.9	-22.9	-24.7		87			44	47	29.98	
Max.	304		25.9		60.4	58			54	57	51		-20	-16	-21		100			53	53	30.24	1.41
Min.	61		3.6		10.7	44			46	47	43		-30	-30	-31		21			18	41	29.59	0

Data are subject to further review and editing. Please refer any questions to the Western Regional Climate Center.
° 1 ly = 1 cal/cm² = 4.1855 J/cm² = 3.6855 BTU/ft² = .01163 KW-hr/m²

APPENDIX E

Bibliography

Ahammed, M Masoor (2003). *Effect of Holding Time and Temperature on Bacterial Counts.* Indian Journal of Environmental Health, 45(3):209-12. August 2003. https://www.researchgate.net/publication/8396598_Effect_of_holding_time_and_temperature_on_bacterial_counts

Anima RJ (1991). *Pollution Studies of Drakes Estero and Abbotts Lagoon, Point Reyes National Seashore, Open File Report 91-145.* Prepared by US Geological Survey, Menlo Park CA. 1991. https://pubs.usgs.gov/of/1991/0145/report.pdf

Aulenbach, Brent T (2009). *Bacteria Holding Times for Fecal Coliform by mFC agar Method and Total Coliform and Escherichia coli by Colilert-18 and Quanti-Tray Method.* Environmental Monitoring and Assessment, 161, 147–159 (2010). https://doi.org/10.1007/s10661-008-0734-3

Boehm, AB and LM Sassoubre (2014). *Enterococci as Indicators of Environmental Fecal Contamination.* In: Gilmore MS, Clewell DB, Ike Y, et al., editors. Enterococci: From Commensals to Leading Causes of Drug Resistant Infection [Internet]. Boston: Massachusetts Eye and Ear Infirmary; 2014-. 5 February 2014. https://www.ncbi.nlm.nih.gov/books/NBK190421/

California Coastal Commission (2020). *Final Strategic Plan, 2121-2025, Protecting California's Coast for Present and Future Conditions.* Prepared by California Coastal Commission, San Francisco CA. 23 October 2020. https://documents.coastal.ca.gov/assets/strategicplan/CCC_Strategic_Plan_Adopted_11.06.20.pdf

Dipankar, D, Mohanty, BP and BJ Lesikar (2013). *Estimating Escherichia coli loads in Streams Based on Various Physical, Chemical, and Biological Factors.* Water Resources Research, Vol. 49, 2896-2906, doi:10.1002/wrcr.20265. 2013. https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1002/wrcr.20265

Federal Highway Administration (2018). *Supplemental Environmental Assessment and Subsequent Initial Study/Proposed Mitigated Negative Declaration, State Clearing No. 2015072028.* Prepared by US Department of Transportation, Federal Highway Administration, Central Federal Lands Highway Division, Lakewood CO in cooperation with Marin County, San Rafael CA. June 2018. https://www.marincounty.org/-/media/files/departments/cd/planning/environmental-impact/sir-francis-drake-blvd-improvement-project/sfdb_seasis.pdf?la=en

Jin, G, Jeng, HW, Bradford, H and AJ Englande (2004). *Comparison of E. coli, Enterococci, and Fecal Coliform as Indicators for Brackish Water Quality Assessment.* Water Environ Research, May-Jun 2004;76(3):245-55. doi: 10.2175/106143004x141807. https://pubmed.ncbi.nlm.nih.gov/15338696/

Ketcham, Brannon J (2001). *Point Reyes National Seashore, Water Quality Monitoring Report: May 1999 - May 2001.* Point Reyes National Seashore. November 2001. http://www.krisweb.com/biblio/southmarin_nps_pore_2001_wqreport.pdf

Korajkic, A, Wanjugi, P, Brooks, L, Cao, Y and VJ Harwood. *Persistence and Decay of Fecal Microbiota in Aquatic Habitats.* Microbial and Molecular Biology Reviews 83:e00005-19. 2 October 2019. ttps://mmbr.asm.org/content/mmbr/83/4/e00005-19.full.pdf

Kratzer, CR, Saleh, DK, and Celia Zamora (2006). *Assessment of Hydrologic and Water Quality Data Collected in Abbotts Lagoon Watershed, Point Reyes National Seashore, California during Water Years 1999 and 2000. Scientific Investigations Report 2005-5261, Prepared in cooperation with the National Park Service.* Prepared by United States Geological Survey, Sacramento CA. 2006. https://pubs.usgs.gov/sir/2005/5261/sir_2005-5261.pdf

NOAA (2006). *Endangered and Threatened Species; Designation of Critical Habitat for Seven Evolutionarily Significant Units of Pacific Salmon and Steelhead in California, Effective Date 01/02/2006.* 70 FR 52487. 2 September 2005. https://www.govinfo.gov/content/pkg/FR-2005-09-02/pdf/05-16389.pdf

National Park Service (2009). *Restoring Salmon and Trout Habitat at East Schooner Creek, Point Reyes National Seashore.* Prepared by National Park Service, Pacific Coast Science and Learning Center, Point Reyes Station CA. May 2009.

National Park Service (2019). *A Natural Resource Condition Assessment for Point Reyes National Seashore, Natural Resource Report NPS/PORE/NRR-2019/1895.* National Park Service, Fort Collins CA. March 2019. http://npshistory.com/publications/pore/nrr-2019-1895.pdf

National Park Service (2020). *General Management Plan Amendment, Final Environmental Impact Statement, Point Reyes National Seashore, North District of Golden Gate National Recreation Area* Prepared by National Park Service. US Department of Interior, National Park Service, Point Reyes National Seashore, Point Reyes Station CA. September 2020. https://parkplanning.nps.gov/documentsList.cfm?projectID=74313

North Coast RWQCB (2015). *Coastal Watershed Pathogen Indicatory Study, Quality Assurance Project Plan, Version 1.0*. Prepared by North Coast Region, Regional Water Quality Control Board, Santa Rosa CA. 1 November 2015. https://www.waterboards.ca.gov/northcoast/water_issues/programs/tmdls/coastal_pathogen/pdf/181219/Coastal_Pathogen_Study_QAPP_1Nov2015.pdf

North Coast RWQCB (2018). *Water Quality Control Plan for the North Coast Region.* North Coast Regional Water Quality Control Board, Santa Rosa CA. June 2018. https://www.waterboards.ca.gov/northcoast/water_issues/programs/basin_plan/190204/Final%20Basin%20Plan_20180620_lmb.pdf

Oregon DEQ (2011). *Harmful Algal Bloom (HAB) Strategy - Appendix D.* Oregon Department of Environmental Quality, Portland OR. June 2011. https://www.oregon.gov/deq/FilterDocs/habsAppendixD.pdf

Pawley, A and M Lay (2013). *Coastal Watershed Assessment for Golden Gate National Recreation Area and Point Reyes National Seashore, Natural Resource Report NPS/PWR/NRR-2013/641.* Prepared by Anita Pawley and Mui Lay. US Department of Interior, National Park Service, Natural Resource Stewardship and Science, Fort Collins CO. March 2013. http://npshistory.com/publications/goga/nrr-2013-641.pdf

Pope, ML, Bussen, M, Feige, MA, Shadix, L, Gonder, S, Rodgers, C, Chamters, Y, Pulz, J, Miller, K, Connell, K, and J Standridge (2003). *Assessment of the Effects of Holding Time and Temperature on Escherichia coli Densities in Surface Water Samples.* Applied and Environmental Microbiology, DOI: 10.1128/AEM.69.10.6201-6207.2003. October 2003. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC201187/pdf/0326.pdf

RWQCB (2019). *San Francisco Bay Basin (Region 2), Water Quality Control Plan (Basin Plan).* Prepared by California Regional Water Quality Control Board, San Francisco Bay Region, Oakland CA. 5 November 2019. https://www.waterboards.ca.gov/sanfranciscobay/water_issues/programs/planningtmdls/basinplan/web/docs/ADA_compliant/BP_all_chapters.pdf

Selvakumar, A, Borst, M, Boner, M, and P Mallon)2004). *Effects of Sample Holding Time on Concentrations of Microorganisms in Water Samples.* Water Environ Research Jan-Feb 2004;76(1):67-72, DOI: 10.2175/106143004x141591. Jan-Feb 2004. https://pubmed.ncbi.nlm.nih.gov/15058466/

SWRCB (1968). *Statement of Policy with Respect to Maintaining High Quality Waters of California, Resolution No. 68-16.* State Water Resources Control Board, Sacramento CA. 1968. https://www.waterboards.ca.gov/board_decisions/adopted_orders/resolutions/1968/rs68_016.pdf

SWRCB (2019). *Part 3 of the Water Quality Control Plan for Inland Surface Waters, Enclosed Bays, and Estuaries of California - Bacteria Provisions and a Water Quality Standards Variance Policy.* Prepared by State Water Resources Control Board, Sacramento CA. 4 February 2019. https://www.waterboards.ca.gov/bacterialobjectives/docs/bacteria.pdf

US Environmental Protection Agency (2006). *Assessment of the Effects of Holding Time on Fecal Coliform and Salmonella Concentrations in Biosolids.* US Environmental Protection Agency, Washington DC. August 2006. https://www.epa.gov/sites/production/files/2018-11/documents/assessment-fecal-coliform-salmonella-biosolids.pdf

US Environmental Protection Agency (2012). *Recreational Water Quality Criteria. Office of Water Publication 820-F-12-058.* US Environmental Protection Agency, Washington DC. 2012. https://www.epa.gov/sites/production/files/2015-10/documents/rwqc2012.pdf

Voeller D, Ketcham B, and Becker B (2020a). *Improved Water Quality in Coastal Watersheds at Point Reyes National Seashore Associated with Rangeland Best Management Practices, 2000-2013.* This document is contained within "Appendix L, Coastal Watershed Water Quality Analysis" of the Final Environmental Impact Statement for the General Plan Amendment covering Point Reyes National Seashore and North District Golden Gate National Recreation Area. 14 July 2020. The link to the Appendices for the Final Environmental Impact Statement: https://parkplanning.nps.gov/showFile.cfm?projectID=74313&MIMEType=application%252Fpdf&filename=Point%20Reyes%5FNorth%20District%20Golden%20Gate%20NRA%20GMP%20and%20EIS%20Appendices%5F508%20v21%2Epdf&sfid=440979

Voeller D, Ketcham B, and Becker B (2020b). *Supplement for Improved Water Quality in Coastal Watersheds at Point Reyes National Seashore Associated with Rangeland Best Management Practices, 2000-2013.* This document is contained within "Appendix L, Coastal Watershed Water Quality Analysis" of the Final Environmental Impact Statement for the General Plan Amendment covering Point Reyes National Seashore and North District Golden Gate National Recreation Area. 13 July 2020. The link to the Appendices for the Final Environmental Impact Statement: https://parkplanning.nps.gov/showFile.cfm?projectID=74313&MIMEType=application%252Fpdf&filename=Point%20Reyes%5FNorth%20District%20Golden%20Gate%20NRA%20GMP%20and%20EIS%20Appendices%5F508%20v21%2Epdf&sfid=440979

Woelfle-Erskine C, Larsen LG, SM Carlson (2017). *Abiotic Habitat Thresholds for Salmonid Over-Summer Survival in Intermittent Streams.* Ecosphere 8(2):e01645.10.1002/ecs21645. February 2017. https://esajournals.onlinelibrary.wiley.com/doi/pdf/10.1002/ecs2.1645

Wade, TJ, Calderon, RL, Sams, E, Beach, M, Brenner, KP, Williams, AH, and AP Dufour (2006). *Rapidly Measured Indicators of Recreational Water Quality Are Predictive of Swimming-Associated Gastrointestinal Illness.* Environmental Health Perspectives, Vol 114, No 1. January 2006. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1332651/pdf/ehp0114-000024.pdf

Laura Cunningham
California Director
Western Watersheds Project
PO Box 70
Beatty, NV 89003
tel: (775) 513-1280
fax: (208) 475-4702
email: lcunningham@westernwatersheds.org

Superintendent
Point Reyes National Seashore
1 Bear Valley Road
Point Reyes Station, California 94956

Via email craig_kenkel@nps.gov. US Mail thumb drive.
Cc: PointReyesManagementPlan@coastal.ca.gov

January 27, 2021

RE: Point Reyes National Seashore General Management Plan Amendment Supplemental Comments.

Dear Superintendent,

Please place this letter in the administrative record for the Environmental Impact Statement for a General Management Plan Amendment for Point Reyes National Seashore and the north district of Golden Gate National Recreation Area.

1. **A Supplemental Environmental Impact Statement Must Be Written Because the Proposed Point Reyes National Seashore General Management Plan Amendment Is Not Consistent With the Coastal Zone Management Act and California Coastal Act.**

The California Coastal Commission (CCC) filed its Staff Report (CCC Staff Report 2020) on December 18, 2020, in anticipation of a Commission hearing on January 14, 2012.[1] Staff reviewed Point Reyes National Seashore's proposed General Management Plan Amendment (GMPA) currently in review under the National Environmental Policy Act, and analyzed how the Plan would be implemented consistent with the federal Coastal Zone Management Act (CZMA) and California Coastal Act. In its report, Staff recommended a conditional concurrence to the Commissioners, meaning certain sections of the GMPA were inconsistent with the coastal laws unless mitigated to less than significant and brought into future consistency with the law satisfactory to Commission opinion.

Specifically, CCC Staff determined that the GMPA was not consistent with water quality from ranching activities on the Seashore, as well as not consistent with "spillover" effects from impaired water quality that may impair marine resources (such as anadromous salmonids,

[1] https://documents.coastal.ca.gov/reports/2021/1/Th6b/Th6b-1-2021-report.pdf

eelgrass habitats, coastal fish populations, orcas, whales, seals, sea lions, and other imperiled species):

> The most significant spillover effects from proposed ranching activities relate to water quality and the protection of marine resources. Staff does not believe that the GMPA as proposed is consistent with Coastal Act policies related to marine resources (Section 30230) and water quality (Section 30231), particularly for the PRNS portion of the GMPA planning area. (CCC Staff Report 2020 at 5)

Staff explains that unlike the Tomales Bay watershed in park lands, the Pacific Coast drainages lack recent rigorous water quality sampling, and water bodies are impaired. The GMPA analysis lacks any public discussion of detailed plans, mitigation measures, or Best Management Practices:

> In contrast, areas of the GMPA outside the Tomales Bay watershed (i.e., lands within PRNS) have not received the same attention. Available water quality data is much more limited and has not been collected since 2013. The data that are available indicate that water quality standards were not typically being met in creeks in PRNS that drain into Drake's Estero and the Pacific Ocean. Importantly, NPS is proposing to implement the same suite of best management practices and water quality protection measures in PRNS that were successful in addressing significant water quality problems in areas upstream of Tomales Bay. However, the GMPA does not describe where and on what timeline these measures will be implemented, or how their efficacy will be evaluated. (*Id.* at 6)

Staff suggests conditions that National Park Service (NPS) could undertake in order to fulfill meeting full consistency with coastal laws, but this would exclude the public. These significant new circumstances require a Supplemental Environmental Impact Statement be analyzed in order to include public comment and address unanalyzed impacts to marine resources and water quality of Pacific Coast drainages.

Understanding the significance of this lack of review of important information, on January 7, 2021, both the CCC and NPS announced a sudden delay in in the Commission consistency determination hearing, and the January 14 hearing was canceled. See the CCC email screenshot below to Laura Cunningham. Point Reyes National Seashore copied CCC text and sent an email alert to subscribers (screenshot image below), dated January 7, 2021, to Laura Cunningham. As of this date, no new CCC hearing date has been scheduled. This only reinforces that significant effects have not been analyzed, and the public should be allowed to comment on Pacific Coast water quality impacts in a popular National Seashore. Many significant spillover impacts to marine resources as effected by ranching on these public lands have not been analyzed, as detailed below in this letter.

The text from the CCC email alert reads:

> Please be advised that the California Coastal Commission's public hearing regarding CD-0006-20, the National Park Service's General Management Plan Amendment for Point Reyes National Seashore and north district of the Golden Gate National Recreation Area,

has been postponed and will not occur on January 14. A new hearing date for this item will be announced once it is scheduled.

Coastal Point Reyes Management Plan Thu, Jan 7, 2:26 PM (8 days ago)
to

Hello –

Please be advised that the California Coastal Commission's public hearing regarding CD-0006-20, the National Par Service's General Management Plan Amendment for Point Reyes National Seashore and north district of the Golden Gate National Recreation Area, has been postponed and will not occur on January 14. A new hearing date for this item will be announced once it is scheduled.

We kindly request that you continue to direct any correspondence to the PointReyesManagementPlan@coastal.ca.gov email inbox.

Thank you.

California Coastal Commission
Office of Energy, Ocean Resources and Federal Consistency
455 Market Street, Suite 300
San Francisco, California 94105
www.coastal.ca.gov

Center for Biological Diversity * Coalition to Protect America's National Parks * Sierra Club * Environmental Action Committee of West Marin (EAC) * Marin Audubon Society * Resource Renewal Institute * National Parks Conservation Association * Save Our Seashore *

Action for Animals * Alameda Creek Alliance * All-Creatures.org * Animal Legal Defense Fund * Animals Are Sentient Beings, Inc. * Biodiversity First! * Californians for Western Wilderness * Center for Farmworker Families * Climate Action Now! * Coalition on the Environment and Jewish Life * Committee for the Preservation of the Tule Elk * Conservation Congress * Conservation Council for Hawaii * Conserve Southwest Utah * Dorothy King Young Chapter of the California Native Plant Society * Earth Island Institute * EarthAction * Eastern Coyote/Coywolf Research * Ecologistics, Inc. * Ecology Party of Florida * Endangered Habitats League * Endangered Species Coalition * Environmental Protection Information Center * Eyak Preservation Council * ForELK * Friends of the Black-tail Prairie Dog * Friends of the Earth U.S. * Fund for Wild Nature * Gallinas Watershed Council * Global Movement Network * Golden Gate Audubon Society * Golden West Women Flyfishers * Granite Chief Wilderness Protection League * Harvard Law School Animal Law and Policy Clinic * Hilton Pond Center for Piedmont Natural History * Howling For Wolves * In Defense of Animals * Interfaith Council for the Protection of Animals and Nature * International Marine Mammal Project of Earth Island Institute * Kickapoo Peace Circle * Klamath Forest Alliance * Madrone Audubon Society * Marin Chapter, California Native Plant Society * MLK Coalition of Greater Los Angeles * Movement Rights * National Wolfwatcher Coalition * Northcoast Environmental Center * Northeast Oregon Ecosystems * Northwest Animal Rights Network * Northwest Arkansas Audubon Society * NY4WHALES * Ocean Voyages Institute * Oceanic Preservation Society * Old Growth Forest Network * OVEC-Ohio Valley Environmental Coalition * Patagonia * Paula Lane Action Network (PLAN) * Pelican Media * Petaluma Wetlands Alliance * Planning and Conservation League * Point Reyes Safaris * Predator Defense * Project Coyote Public Interest Coalition * Public Lands Conservancy * Public Trust Alliance * Rainforest Action Network* Regional Parks Association * RESTORE: The North Woods * Sandra Lee Photography * Santa Cruz Climate Action Network * Save Our Sky Blue Waters * SAVE THE FROGS! * Shark Stewards * Social Compassion in Legislation * Spottswoode Winery, Inc. * Supporters for Del Norte Roosevelt Elk * Tending the Ancient Shoreline Hill * The Fire Restoration Group * The Rewilding Institute * The Wildlife Trust * Topanga Peace Alliance * Turtle Island Restoration Network * Watershed Alliance of Marin * Wellkind * Western Watersheds Project * Wholly H2O * Wild Zone Conservation League * WildCare * Wilderness Watch * WildernessPress Photography * Yellowbilled Tours

January 7, 2021

RE: Coastal Consistency Determination by the California Coastal Commission for the Proposed Point Reyes National Seashore General Management Plan Amendment CD-0006-20

Dear California Coastal Commissioners,

The National Park Service (NPS) is asking the Coastal Commission to fast-track concurrence with a Consistency Determination for the Proposed Point Reyes National Seashore General Management Plan

Amendment (GMPA), despite inadequate information regarding coastal zone impacts and the fact that the proposed plan and expanded agricultural activities are not consistent to the maximum extent practicable with the California Coast Management Program (CCMP).

The undersigned **100** conservation groups, environmental justice organizations, and local businesses hold diverse positions on the future role of agriculture in the Seashore, ranging from supporting to opposing the continuation of agriculture leases in the Seashore. **Yet we are united in our request that the Coastal Commission Object to the Point Reyes plan at its January 14, 2021 Commission meeting. It is substantively and politically prudent for the Commission to allow time for the Commission staff and the Biden administration's NPS to *work together* – free of the current political pressure – to finalize this plan.**

As we outline below, this process and plan have been co-opted by the Trump administration in its waning days. There is no reason why the Coastal Commission should fast-track approval of a plan and forgo the careful consideration that Californians and Point Reyes National Seashore deserve.

- Your staff requested that the NPS extend the review deadline through the March 2021 Commission meeting, calling the extension "warranted and necessary." In response to this request, the NPS set a deadline of January 20, 2021, signaling that the Trump administration is intent on fast-tracking the controversial and complex plan before the new administration assumes office, even if it comes at the expense of not allowing California (through its Coastal Commission) to protect its coastal resources.

- In a multi-party Settlement Agreement in 2017, the NPS, environmental groups, Seashore ranchers, and Marin County agreed that the NPS could have until July 2021 to complete the GMPA. Your staff's request to have until March 2021 in order to fully review the plan falls squarely within this agreed upon timeframe, yet the Trump administration now wishes to prevent the Commission from conducting a careful review process.

- Your staff has reported a high level of public interest in the GMPA (e.g. Commission staff recently stating it has received more than 20,000 public comments during its review of the GMPA opposing the NPS plan for ranching at Point Reyes National Seashore and Golden Gate National Recreation Area and its spillover impacts to wildlife and other public resources in the coastal zone).

- Your staff has determined that there are significant spillover effects from proposed ranching activities in the plan related to water quality and the protection of marine resources. Your staff believes that the current GMPA is inconsistent with Coastal Act policies related to marine resources (Section 30230) and water quality (Section 30231), particularly for the Point Reyes portion of the GMPA planning area. Your staff also raised concerns that there are limited, insufficient water quality data available for Point Reyes National Seashore, where water quality standards have historically not been met in creeks and wetlands that drain into Drakes Estero, Abbotts Lagoon, and the Pacific Ocean. The efficacy of proposed best management practices and water quality protection measures for coastal resources in the GMPA are, at best, uncertain.

Any water quality assessment plan including a timeline for compliance targets and enforcement measures for Point Reyes should be finalized before any decision on concurrence.

· Your staff's concern that more time was needed to adequately review this GMPA is confirmed in the NPS Consistency Determination and the Commission staff report – both which are missing credible analyses of additional impacts to the environment and public access that will result from the GMPA, many of them with spillover effects on the coastal zone, including impacts to water quality, water quantity, and migratory birds. For example, the Staff Report states the NPS informed Commission staff that "we expect adjustments to the timing of harvest mowing to be limited." This refers to harvest of silage, which overlaps with bird nesting season, and the NPS is stating that it won't end the unnecessary killing of birds due to this practice. Related, the NPS highlights its lack of commitment to ensure protection of coastal resources, stating (emphasis ours) that "Approaches to minimize harvest impacts on wildlife should be considered when using this Practice Standard (e.g., harvest timing, cutting procedures, and cover patterns)." (GMPA Appendix F pg 25), yet "considerations" does not equal protection.

This is just one of the many examples of the fine details within the GMPA that require additional time for careful analysis and point to why the Commission should object and let the Staff have more time to address by working with a NPS that isn't being politically pressured.

· GMPA also lacks specificity on proposed mitigation measures; the NPS refers to this missing information as "programmatic details" which will be described at some future date and "may be subject to future review by the Commission, after site-specific actions are developed."

The National Seashore is a keystone for California's interconnected coastal resources. This Federal administration's refusal to accept the Commission's proposed timeline is an attempt to usurp the state's ability to request additional information. It denies the Commission the time necessary to adequately analyze and evaluate how the maintenance of ranching operations and further agricultural development in these national parks will affect coastal resources for decades to come.

The Commission needs more time and information to confidently decide whether the NPS' plan is adequate and consistent with protecting the California coast. Please object to the Point Reyes plan at the January 14 Commission meeting.

Sincerely,

Center for Biological Diversity
Randi Spivak, Public Lands Program Director
Washington, DC

Resource Renewal Institute
Chance Cutrano, Director of Programs
Mill Valley, CA

Environmental Action Committee of West Marin (EAC)
Morgan Patton, Executive Director
Point Reyes Station, CA

Marin Audubon Society
Barbara Salzman, President
Mill Valley, CA

National Parks Conservation Association
Neal Desai, Senior Director, Pacific Region
Sacramento, CA

Save Our Seashore
Gordon Bennett, President
Inverness, CA

Action for Animals
Eric Mills, Coordinator
Seattle, WA

Alameda Creek Alliance
Jeff Miller, Director
Fremont, CA

All-Creatures.org
Veda Stram
Athens, NY

Animal Legal Defense Fund
Cristina Stella, Managing Attorney
Cotati, CA

Animals Are Sentient Beings, Inc.
Sarah B. Stewart, President
Watertown, MA

Biodiversity First!
Linda Seeley, Secretary
Shandon, CA

Californians for Western Wilderness
Michael Painter, Coordinator
San Francisco, CA

California Native Plant Society, Marin Chapter
Carolyn K Longstreth, Board Member
Mill Valley, CA

Center for Farmworker Families
Dr. Ann López, Executive Director
Felton, CA

Climate Action Now!
Markos Major, Director
San Francisco, CA

Coalition on the Environment and Jewish Life
Rabbi Daniel Swartz, Executive Director
Scranton, PA

Coalition to Protect America's National Parks
Philip A. Francis, Jr., Chair
Washington, DC

Committee for the Preservation of the Tule Elk
Bruce E. Keegan
San Francisco, CA

Conservation Congress
Denise Boggs, Director
Rohnert Park, CA

Conservation Council for Hawaii
Moana Bjur, Executive Director
Honolulu, HI

Conserve Southwest Utah
Tom Butine, Board President
St. George, UT

Dorothy King Young Chapter of the California Native Plant Society
Renee Pasquinelli, Conservation Co-chair
Gualala, CA

EarthAction
Lois Barber, Executive Director
Amherst, MA

Earth Island Institute
David Phillips, Executive Director
Berkeley, CA

Eastern Coyote/Coywolf Research
Jonathan Way, Founder
Barnstable, MA

Ecologistics, Inc.
Stacey Hunt, CEO
San Luis Obispo, CA

Ecology Party of Florida
Cara L. Campbell, Chair
Ft. Lauderdale, FL

Endangered Habitats League
Dan Silver, Executive Director
Los Angeles, CA

Endangered Species Coalition
Tara Thornton, Deputy Director
Washington, DC

Environmental Protection Information Center
Thomas Wheeler, Executive Director
Arcata, CA

Eyak Preservation Council
Carol Hoover, Executive Director
Cordova, AK

The Fire Restoration Group
Craig Thomas, Director
Garden Valley, CA

ForELK
Diana Oppenhiem, Founder
San Francisco, CA

Friends of the Black-tail Prairie Dog
David Orr, Founder and President
Austin, TX

Friends of the Earth U.S.
Ariel Moger, Legislative and Political Coordinator
Washington, DC

Fund for Wild Nature
Marnie Gaede, President
Sebastopol, CA

Gallinas Watershed Council
Judy Schriebman, Secretary
San Rafael, CA

Global Movement Network
Diana Oppenheim, Founder
San Francisco, CA

Golden Gate Audubon Society
Laura Cremin, Vice President
Berkeley, CA

Golden West Women Flyfishers
Cindy Charles, Conservation Chair
San Francisco, CA

Granite Chief Wilderness Protection League
Daniel Heagerty, Director
Mill Valley, CA

Harvard Law School Animal Law and Policy Clinic
Katherine A. Meyer, Director
Cambridge, MA

Hilton Pond Center for Piedmont Natural History
Dr. Bill Hilton Jr., Executive Director
York, SC

Howling For Wolves
Maureen Hackett, Founder and President
Hopkins, MN

In Defense of Animals
Lisa Levinson, Wild Animals Campaign Director
San Rafael, CA

Interfaith Council for the Protection of Animals and Nature
Lewis Regenstein, President
Atlanta GA

International Marine Mammal Project
Mark J. Palmer, Associate Director
Berkeley, CA

Kickapoo Peace Circle
Marcia Halligan
Viroqua, WI

Klamath Forest Alliance
Kimberly Baker, Executive Director
Arcata, CA

Madrone Audubon Society
Susan Kirks, President
Sonoma, CA

MLK Coalition of Greater Los Angeles
Julie Levine
Los Angeles, CA

Movement Rights
Pennie Opal Plant, Co-founder
San Francisco, CA

National Wolfwatcher Coalition
Nancy Warren Executive Director
Duluth, MN

Northcoast Environmental Center
Larry Glass, Executive Director
Arcata, CA

Northeast Oregon Ecosystems
Wally Sykes
Joseph, OR

Northwest Animal Rights Network
Rachel Bjork, Board President
Seattle, WA

Northwest Arkansas Audubon Society
Carol Joan Patterson
Fort Smith, AR

NY4WHALES
William Rossiter, Vice President
New York, NY

Oceanic Preservation Society
Courtney Vail, Director of Strategic Campaigns
Greenbrae, CA

Ocean Voyages Institute
Mary T Crowley, President and Founder
Sausalito, CA

Ohio Valley Environmental Coalition (OVEC)
Vivan Stockman, Executive Director
Huntington, WV

Old Growth Forest Network
Joan Maloof, Executive Director
Easton, MD

Patagonia
Hilary Dessouky, General Counsel
Ventura, CA

Paula Lane Action Network (PLAN)
Susan Kirks, Chair, Board of Directors
Petaluma, CA

Pelican Media
Judy Irving, Executive Director
San Francisco, CA

Petaluma Wetlands Alliance
John Schribbs, President
Petaluma, CA

Planning and Conservation League
Jonas Minton, Senior Water Policy Advisor
Sacramento, CA

Point Reyes Safaris
Daniel Dietrich, Owner
Inverness, CA

Predator Defense
Brooks Fahy, Executive Director
Eugene, OR

Project Coyote
Camila Fox, Executive Director
Mill Valley, CA

Public Interest Coalition
Marilyn Jasper, Chair
Loomis, CA

Public Lands Conservancy
Don Neubacher, Board Member
Point Reyes, CA

Public Trust Alliance
Michael Warburton, Executive Director
Mill Valley, CA

Rainforest Action Network
Ginger Cassady, Executive Director
San Francisco, CA

Regional Parks Association
Amelia Wilson, President
Berkeley, CA

RESTORE: The North Woods
Michael Kellett, Executive Director
Concord, MA

The Rewilding Institute
John Davis, Executive Director
Albuquerque, NM

Sandra Lee Photography
Sandy Zelasko, Owner
Valley Center, CA

Santa Cruz Climate Action Network
Pauline Seales, Organizer
Santa Cruz, CA

Save Our Sky Blue Waters
Lori Andresen, President
Duluth, MN

SAVE THE FROGS!
Kerry Kriger, Ph.D.
Laguna Beach, CA

Shark Stewards
David McGuire, Director
Sausalito, CA

Sierra Club
Olga Bolotina, SF Bay Chapter Chair
Berkeley, CA

Social Compassion in Legislation
Nickolaus Sackett, Director of Legislative Affairs
Laguna Beach, California

Spottswoode Winery, Inc.
Beth Novak Milliken & Lindy Novak
St. Helena, CA

Supporters for Del Norte Roosevelt Elk
Phoebe Lenhart
Crescent City, CA

Tending the Ancient Shoreline Hill
Margot Cunningham, Head
Richmond, CA

Topanga Peace Alliance
Julie Levine
Topanga, CA

Turtle Island Restoration Network
Todd Steiner, Executive Director
Forest Knolls, CA

Watershed Alliance of Marin
Laura Chariton, President
Mill Valley, CA

Wellkind
Catriona Glazebrook, Executive Director
Burlingame, CA

Western Watersheds Project
Erik Molvar, Executive Director
Laramie, WY

Wholly H2O
Elizabeth Dougherty, Executive Director
Oakland, CA

WildCare
Alison Hermance, Director of Communications
San Rafael, CA

Wild Horse Education
Laura Leigh, President
Reno, NV

WildernessPress Photography
Andrw Carothers-Liske, Owner
Emeryville, CA

Wilderness Watch
George Nickas, Executive Director
Missoula, MT

The Wildlife Trust
Edward S. Loosli, President
Walnut Creek, CA

Wild Zone Conservation League
Patrick Lee Hord, Director
El Cajon, CA

Yellowbilled Tours
Richard Cimino, Owner
Larkspur, CA

2. Coastal and Marine Natural Resources Are Impaired Due to Cattle Ranching at Point Reyes National Seashore.

Water quality impairment of marine biological resources along the Point Reyes coast from spillover effects of beef and dairy ranching have not been adequately analyzed, or have been completely lacking in any review.

Proposed Critical Habitat for southern resident killer whale (*Orcinus orca*), which may be impacted by cattle water pollution flowing into the Pacific from Point Reyes National Seashore ranches. Map generated from GIS data at https://www.fisheries.noaa.gov/resource/map/critical-habitat-killer-whale-southern-resident-dps-proposed-2019

The Southern resident population of killer whales is proposed for revised Critical Habitat designation in new areas, including all coastal waters off Point Reyes National Seashore by the National Marine Fisheries Service.[2]

Orcas are impacted by water pollution from land uses, and the collapse of their favored food--salmon (which need clean, clear, cold, unimpaired streams and rivers in California to spawn in, and healthy eelgrass beds).[3] Orcas depend on Pacific herring (*Clupea pallasii*) in the food chain to supply them with enough salmon to eat.[4]

Eelgrass (*Zostera marina*) forms the base of a vast food pyramid that supports herring, salmon, and their predators such as orcas. Eelgrass beds are important ecological communities of estuaries and shallow bays along the California coast, and grow in Drake's Estero and Tomales Bay. Eelgrass beds are spawning habitat for Pacific herring, juvenile habitat for salmon, as well as primary food for many trophic levels. Eelgrass beds have been in decline due to water pollution, coastal disturbance and other anthropogenic activities (Ramey 2008). The California Coastal Act sought to increase protection for these marine resources.

Because of the importance of coastal eelgrass habitats to marine fisheries, agencies have enacted several protection and mitigation plans along the Pacific Coast.[5] Turbidity can negatively impact eelgrass by cutting the amount of sunlight reaching photosynthetic organs of the plant, and reducing productivity (NMFS 2010, 2011). Livestock grazing, trampling, erosion, and sedimentation on the ranches of Point Reyes National Seashore and Golden Gate National Recreation Area contribute fine sediments into streams and creeks, which flow into Drake's Estero and Tomales Bay. The impacts of turbidity to eelgrass communities has not been analyzed.

Nutrient loading into eelgrass beds also is a threat, including from animal waste, watersheds nutrient input, fertilizers, and other land sources (NMFS 2014 at 14). Mitigation for impacts caused by dairy waste washed into bays and estuaries was unanalyzed by NPS and the CCC. Anoxic conditions and extremely high concentrations of ammonium, total phosphorus, suspended solids, and fecal coliform bacteria throughout the water column for approximately 30 km downstream from the point of entry have been documented as impacts of waste effluent spills from CAFOs (Burkholder et al. 2007 at 309). Waste effluent spills also stimulated blooms of toxic and noxious algae. In freshwaters, these blooms include toxic and noxious cyanobacteria while in estuaries, harmful haptophytes and toxic dinoflagellates arise (*ibid*.). Nutrient input, including Nitrogen, Phosphorus, and suspended solids, can increase algal blooms and phytoplankton production, which can actually shade out eelgrass in deeper waters. Even when nutrients such as Nitrogen are limited, turbidity can continue to reduce eelgrass beds (Carstensen et al. 2013).

[2] https://www.fisheries.noaa.gov/action/critical-habitat-southern-resident-killer-whale

[3] https://us.whales.org/2019/09/23/more-protected-habitat-proposed-for-southern-resident-orcas/, https://www.whaleresearch.com/orca-population, https://www.endangered.org/campaigns/southern-resident-orcas/

[4] https://vancouversun.com/news/local-news/stop-herring-fishery-to-save-troubled-orcas-environmental-groups-say

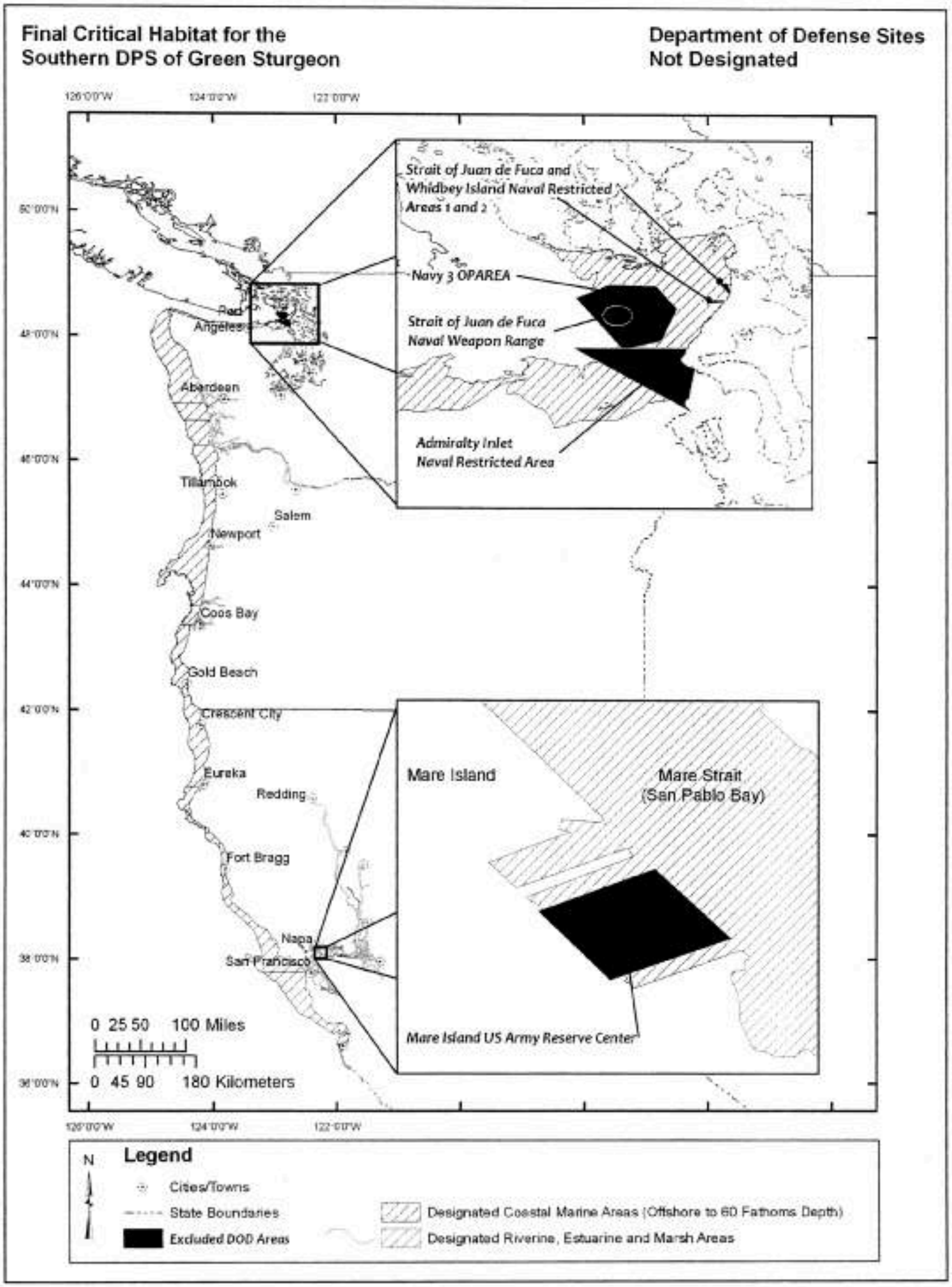
[5] https://www.fisheries.noaa.gov/west-coast/habitat-conservation/seagrass-west-coast

Concerned local residents have written letters to the California Coastal Commission summarizing impacts to marine resources, and for reference, a good letter about eelgrass impacts of NPS management at Point Reyes National Seashore is included (Polvorosa-Kline 2020).

Other Critical habitat units mapped adjacent to Point Reyes National Seashore include the following. Significant spillover effects from livestock ranching on Point Reyes National Sesahore to these imperiled marine species was not analyzed in the NPS Final EIS/GMPA.

Critical habitat for the Southern Distinct Population Segment of North American green sturgeon (*Acipenser medirostris*) lies off the coast of Point Reyes National Seashore. Critical habitat in coastal marine areas is defined by the zone between the 60 fathom depth bathymetry line and the line on shore reached by mean lower low water.[6] Water quality and sedimentation of habitats are threats.

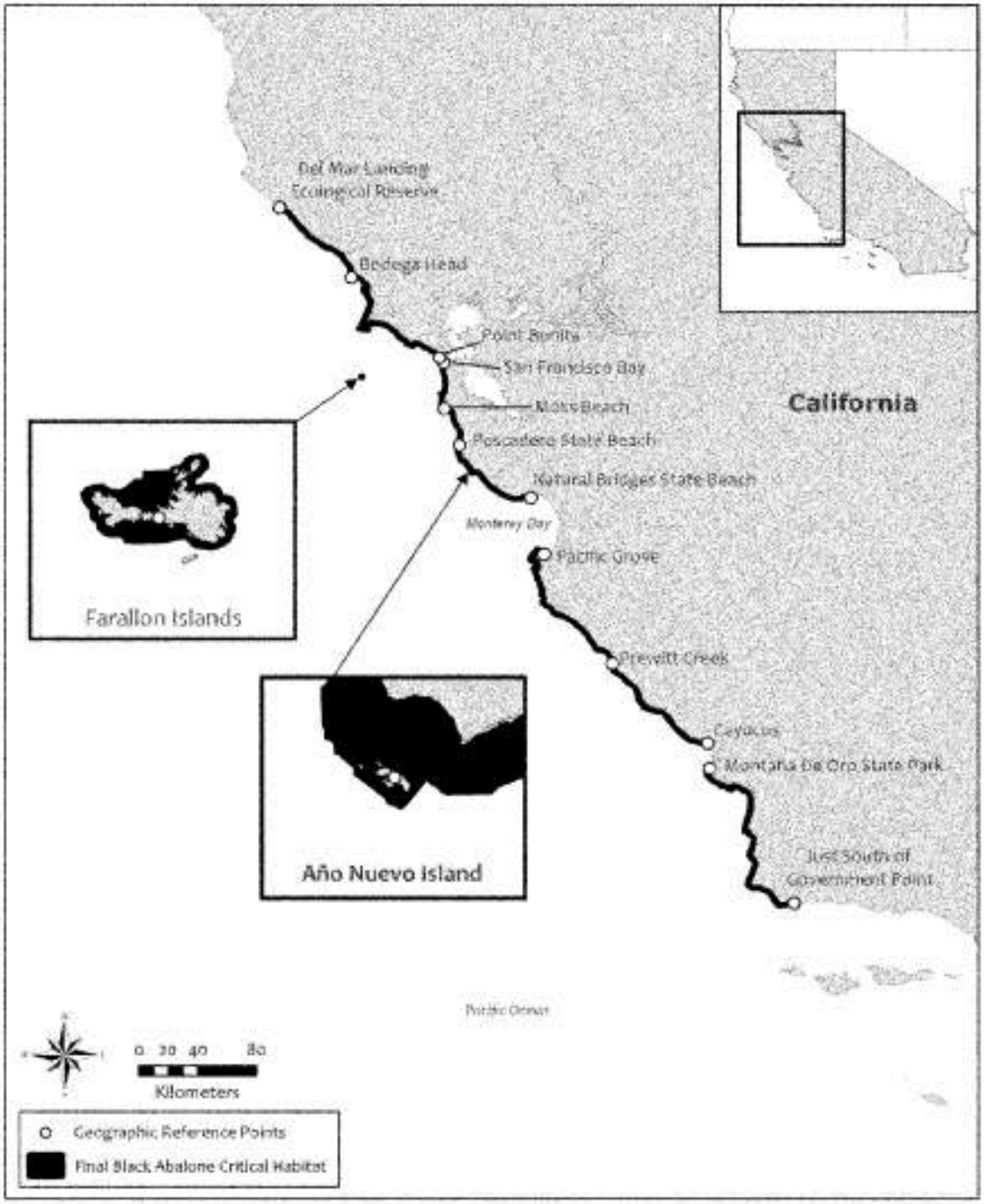
[6] https://www.ecfr.gov/cgi-bin/text-idx?SID=8931f367cf19553f0511b33d43a9961c&mc=true&node=se50.10.226_1219&rgn=div8



Green sturgeon critical habitat. Source: https://www.ecfr.gov/cgi-bin/text-idx?SID=8931f367cf19553f0511b33d43a9961c&mc=true&node=se50.10.226_1219&rgn=div8

Critical habitat for black abalone (*Haliotis cracherodii*) occurs adjacent to Point Reyes National Seashore, but was not analyzed in the Final EIS. Critical habitat includes rocky intertidal and subtidal habitats within these areas from the mean high water line line to a depth of −6 m relative to mean lower low water line, as well as the marine waters above the rocky habitats. Suitable water quality includes temperature (*i.e.*, tolerance range: 12 to 25 °C; optimal range: 18 to 22 °C), salinity (*i.e.*, 30 to 35 ppt), pH (*i.e.*, 7.5 to 8.5), and other chemical characteristics necessary for normal settlement, growth, behavior, and viability of black abalone.[7]

[7] https://www.ecfr.gov/cgi-bin/text-idx?SID=8931f367cf19553f0511b33d43a9961c&mc=true&node=se50.10.226_1221&rgn=div8

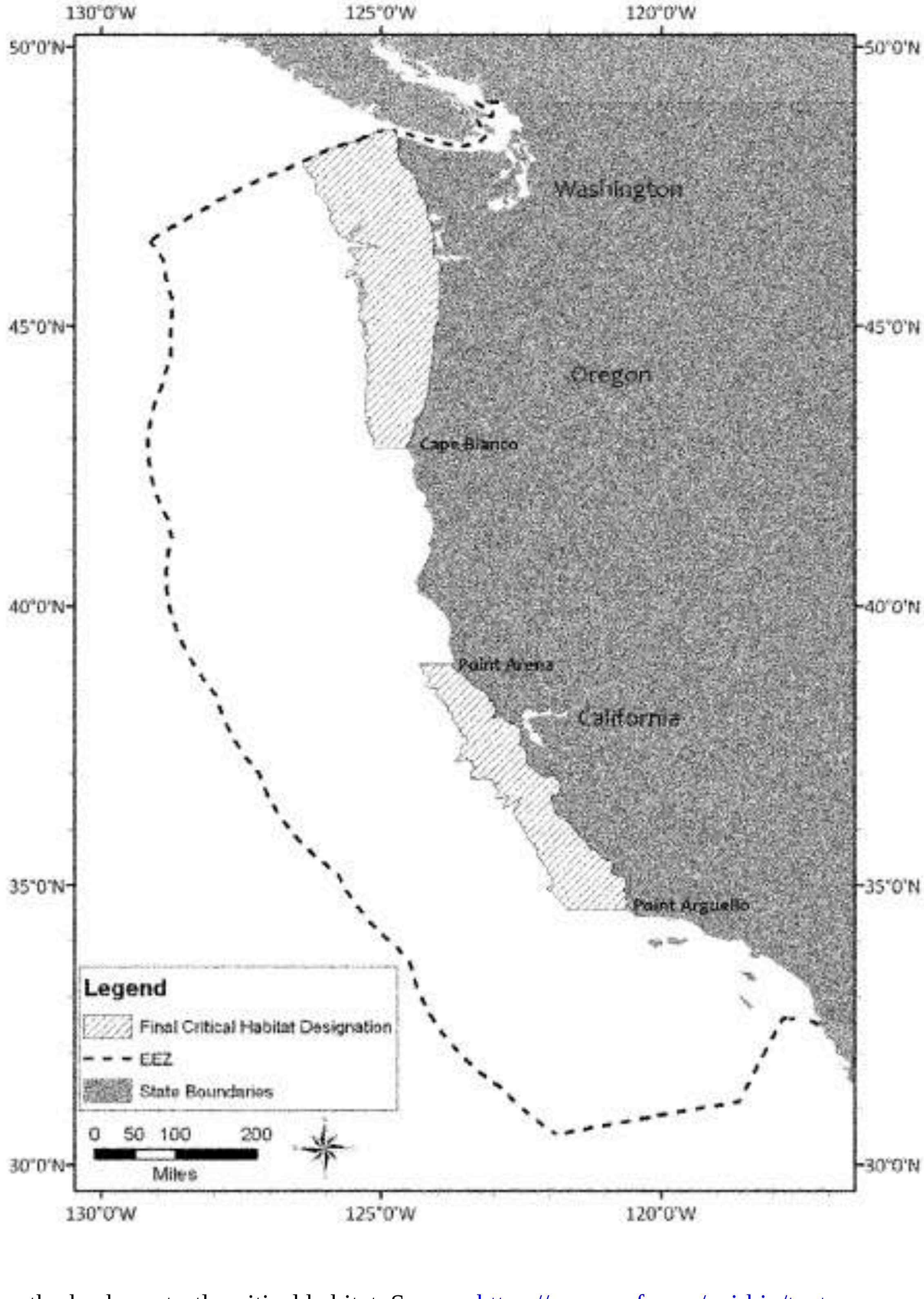


Black abalone critical habitat. Source: https://www.ecfr.gov/cgi-bin/text-idx?SID=8931f367cf19553f0511b33d43a9961c&mc=true&node=se50.10.226_1221&rgn=div8

Critical habitat for leatherback turtles (*Dermochelys coriacea*) is also adjacent to Point Reyes National Seashore. Critical habitat extends to a water depth of 80 meters from the ocean surface and is delineated along the shoreline at the line of extreme low water, except in the case of estuaries and bays where Convention on the International Regulation for Preventing Collisions at Sea COLREGS lines (defined at 33 CFR part 80) shall be used as the shoreward boundary of critical habitat.[8] The Point Reyes national Seashore Final EIS/GMPA failed to analyze spillover effects from livestock grazing and ranching to this critical habitat unit.

---

[8] https://www.ecfr.gov/cgi-bin/text-idx?SID=79c870d9a02a7e22b18473ef2efb7556&mc=true&node=se50.10.226_1207&rgn=div8



Leatherback sea turtle critical habitat. Source: https://www.ecfr.gov/cgi-bin/text-idx?SID=79c870d9a02a7e22b18473ef2efb7556&mc=true&node=se50.10.226_1207&rgn=div8

Cattle on A Ranch just north of the famous lighthouse, Point Reyes National Seashore overlooking the Pacific Ocean. January 5, 2021. Photo: Jocelyn Knight.

The only road to Chimney Rock and the historic boathouse through A Ranch just north of the famous lighthouse, Point Reyes National Seashore overlooking the Pacific Ocean. A ‘Do Not Enter’ sign wrongfully precludes the public from accessing this part of public lands and the National Seashore. January 5, 2021. Photo: Jocelyn Knight.

C Ranch modern plastic calf huts on Point Reyes National Seashore. This is not ‘historic dairying.’ January 5, 2021. Photo: Jocelyn Knight.

Ponds on C Ranch flow downhill that drain into Drakes Bay and Drakes Beach where elephant seals reside. Point Reyes National Seashore. January 5, 2021. Photo: Jocelyn Knight.

C Ranch livestock-impacted denuded pastures with mud, on former coastal prairie. Point Reyes National Seashore. January 5, 2021. Photo: Jocelyn Knight.

Elephant seal at Point Reyes National Seashore. January 5, 2021. Photo: Jocelyn Knight.

Elephant seals rest on the shore of Drakes Beach below B and C Ranches in Point Reyes National Seashore. January 5, 2021. Photo: Jocelyn Knight.

A Ranch dairy cattle waiting to be milked. Point Reyes National Seashore. January 5, 2021. Photo: Jocelyn Knight.

Dairy manure truck on C Ranch, used to spread excess manure on fields in the National Seashore watersheds which drain to the Pacific Ocean. Point Reyes National Seashore. January 5, 2021. Photo: Jocelyn Knight.

3. Salmonid Critical Habitat Is Significantly Impaired Despite Mitigation and Best Management Practices.

The California Coastal Commission has jurisdiction over NPS with respect to spillover lands and water but in the coastal zone, and park streams that are crucial spawning habitat for ocean-going anadromous fish must be considered under CCC jurisdiction.

I have entered numerous photos into the record to the superintendent of Point Reyes National Seashore and in a separate letter to the CCC showing how Critical Habitat for Federally Endangered Central Coast Coho salmon population habitats and Federally Threatened steelhead trout Critical Habitat does not appear to currently have cattle grazing impacts mitigated to less than significant.

Evidence that NPS Best Management Practices (BMPs) mentioned in the GMPA for the Tomales Watershed to attempt to halt severe impairment of cattle-degraded anadromous fish streams and Critical Habitat are not efficacious towards recovering these anadromous fish populations in my expert opinion. In 1992-1993 I worked for California Department of Fish and Wildlife as a seasonal fishery biologist surveying salmonid streams across the state, measuring spawning habitat, water quality, and stream characters. NPS efforts at "restoration" are not effective in my opinion.

The photos I took in January 2020 of critical habitat for coho salmon and steelhead in Olema Creek makes me highly question whether Tomales Bay watersheds are meeting water quality standards adequately enough to sustain rare salmonids. I can see turbidity, extreme streambank collapse, and erosion and sedimentation of salmon habitat. The straw wattles (BMPs) are sliding into the stream. To me this is still extreme impairment.

The 2012 Final Central California Coast Coho Salmon ESU Recovery Plan discusses factors leading federal listing (at 89-90):

> Land use activities associated with logging, road construction, urban development, mining, agriculture, and recreation have significantly altered coho salmon habitat quantity and quality (61 FR 56138). Impacts of concern associated with these activities included the following: alteration of streambank and channel morphology, alteration of ambient stream water temperatures, elimination of spawning and rearing habitat, fragmentation of available habitats, elimination of downstream recruitment of spawning gravels and large wood, removal of riparian vegetation resulting in increased stream bank erosion, and degradation of water quality (61 FR 56138). Of particular concern was the increased sediment input into spawning and rearing areas resulting from the loss of channel complexity, pool habitat, suitable gravel substrate, and LWD (61 FR 56138). Decreased large woody material in streams has also reduced habitat complexity and contributed to the loss of cover, shade, and pools which are required by juvenile coho salmon (60 FR 38011). Agricultural practices had contributed to the degradation of salmonid habitat in the ESU through water diversions for irrigation, inadequate riparian protections, sedimentation, overgrazing in riparian areas, and compaction of soils in upland areas from livestock.

Since listing, restoration of streams is outpaced by degradation. Stream disconnection from floodplains, removal of riparian vegetation, and agricultural activities continue to need to be addressed (*id.* at 91).

Tomales Bay watershed impairment continues despite NPS attempts at mitigation, Critical Habitat for Central Coast Coho salmon and Steelhead trout. April 15, 2019 photo of BMPs of straw wattles and seeded European rye grass not efficacious at restoring salmonid habitat on Olema Creek, Point Reyes National Seashore and Golden Gate National Recreation Area cattle-grazed watershed. Water is turbid, not clear, and severe bank collapse is continuing. Photo: Laura Cunningham.

April 15, 2019 photo of salmonid habitat on Olema Creek, Point Reyes National Seashore and Golden Gate National Recreation Area cattle-grazed watershed. Water is turbid, not clear, and severe bank collapse is continuing. Photo: Laura Cunningham.

April 15, 2019 photo of BMPs of straw wattles and seeded European rye grass not efficacious at restoring salmonid habitat on Olema Creek, Point Reyes National Seashore and Golden Gate National Recreation Area cattle-grazed watershed. Water is turbid, not clear, and severe bank collapse is continuing. Photo: Laura Cunningham.

April 15, 2019 photo of BMPs of straw wattles and seeded European rye grass not efficacious at restoring salmonid habitat on Olema Creek, Point Reyes National Seashore and Golden Gate National Recreation Area cattle-grazed watershed. Water is turbid, not clear, and severe bank collapse is continuing. Wattles are falling into the stream and are not able to halt the severe erosion and sedimentation. Photo: Laura Cunningham.

April 15, 2019 photo of BMPs of straw wattles and seeded European rye grass not efficacious at restoring salmonid habitat on Olema Creek, Point Reyes National Seashore and Golden Gate National Recreation Area cattle-grazed watershed. Water is turbid, not clear, and severe bank collapse is continuing. Photo: Laura Cunningham.

These weak, ineffectual BMPs are doing nothing to actually restore this deeply incised stream. Much better restoration techniques should be used to restore salmonid habitat raise the streambed level and reconnect the stream with the historic floodplain.

Healthy stable stream systems should have vegetated banks and bars, and limited bank erosion. Evidence of degradation instability includes perched tributaries, terraces, exposed tree roots, early seral vegetation colonization, narrow and deep channel, and failed revetments due to undercutting (Yochum 2018). All these instability indicators are evident on Olema Creek in these grazed watersheds.

Stream evolution models indicate Olema Creek in this salmonid habitat stretch is in the Degradation and Rapid widening stage: Incising with unstable, retreating banks that collapse by slumping and/or rotational slips. Failed material is scoured away and the enlarged channel becomes disconnected from its former floodplain, which becomes a terrace.

Yochum (2018) at 54 describes how livestock grazing causes this:

> Livestock grazing in riparian zones can negatively influence herbaceous species composition, productivity, and commonly modifies the structure and composition of woody plant communities …. The result is often destabilized streambanks and reduced channel cover and shading. The decreased stability leads to overwidened channels, decreased flow depth and, in combination with the decreased shading, substantial increases in peak summer temperatures. Temperature increases are a substantial concern with cold water fishes and are especially problematic for native endangered, threatened, or species of concern.

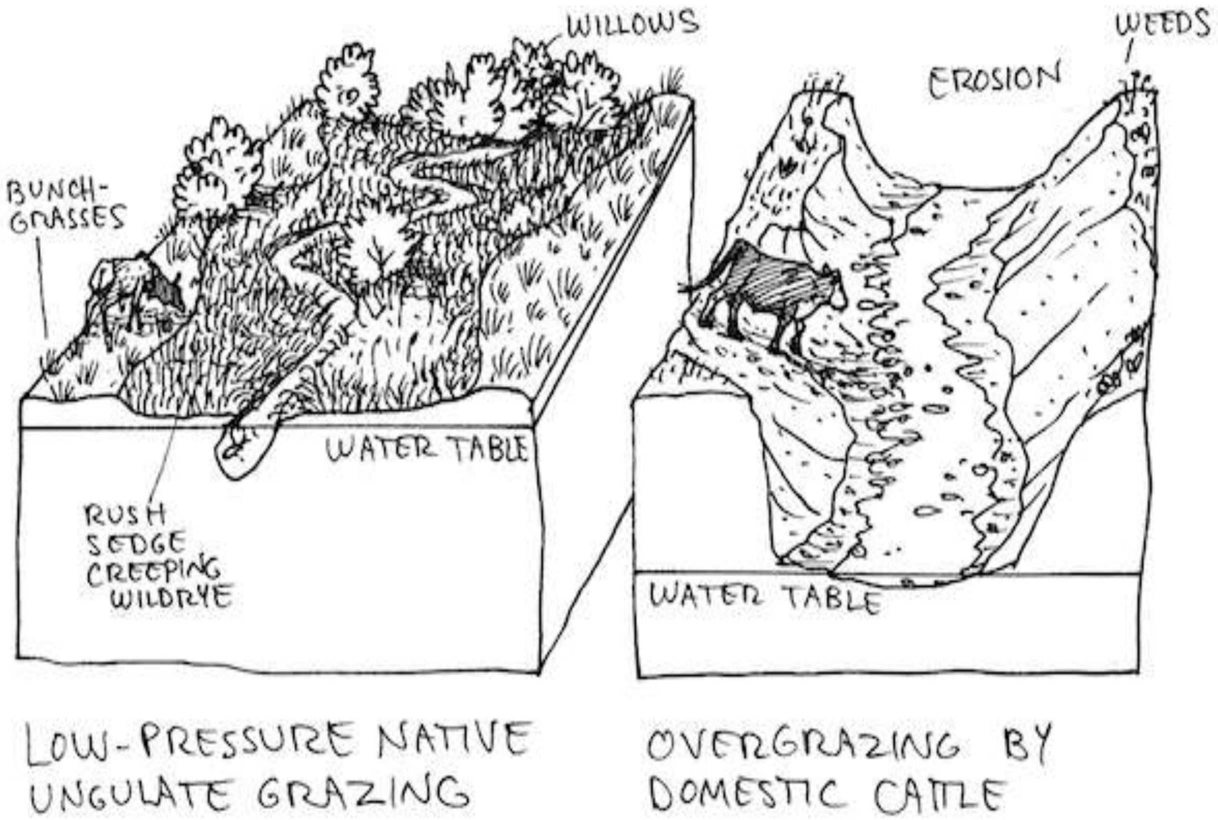


Diagram illustrating a model of native wet meadow and riparian light grazing regimes with elk in comparison with livestock-impacted riparian and meadow systems degraded by excessive grazing, trampling, erosion, and streambank collapse. This is the current situation at Olema Creek on NPS-managed lands. Illustration: Laura Cunningham.

Yochum continues (*id.* at 60):

> In general, fish and other aquatic and riparian corridor species need appropriate and sufficient physical habitat, water quality, and instream flows to thrive. Channelized and incised streams, as well as streams without connections to their floodplains, are fundamental impairments along many stream corridors. The lack of thalweg longitudinal profile complexity is a common physical impairment for cold-water fishes. The removal of instream wood, through channel clearing and snagging activities, has contributed

substantially to the lack of cover and complexity. One of the most common water quality impairments is excessive peak summer temperatures, which can be related to flow depletions associated with reservoirs and stream diversions.

Much more active restoration methods are needed on these damaged instable stream reaches, such as placement of logs and rock, Post-Assisted Log Structures (PALs), Beaver Dam Analog (BDAs), and other methods to stop severe bank destabilization and erosion, and reconnect the channel with the floodplain. Woody bank vegetation is needed, not seeded European grains with shallow roots and annual growth form.

Salmonids such as coho salmon and steelhead trout need certain ranges of clear water (low turbidity) and cold temperature in streams for migration from ocean habitats to spawning habitats (Roni et al. 2014 at 2). Pool-riffle habitats are also needed, with adequate cover from predators, which complex, meandering streams containing woody debris and overhanging vegetation provide. Deeply incised channels with simplified stream habitats do not provide this. Egg-laying and juvenile rearing habitats in these streams also requires well-oxygenated gravels free of mud and sediment. Livestock grazing causes erosion and sedimentation of these spawning and rearing gravels, choking out clean water and well-oxygenated gravels.

The classic measures of salmonid stream health that I am familiar with, working as a seasonal fishery biologist in the 1990s with the California Department of Fish and Wildlife, appear to be lacking in the analysis of coho salmon and steelhead trout recovery. Embeddedness of spawning gravels by sediments eroded out of grazed watersheds, large woody debris, stream substrates, turbidity, and other measures are not analyzed. Upslope effectiveness monitoring does not appear to be undertaken (Fitzgerald 2004 at 42).

Female salmonids select sites where flow conditions within the gravel are favorable for successful incubation of eggs and alevin. Spawning sites often occur where channel and stream bed morphology create surface or sub-surface flow patterns that enhance intergravel flow and oxygen delivery. The oxygen supplied to the eggs by water flowing through the gravel comes from interchange with water flowing above the stream bed or the influx of deep groundwater into the stream bed. Factors such as the velocity of surface water, the rate of intra-gravel flow through gravel deposits, or the presence of up-welling groundwater appear to be important criteria used by many stocks to select spawning sites favorable to the survival of eggs and alevin. Embeddedness is an important measure of streambed habitat for young salmon (Sylte and Fishenich 2002).

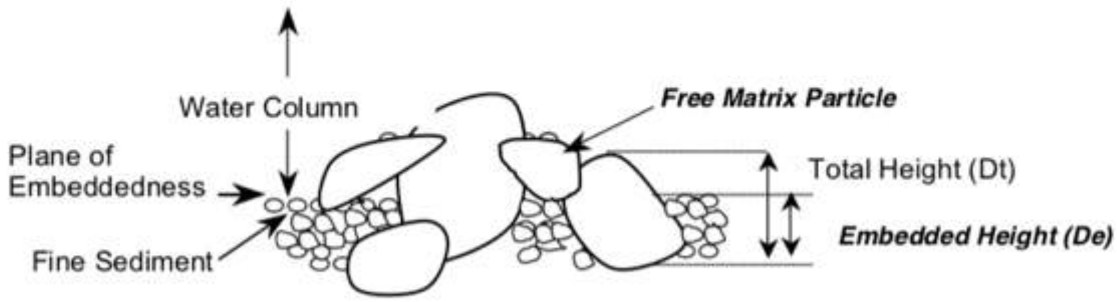


Figure 2. Schematic representation of embeddedness

Diagram from Sylte and Fischenich 2002 at 2.

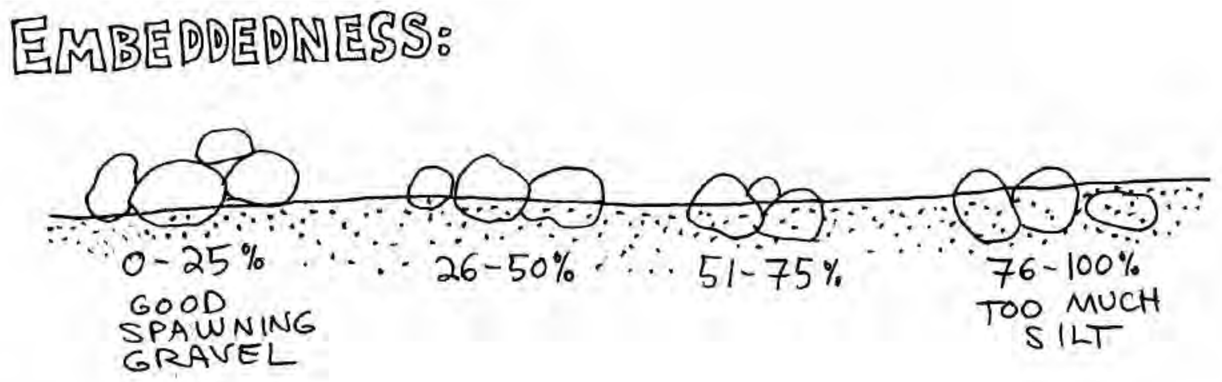


Illustration of embeddedness levels of salmonid gravel with siltation. Laura Cunningham.

Livestock grazing, timber harvesting and road building can increase levels of sediment delivery to channels, which may increase water turbidity, fill pools, and reduce rearing habitat of juvenile coho salmon. Increased water turbidity may have lethal or sub-lethal effects on salmonids. These effects include physiological stress, such as gill trauma and decreased osmoregulatory ability, and behavioral changes, such as delayed migration, decreased feeding rates, and altered prey selection. Embeddedness of substrates with fine sediments may reduce production, primarily by reducing egg-to-emergence survival and aquatic invertebrate production. The sedimentation of coastal estuaries, due to increased upstream erosion, has been documented in rivers of the northern California coast; this reduces good rearing habitat for coho salmon before they migrate to sea.

Areas where permeability is reduced because the substrate is compacted or contains high concentrations of fine sediments are often avoided. Suspended sediments in water can be measured by turbidity, which is the optical property of scattered light in the water column. Increased stocking density and mechanized agricultural practices that increase soil compaction, bare soils, runoff, and erosion from arable and pasture soils (Mattingley 2017).

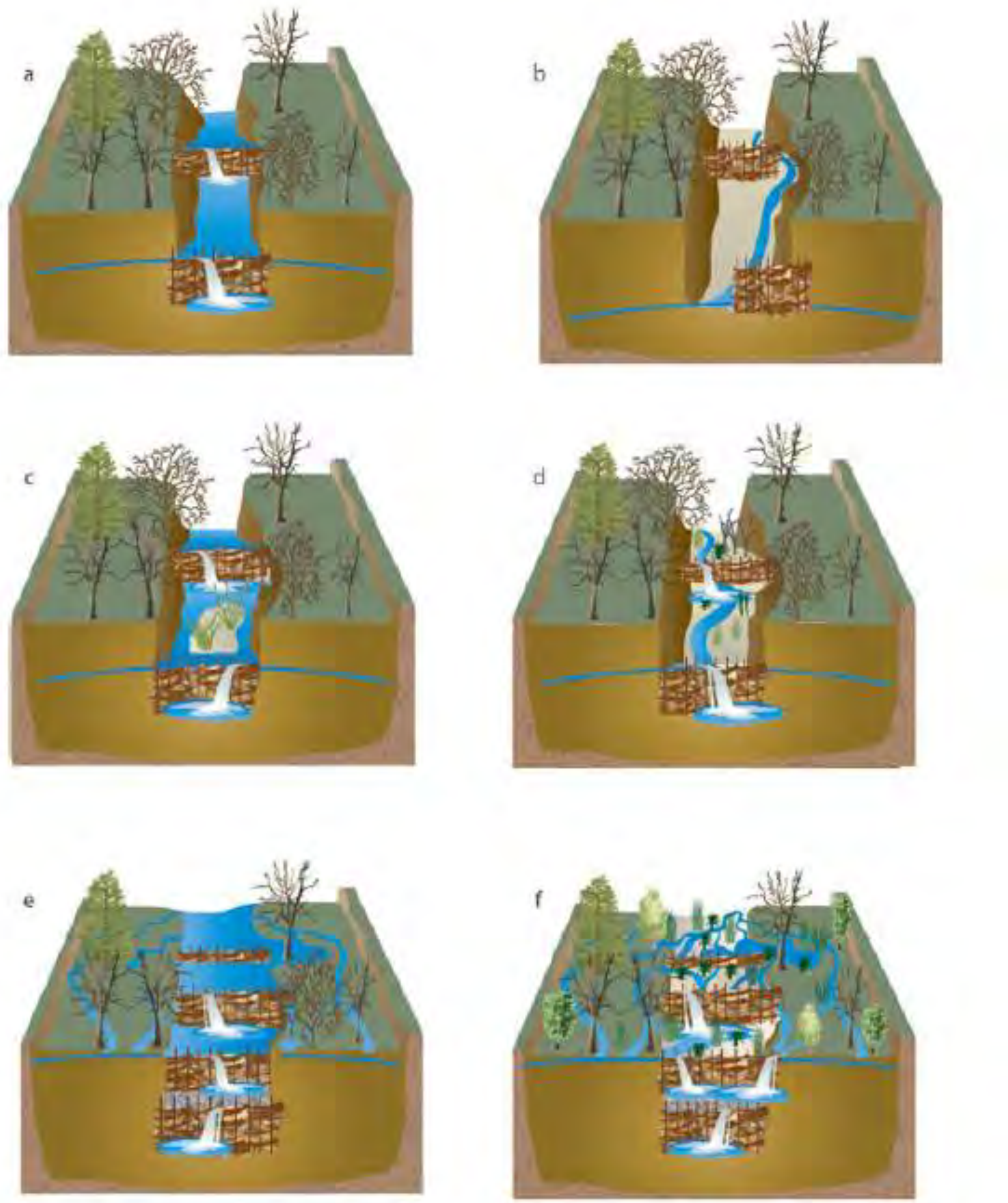


Figure 13 – Expected geomorphic responses following the Cluer and Thorne (2013) channel evolution model (from Stage 3 to 0) after the installation (a) of BDAs, their initial 'failure' by end-cutting (b), subsequent repair (c) and aggradation leading to floodplain reconnection in an incised system. Figure from Pollock et al. (2014). In practice, PALS can force the same processes of channel-widening and aggradation as BDAs.

Illustration of the restoration process for returning a deeply incised channel to reconnection with the floodplain and functioning salmonid habitat (Shahverdian et al. 2019 at 18).

Alteration and degradation of creeks has occurred commonly in California, resulting in simplifying and downcutting the creek channel and creating non-functioning floodplains.

Restoration activities must be targeted not only to halt downcutting, but also focus on improving the natural form and function of the creek and increasing salmonid spawning and rearing habitat (Earley et al. 2013).

4. Mowing Impairs Native Plant Communities

Livestock operations are allowed to mechanically mow native vegetation to remove woody shrubs that are unpalatable to cattle. Coyote brush (*Baccharis pilularis*) is part of the North Coastal Scrub native plant community and mixes in with Coastal Prairie. Yet photos show mowing and destroying coyote brush in beef cattle pastures on G Ranch in Point Reyes National Seashore in January 2021. Other native plants may also be crushed and chopped by this practice.

Coyote brush mowed on G Ranch beef cattle pasture, Point Reyes National Seashore, January 2021. Photo: Anonymous.

Coyote brush mowed on G Ranch beef cattle pasture, Point Reyes National Seashore, January 2021. Photo: Anonymous.

Coyote brush mowed on G Ranch beef cattle pasture, Point Reyes National Seashore, January 2021. Disturbed bare soil will also increase erosion and turbidity of water bodies and estuaries during rain event runoff. Photo: Anonymous.

5. New Fencing On the Seashore Is Not Wildlife Friendly As Promised In the EIS.

Wildlife photographers documented new fencing on B Ranch in Point Reyes National Seashore that is not wildlife-friendly, as should be required in a national park unit.

New NPS fencing at B Ranch that drains into Drake's Bay. Photo: Jocelyn Knight, January 5, 2021.

Tule elk bulls on the bluffs of C Ranch on Point Reyes National Seashore, January 5, 2021. Photo: Jocelyn Knight.

6. Administrative History Shows the Original Intent to Retire Cattle Grazing On the Seashore.

The Administrative History of Point Reyes National Seashore (Sadin 2007) shows definitively that NPS knows ranching was never meant to stay. The original intent was not to keep the ranching industry:

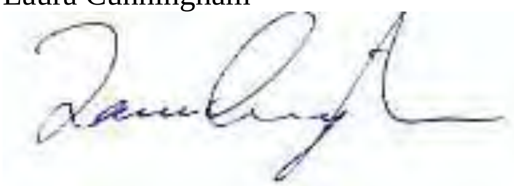
> The legislative history of a national park—or, in this case, a national seashore—helps explain how and why that National Park Service site came into existence. The ideals, objectives, and language of the authorization process form the legislative intent of Point Reyes National Seashore's establishment that provides park managers, politicians, and the public with a fuller understanding of the seashore's mandated goals, mission, and meaning. The legislative story of the Point Reyes Act reveals that Congress intended to preserve and protect three different elements, namely, recreational opportunities, natural beauty, and the scientific and historic merits of the Point Reyes Peninsula. Congressional bills, committee reports, and floor debates did not single out one element as the paramount justification for creating the national seashore. Point Reyes was never intended to be a one-dimensional park, even though the NPS soon placed it in the recreation area category of park management. Legislators also paid keen attention to the property rights of these landowners; but, as the following discussion reveals, the ranches

> and dairies were not elements that the NPS, most seashore supporters, and legislators initially sought to protect within the scope of the national seashore premise. (Sadin 2007 at 71)

Point Reyes National Seashore and Golden Gate National Recreation Area should be prime California examples of conservation and restoration efforts to protect native wildlife and imperiled species, as well as allowing better public access to coastal areas, sustainable recreation, and wildlife viewing.

Thank you,

Laura Cunningham



California Director
Western Watersheds Project
Cima CA 92323
Mailing: PO Box 70
Beatty NV 89003
775-513-1280
lcunningham@westernwatersheds.org

References:

Burkholder, J., Libra, P. Weyer, S. Heathcote, D. Kolpin, P. S. Thorne, and M. Wichman. 2007. Impacts of Waste from Concentrated Animal Feeding Operations on Water Quality. Environmental Health Perspectives Vol. 115, No. 2.

California Coastal Commission (CCC). 2020. Staff Report on the General Management Plan amendment for Point Reyes National Seashore. CD-0006-20. Accessed 1/2021 at https://documents.coastal.ca.gov/reports/2021/1/Th6b/Th6b-1-2021-report.pdf

Carstensen, J., D. Krause-Jensen, S. Markager, K. Timmermann , and J Windolf. 2013. Water clarity and eelgrass responses to nitrogen reductions in the eutrophic Skive Fjord, Denmark. Hydrobiologia (2013) 704:293–309 DOI 10.1007/s10750-012-1266-y

Earley, L. A., S.L. Giovannetti, and M.R. Brown. 2013. Fall Chinook Salmon Redd Mapping for the Clear Creek Restoration Project, 2008-2012. U.S. Fish and Wildlife Service, Red Bluff Fish and Wildlife Office, Red Bluff, California.

Fitzgerald, R. 2004. Salmonid freshwater habitat targets for sediment-related parameters. State Water Resources Control Board North Coast Region, 5550 Skylane Boulevard, Suite A Santa Rosa, California 95403 707-576-2220. Accessed January 2021 at https://www.waterboards.ca.gov/northcoast/water_issues/programs/basin_plan/110504/110504-targets.pdf.

Mattingley, L. 2017. The impact of excess fine sediment on invertebrates and fish in riverine systems. Salmon and Trout Conservation. Access January 2020 at https://www.salmon-trout.org/wp-content/uploads/2017/09/STC-The-impact-of-excess-fine-sediment-on-invertebrates-and-fish-in-riverine-systems.pdf

National Marine Fisheries Service (NMFS). 2010. San Francisco Bay Light Monitoring Survey Protocol. Accessed January 2021 at https://archive.fisheries.noaa.gov/wcr/publications/habitat/california_eelgrass_mitigation/sfb_lightmonitoringprotocol.pdf.

NMFS. 2011. Turbidity Best Monitoring Practices (BMP) Flowchart. Accessed January 2021 at https://archive.fisheries.noaa.gov/wcr/publications/habitat/california_eelgrass_mitigation/turbiditybmpflowchart072511.pdf.

NMFS. 2012. Final Recovery Plan for Central California Coast coho salmon Evolutionarily Significant Unit. National Marine Fisheries Service, Southwest Region, Santa Rosa, California.

NMFS. 2014. California Eelgrass Mitigation Policy and Implementing Guidelines. Accessed January 2021 at https://media.fisheries.noaa.gov/dam-migration/cemp_oct_2014_final.pdf.

Ramey, K. 2008. Status of the Fisheries Report. California Department of Fish and Game.

Roni, P., G. R. Pess, T. J. Beechie, and K. M. Hanson. 2014. Fish-Habitat Relationships and the Effectiveness of Habitat Restoration. NOAA Technical Memorandum NMFS-NWFSC-127. Northwest Fisheries Science Center Fish Ecology Division Watershed Program 2725, Montlake Boulevard East, Seattle, Washington 9811. National Oceanic and Atmospheric Administration National Marine Fisheries Service .

Sadin, Paul. 2007. Managing a Land In Motion: Administrative History of Point Reyes National History. Prepared for National Park Service, Point Reyes National Seashore, Point Reyes, California, 94956. Historical Research Associates, Inc., 1904 Third Avenue, Suite 240, Seattle, Washington 98101.

Shahverdian, S.M., Wheaton, J.M., Bennett, S.N., Bouwes, N., Camp, R., Jordan, C.E., Portugal, E. and Weber, N., 2019. Chapter 4. Mimicking and Promoting Wood Accumulation and Beaver Dam Activity with Post-Assisted Log Structures and Beaver Dam Analogues In: J.M. Wheaton, S.N. Bennett, N. Bouwes, J.D. Maestas and S.M. Shahverdian (Editors), Low-Tech Process-Based Restoration_of Riverscapes: Design Manual. Utah State University Restoration Consortium, Logan, Utah. 66 pp.

Sylte, T. L., and Fischenich, J. C. 2002. Techniques for measuring substrate embeddedness, EMRRP Technical Notes Collection (ERDC TN-EMRRP-SR-36), U.S. Army Engineer Research and Development Center, Vicksburg, MS. http://www.wes.army.mil/el/emrrp

Yochum, Steven E. 2018. Guidance for Stream Restoration. U.S. Department of Agriculture, Forest Service, National Stream & Aquatic Ecology Center, Technical Note TN-102.4. Fort Collins, CO.

Impacts of Waste from Concentrated Animal Feeding Operations on Water Quality

JoAnn Burkholder,[1] Bob Libra,[2] Peter Weyer,[3] Susan Heathcote,[4] Dana Kolpin,[5] Peter S. Thorne,[3] and Michael Wichman[6]

[1]North Carolina State University, Raleigh, North Carolina, USA; [2]Iowa Geological Survey, Iowa City, Iowa, USA; [3]The University of Iowa, Iowa City, Iowa, USA; [4]Iowa Environmental Council, Des Moines, Iowa, USA; [5]Toxic Substances Hydrology Program, U.S. Geological Survey, Iowa City, Iowa, USA; [6]University Hygienic Laboratory, Iowa City, Iowa, USA

Waste from agricultural livestock operations has been a long-standing concern with respect to contamination of water resources, particularly in terms of nutrient pollution. However, the recent growth of concentrated animal feeding operations (CAFOs) presents a greater risk to water quality because of both the increased volume of waste and to contaminants that may be present (e.g., antibiotics and other veterinary drugs) that may have both environmental and public health importance. Based on available data, generally accepted livestock waste management practices do not adequately or effectively protect water resources from contamination with excessive nutrients, microbial pathogens, and pharmaceuticals present in the waste. Impacts on surface water sources and wildlife have been documented in many agricultural areas in the United States. Potential impacts on human and environmental health from long-term inadvertent exposure to water contaminated with pharmaceuticals and other compounds are a growing public concern. This workgroup, which is part of the Conference on Environmental Health Impacts of Concentrated Animal Feeding Operations: Anticipating Hazards—Searching for Solutions, identified needs for rigorous ecosystem monitoring in the vicinity of CAFOs and for improved characterization of major toxicants affecting the environment and human health. Last, there is a need to promote and enforce best practices to minimize inputs of nutrients and toxicants from CAFOs into freshwater and marine ecosystems. *Key words:* ecology, human health, poultry, swine, water contaminants, wildlife. *Environ Health Perspect* 115:308–312 (2007). doi:10.1289/ehp.8839 available via *http://dx.doi.org/* [Online 14 November 2006]

Background and Recent Developments

Concentrated animal feed operations and water quality. Animal cultivation in the United States produces 133 million tons of manure per year (on a dry weight basis) representing 13-fold more solid waste than human sanitary waste production [U.S. Environmental Protection Agency (U.S. EPA) 1998]. Since the 1950s (poultry) and the 1970s–1980s (cattle, swine), most animals are now produced for human consumption in concentrated animal feeding operations (CAFOs). In these industrialized operations, the animals are held throughout their lives at high densities in indoor stalls until they are transported to processing plants for slaughter. There is substantial documentation of major, ongoing impacts on aquatic resources from CAFOs, but many gaps in understanding remain.

Contaminants detected in waste and risk of water contamination. Contaminants from animal wastes can enter the environment through pathways such as through leakage from poorly constructed manure lagoons, or during major precipitation events resulting in either overflow of lagoons and runoff from recent applications of waste to farm fields, or atmospheric deposition followed by dry or wet fallout (Aneja 2003). The magnitude and direction of transport depend on factors such as soil properties, contaminant properties, hydraulic loading characteristics, and crop management practices (Huddleston 1996). Many contaminants are present in livestock wastes, including nutrients (Jongbloed and Lenis 1998), pathogens (Gerba and Smith 2005; Schets et al. 2005), veterinary pharmaceuticals (Boxall et al. 2003; Campagnolo et al. 2002; Meyer 2004), heavy metals [especially zinc and copper; e.g., Barker and Zublena (1995); University of Iowa and Iowa State Study Group (2002)], and naturally excreted hormones (Hanselman et al. 2003; Raman et al. 2004). Antibiotics are used extensively not only to treat or prevent microbial infection in animals (Kummerer 2004), but are also commonly used to promote more rapid growth in livestock (Cromwell 2002; Gaskins et al. 2002; Liu et al. 2005). In addition, pesticides such as dithiocarbamates are applied to sprayfields (Extension Toxicology Network 2003). Although anaerobic digestion of wastes in surface storage lagoons can effectively reduce or destroy many pathogens, substantial remaining densities of microbial pathogens in waste spills and seepage can contaminate receiving surface- and groundwaters (e.g., Burkholder et al. 1997; Mallin 2000). Pharmaceuticals can remain present as parent compounds or degradates in manure and leachates even during prolonged storage. Improper disposal of animal carcasses and abandoned livestock facilities can also contribute to water quality problems. Siting of livestock operations in areas prone to flooding or where there is a shallow water table increases the potential for environmental contamination.

The nutrient content of the wastes can be a desirable factor for land application as fertilizer for row crops, but overapplication of livestock wastes can overload soils with both macronutrients such as nitrogen (N) and phosphorous (P), and heavy metals added to feed as micronutrients (e.g., Barker and Zublena 1995). Overapplication of animal wastes or application of animal wastes to saturated soils can also cause contaminants to move into receiving waters through runoff and to leach through permeable soils to vulnerable aquifers. Importantly, this may happen even at recommended application rates. As examples, Westerman et al. (1995) found 3–6 mg nitrate (NO_3)/L in surface runoff from sprayfields that received swine effluent at recommended rates; Stone et al. (1995) measured 6–8 mg total inorganic N/L and 0.7–1.3 mg P/L in a stream adjacent to swine effluent sprayfields. Evans et al. (1984) reported 7–30 mg NO_3/L in subsurface flow draining a sprayfield for swine wastes, applied at recommended rates. Ham and DeSutter (2000) described export rates of up to 0.52 kg ammonium m^{-2} $year^{-1}$ from lagoon seepage; Huffman and Westerman (1995) reported that groundwater near swine waste lagoons averaged 143 mg inorganic N/L, and estimated export rates at 4.5 kg inorganic N/day. Thus, nutrient losses into receiving waters can be excessive relative to levels (~ 100–200 µg inorganic N or P/L)

This article is part of the mini-monograph "Environmental Health Impacts of Concentrated Animal Feeding Operations: Anticipating Hazards—Searching for Solutions."

Address correspondence to P.S. Thorne, College of Public Health, 100 Oakdale Campus, The University of Iowa, 176 IREH, Iowa City, IA 52242 USA. Telephone: (319) 335-4216. Fax: (319) 335-4225. E-mail: peter-thorne@uiowa.edu

This workshop was supported by grant no. P30 ES05605-14S from the Environmental Health Sciences Research Center at The University of Iowa and the National Institute of Environmental Health Sciences.

The authors declare they have no competing financial interests.

Received 10 November 2005; accepted 13 November 2006.

known to support noxious algal blooms (Mallin 2000). In addition to contaminant chemical properties, soil properties and climatic conditions can affect transport of contaminants. For example, sandy, well-drained soils are most vulnerable to transport of nutrients to underlying groundwater (Mueller et al. 1995). Nutrients can also readily move through soils under wet conditions (McGechan et al. 2005).

Presence of contaminants in water sources. The presence of many contaminants from livestock waste has been documented in both surface water and groundwater supplies in agricultural areas within the United States (e.g., Campagnolo et al. 2002; Kolpin et al. 2002; Meyer 2004). Urban wastewater streams also contain these contaminants, and efforts to accurately determine sources of contamination are under way (Barnes et al. 2004; Cordy et al. 2004; Kolpin DW, unpublished data). The U.S. Geological Survey (USGS) began pilot surveillance programs for organic wastewater contaminants in 1999 and expanded that effort to a national scale over the past 5 years (Kolpin et al. 2002). Recent USGS efforts have focused specifically on water quality in agricultural locations (Kolpin DW, unpublished data). Nutrient levels have been detected in high parts per million (milligrams per liter) levels; pharmaceuticals and other compounds are generally measured in low levels (ppb [micrograms per liter]). In Europe, surveillance efforts conducted in Germany documented the presence of veterinary pharmaceuticals in water resources (Hirsch et al. 1999).

Animal wastes are also rich in organics and high in biochemical oxygen-demanding materials (BOD); for example, treated human sewage contains 20–60 mg BOD/L, raw sewage contains 300–400 mg BOD/L, and swine waste slurry contains 20,000–30,000 mg BOD/L (Webb and Archer 1994). Animal wastes also carry parasites, viruses, and bacteria as high as 1 billion/g (U.S. EPA 1998). Swine wastes contain > 100 microbial pathogens that can cause human illness and disease [see review in Burkholder et al. (1997)]. About one-third of the antibiotics used in the United States each year is routinely added to animal feed to increase growth (Mellon et al. 2001). This practice is promoting increased antibiotic resistance among the microbial populations present and, potentially, increased resistance of naturally occurring pathogens in surface waters that receive a portion of the wastes.

Contaminant impacts. Some contaminants pose risks for adverse health impacts in wildlife or humans. The effects of numerous waterborne pathogens on humans are well known, although little is known about potential impacts of such microorganisms on aquatic life. With respect to nutrients, excessive phosphorus levels can contribute to algal blooms and cyanobacterial growth in surface waters used for recreation and as sources of drinking water. Research is beginning to investigate the environmental effects, including endocrine disruption and antibiotic resistance issues (Burnison et al. 2003; Delepee et al. 2004; Fernandez et al. 2004; Halling-Sorensen et al. 2003; Sengelov et al. 2003; Soto et al. 2004; Wollenberger et al. 2000). However, knowledge is limited in several crucial areas. These areas include information on metabolites or environmental degradates of some parent compounds; the environmental persistence, fate, and transport and toxicity of metabolites or degradates (Boxall et al. 2004); the potential synergistic effects of various mixtures of contaminants on target organisms (Sumpter and Johnson 2005); and the potential transport and effects from natural and synthetic hormones (Hanselman et al. 2003; Soto et al. 2004). Further, limited monitoring has been conducted of ecosystem health in proximity to CAFOs, including monitoring the effects on habitats from lagoon spills during catastrophic flooding (Burkholder et al. 1997; Mallin et al. 1997; Mallin et al. 2000).

Ecologic and wildlife impacts. Anoxic conditions and extremely high concentrations of ammonium, total phosphorus, suspended solids, and fecal coliform bacteria throughout the water column for approximately 30 km downstream from the point of entry have been documented as impacts of waste effluent spills from CAFOs (Burkholder et al. 1997; Mallin et al. 2000). Pathogenic microorganisms such as *Clostridium perfringens* have been documented at high densities in receiving surface waters following CAFO waste spills (Burkholder et al. 1997). These degraded conditions, especially the associated hypoxia/anoxia and high ammonia, have caused major kills of freshwater fish of all species in the affected areas, from minnows and gar to largemouth bass, and estuarine fish, including striped bass and flounder (Burkholder et al. 1997). Waste effluent spills also stimulated blooms of toxic and noxious algae. In freshwaters, these blooms include toxic and noxious cyanobacteria while in estuaries, harmful haptophytes and toxic dinoflagellates arise. Most states monitor only water-column fecal coliform densities to assess whether waterways are safe for human contact. World Health Organization (WHO) guidelines for cyanobacteria in recreational water are 20,000 cyanobacterial cells/mL, which indicates low probability of adverse health effects, and 100,000 cyanobacterial cells/mL, which indicates moderate probability of adverse health effects (WHO 2003). Yet fecal bacteria and other pathogenic microorganisms typically settle out to the sediments where they can thrive at high densities for weeks to months following CAFO waste effluent spills (Burkholder et al. 1997).

The impacts from CAFO pollutant loadings to direct runoff are more substantial after such major effluent spills or when CAFOs are flooded and in direct contact with surface waters (Wing et al. 2002). Although the acute impacts are often clearly visible—dead fish floating on the water surface, or algal overgrowth and rotting biomass—the chronic, insidious, long-term impacts of commonly accepted practices of CAFO waste management on receiving aquatic ecosystems are also significant (U.S. EPA 1998). One purpose of manure storage basins is to reduce the N content of the manure through volatilization of ammonia and other N-containing molecules. Many studies have shown, for example, that high nutrient concentrations (e.g., ammonia from swine CAFOs, or ammonia oxidized to NO_3, or phosphorus from poultry CAFOs) commonly move off-site to contaminate the overlying air and/or adjacent surface and subsurface waters (Aneja et al. 2003; Evans et al. 1984; Sharpe and Harper 1997; Sharpley and Moyer 2000; Stone et al. 1995; U.S. EPA 1998; Webb and Archer 1994; Westerman et al. 1995; Zahn et al. 1997). Inorganic N forms are added to the atmosphere during spray practices, and both ammonia and phosphate can also adsorb to fine particles (dust) that can be airborne. The atmospheric depositions are noteworthy, considering that a significant proportion of the total ammonium from uncovered swine effluent lagoons and effluent spraying (an accepted practice in some states) reenters surface waters as local precipitation or through dry fallout (Aneja et al. 2003; U.S. EPA 1998, 2000). The contributed nutrient concentrations from the effluent greatly exceed the minimal levels that have been shown to promote noxious algal blooms (Mallin 2000) and depress the growth of desirable aquatic habitat species (Burkholder et al. 1992). The resulting chronically degraded conditions of nutrient overenrichment, while not as extreme as during a major waste spill, stimulate algal blooms and long-term shifts in phytoplankton community structure from desirable species (e.g., diatoms) to noxious species.

A summary of the findings from a national workshop on environmental impacts of CAFOs a decade ago stated that there was "a surprising lack of information about environmental impacts of CAFOs to adjacent lands and receiving waters" (Thu K, Donham K, unpublished data). Although the knowledge base has expanded since that time, especially regarding adverse effects of inorganic N and P overenrichment and anoxia, impacts of many CAFO pollutants on receiving aquatic ecosystems remain poorly understood. As examples, there is poor understanding of the impacts of fecal bacteria and other microbial pathogens from CAFO waste effluent contamination on aquatic communities; impacts of antibiotic-resistant bacteria created from CAFO wastes on aquatic life; impacts of organic nutrient forms preferred by certain noxious plankton; impacts from the contributed pesticides and heavy metals; and impacts from these pollutants acting in concert, additively or synergistically. This lack of information represents a critical gap in our present ability to assess the full extent of CAFO impacts on aquatic natural resources.

Despite their widespread use, antibiotics have only recently received attention as environmental contaminants. Most antibiotics are designed to be quickly excreted from the treated organism. Thus, it is not surprising that antibiotics are commonly found in human and animal waste (Christian et al. 2003; Dietze et al. 2005; Glassmeyer et al. 2005; Meyer 2004) and in water resources affected by sources of waste (Glassmeyer et al. 2005; Kolpin et al. 2002). Although some research has been conducted on the environmental effects from antibiotics (e.g., Brain et al. 2005; Jensen et al. 2003), much is yet to be understood pertaining to long-term exposures to low levels of antibiotics (both individually and as part of complex mixtures of organic contaminants in the environment). The greatest risks appear to be related to antibiotic resistance (Khachatourians 1998; Kummerer 2004) and natural ecosystem functions such as soil microbial activity and bacterial denitrification (Costanzo et al. 2005; Thiele-Bruhn and Beck 2005).

Human health impacts. Exposure to waterborne contaminants can result from both recreational use of affected surface water and from ingestion of drinking water derived from either contaminated surface water or groundwater. High-risk populations are generally the very young, the elderly, pregnant women, and immunocompromised individuals. Recreational exposures and illnesses include accidental ingestion of contaminated water that may result in diarrhea or other gastrointestinal tract distress from waterborne pathogens, and dermal contact during swimming that may cause skin, eye, or ear infections. Drinking water exposures to pathogens could occur in vulnerable private wells; under normal circumstances community water utilities disinfect water sufficiently before distribution to customers. Cyanobacteria (blue–green algae) in surface water can produce toxins (e.g., microcystins) that are known neurotoxins and hepatotoxins. Acute and chronic health impacts from these toxins can occur from exposures to both raw water and treated water (Carmichael et al. 2001; Rao et al. 2002). Removal of cyanotoxins during drinking water treatment is a high priority for the drinking water industry (Hitzfield et al. 2000; Rapala et al. 2002). The WHO has set a provisional drinking water guideline of 1 µg microcystin-LR/L (Chorus and Bartram 1999). While there are no drinking water standards in the United States for cyanobacteria, they are on the U.S. EPA Unregulated Contaminant Monitoring Rule List 3 (U.S. EPA 2006).

Exposure to chemical contaminants can occur in both private wells and community water supplies, and may present health risks. High nitrate levels in water used in mixing infant formula have been associated with risk for methemoglobinemia (blue-baby syndrome) in infants under 6 months of age, although other health factors such as diarrhea and respiratory disease have also been implicated (Ward et al. 2005). The U.S. EPA drinking water standard of 10 mg/L NO_3–N and the WHO guideline of 11 mg/L NO_3–N were set because of concerns about methemoglobinemia. (Note: "nitrate" refers to nitrate–nitrogen). Epidemiologic studies of noncancer health outcomes and high nitrate levels in drinking water have reported an increased risk of hyperthyroidism (Seffner 1995) from long-term exposure to levels between 11–61 mg/L (Tajtakova et al. 2006). Drinking water nitrate at levels < 10 mg/L has been associated with insulin-dependent diabetes (IDDM; Kostraba et al. 1992), whereas other studies have shown an association with IDDM at nitrate levels > 15 mg/L (Parslow et al. 1997) and > 25 mg/L (van Maanen et al. 2000). Increased risks for adverse reproductive outcomes, including central nervous system malformations (Arbuckle et al. 1988) and neural tube defects (Brender et al. 2004; Croen et al. 2001), have been reported for drinking water nitrate levels < 10 mg/L.

Anecdotal reports of reproductive effects of nitrate in drinking water include a case study of spontaneous abortions in women consuming high nitrate water (19–26 mg/L) from private wells (Morbidity and Mortality Weekly Report 1996).

While amassing experimental data suggest a role for nitrate in the formation of carcinogenic *N*-nitroso compounds, clear epidemiologic findings are lacking on the possible association of nitrate in drinking water with cancer risk. Ecologic studies have reported mixed results for cancers of the stomach, bladder, and esophagus (Barrett et al. 1998; Cantor 1997; Eicholzer and Gutzwiller 1990; Morales-Suarez-Varela et al. 1993, 1995) and non-Hodgkin lymphoma (Jensen 1982; Weisenburger 1993), positive findings for cancers of the nasopharynx (Cantor 1997), prostate (Cantor 1997), uterus (Jensen 1982; Thouez et al. 1981), and brain (Barrett et al. 1998), and negative findings for ovarian cancer (Jensen 1982; Thouez et al. 1981). Positive findings have generally been for long-term exposures at > 10 mg/L nitrate. Case–control studies have reported mixed results for stomach cancer (Cuello et al. 1976; Rademacher et al. 1992; Yang et al. 1998); positive results for non-Hodgkin lymphoma at > 4 mg/L nitrate (Ward et al. 1996) and colon cancer at > 5 mg/L (De Roos et al. 2003); and negative results for cancers of the brain (Mueller et al. 2001; Steindorf et al. 1994), bladder (Ward et al. 2003), and rectum (De Roos et al. 2003), all at < 10 mg/L. Cohort studies have reported no association between nitrate in drinking water and stomach cancer (Van Loon et al. 1998); positive associations with cancers of the bladder and ovary at long-term exposures > 2.5 mg/L (Weyer et al. 2001); and inverse associations with cancers of the rectum and uterus, again at > 2.5 mg/L (Weyer et al. 2001).

Exposure to low levels of antibiotics and other pharmaceuticals in drinking water (generally at micrograms per liter or nanograms per liter) represent unintentional doses of substances generally used for medical purposes to treat active disease or prevent disease. The concern is more related to possible cumulative effects of long-term low-dose exposures than on acute health effects (Daughton and Ternes 1999). A recent study conducted in Germany found that the margin between indirect daily exposure via drinking water and daily therapeutic dose was at least three orders of magnitude, concluding that exposure to pharmaceuticals via drinking water is not a major health concern (Webb et al. 2003). It should be noted that when prescribing medications, providers ensure patients are not taking incompatible drugs, but exposure via drinking water is beyond their control.

Endocrine-disrupting compounds are chemicals that exhibit biological hormonal activity, either by mimicking natural estrogens, by canceling or blocking hormonal actions, or by altering how natural hormones and their protein receptors are made (McLachlan and Korach 1995). Although very low levels of estrogenic compounds can stimulate cell activity, the potential for human health effects, such as breast and prostate cancers, and reproductive effects from exposure to endocrine disruptors, is in debate (Weyer and Riley 2001).

Workshop Recommendations

Priority research needs.

- Ecosystems monitoring: Systematic sustained studies of ecosystem health in proximity to large CAFOs are needed, including effects of input spikes during spills or flooding events.
- Toxicologic assessment of contaminants: Identification and prioritization of contaminants are needed to identify those that are most significant to environmental and public health. Toxicity studies need to be conducted to identify and quantify contaminants

(including metabolites), and to investigate interactions (synergistic, additive, and antagonistic effects).

- Fate and transport: Studies of parent compounds and metabolites in soil and water must be conducted, and the role of sediment as a carrier and reservoir of contaminants must be evaluated.
- Surveillance programs: Programs should be instituted to assess private well water quality in high-risk areas. Biomonitoring programs should be designed and implemented to assess actual dose from environmental exposures.

Translation of science to policy.

- Wastewater and drinking water treatment: Processes for water treatment must be monitored to ensure adequate removal or inactivation of emerging contaminants.
- Pollution prevention: Best management practices should be implemented to prevent or minimize release of contaminants into the environment.
- Education: Educational materials should be continued to be developed and distributed to agricultural producers.

References

Aneja VP, Nelson DR, Roelle PA, Walker JT. 2003. Agricultural ammonia emissions and ammonium concentrations associated with aerosols and precipitation in the southeast United States. J Geophys Res 108(D4):ACH12-1–12-11.

Arbuckle TE, Sherman GJ, Corey PN, Walters D, Lo B. 1988. Water nitrates and CNS birth defects: a population-based case-control study. Arch Environ Health 43:162–167.

Barker JC, Zublena JP. 1995. Livestock Manure Nutrient Assessment in North Carolina. Final Report. Raleigh, NC: North Carolina Agricultural Extension Service, North Carolina State University.

Barnes KK, Christenson SC, Kolpin DW, Focazio MJ, Furlong ET, Zaugg SD, et al. 2004. Pharmaceuticals and other organic wastewater contaminants within a leachate plume downgradient of a municipal landfill. Ground Water Monitoring Rev 24:119–126.

Barrett JH, Parslow RC, McKinney PA, Law GR, Forman D. 1998. Nitrate in drinking water and the incidence of gastric, esophageal, and brain cancer in Yorkshire, England. Cancer Causes Control 9:153–159.

Boxall ABA, Kolpin DW, Halling-Sorenson B, Tolls J. 2003. Are veterinary medicines causing environmental risks? Environ Sci Technol 37:286A–294A.

Boxall ABA, Sinclair CJ, Fenner K, Kolpin DW, Maund SJ. 2004. When synthetic chemicals degrade in the environment. Environ Sci Technol 38:369A–375A.

Brain RA, Wilson CJ, Johnson DJ, Sanderson H, Bestari K, Hanson ML, et al. 2005. Effects of a mixture of tetracyclines to *Lemna gibba* and *Miriophyllum sibiricum* evaluated in aquatic microcosms. Environ Pollution 138:425–442.

Brender JD, Olive JM, Felkner M, Suarez L, Marckwardt W, Hendricks KA. 2004. Dietary nitrites and nitrates, nitrosable drugs, and neural tube defects. Epidemiology 15:330–336.

Burkholder JM, Mallin MA, Glasgow HB, Larsen LM, McIver MR, Shank GC, et al. 1997. Impacts to a coastal river and estuary from rupture of a large swine waste holding lagoon. J Environ Qual 26:1451–1466.

Burkholder JM, Mason KM, Glasgow HB. 1992. Water-column nitrate enrichment promotes decline of eelgrass (*Zostera marina* L.): evidence from seasonal mesocosm experiments. Mar Ecol Prog Ser 81:163–178.

Burnison BK, Hartmann A, Lister A, Servos MR, Ternes T, Van der Kraak G. 2003. A toxicity identification evaluation approach to studying estrogenic substances in hog manure and agricultural runoff. Environ Toxicol Chem 22:2243–2250.

Campagnolo ER, Johnson KR, Karpati A, Rubin CS, Kolpin DW, Meyer MT, et al. 2002. Antimicrobial residues in animal waste and water resources proximal to large-scale swine and poultry feeding operations. Sci Total Environ 299:89–95.

Cantor KP. 1997. Drinking water and cancer. Cancer Causes Control 8:292–308.

Carmichael WW, Azevedo SMFO, An JS, Molica RJR, Jochimsen EM, Lau S, et al. 2001. Human fatalities from cyanobacteria: chemical and biological evidence for cyanotoxins. Environ Health Perspect 109:663–668.

Chorus I, Bartram J, eds. 1999. Toxic Cyanobacteria in Water—A Guide to their Public Health Consequences, Monitoring and Management. Geneva:World Health Organization. Available: http://www.who.int/water_sanitation_health/resourcesquality/toxicyanbact/en/ [accessed 5 January 2007].

Christian T, Schneider RJ, Barber HA, Skutlarek D, Meyer GT, Goldrach HE. 2003. Determination of antibiotic residues in manure, soil, and surface waters. Acta Hydrochim Hydrobiol 31:36–44.

Cordy G, Duran N, Bower H, Rice R, Kolpin DW, Furlong ET, et al. 2004. Do pharmaceuticals, pathogens, and other organic wastewater compounds persist when wastewater is used for recharge? Ground Water Monitoring Rev 24:58–69.

Costanzo SD, Murby J, Bates J. 2005. Ecosystem response to antibiotics entering the aquatic environment. Marine Pollut Bull 51:218–223.

Croen LA, Todoroff K, Shaw GM. 2001. Maternal exposure to nitrate from drinking water and diet and risk for neural tube defects. Am J Epidemiol 153:325–331.

Cromwell GL. 2002. Why and how antibiotics are used in swine production. Anim Biotechnol 13:7–27.

Cuello C, Correa P, Haenszel W, Gordillo G, Brown C, Archer M, et al. 1976. Gastric cancer in Columbia. 1. Cancer risk and suspect environmental agents. J Natl Cancer Inst 57:1015–1020.

Daughton CG, Ternes TA. 1999. Pharmaceuticals and personal care products in the environment: agents of subtle change? Environ Health Perspect 107:907–938.

Delepee R, Pouliquen H, Le Bris H. 2004. The bryophyte *Fontinalis antipyretica* Hedw. bioaccumulates oxytetracycline, flumequine and oxolinic acid in the freshwater environment. Sci Total Environ 322:243–253.

De Roos AJ, Ward MH, Lynch CF, Cantor KP. 2003. Nitrate in public water supplies and the risk of colon and rectum cancers. Epidemiology 14:640–649.

Dietze JE, Scribner EA, Meyer MT, Kolpin DW. 2005. Occurrence of antibiotics in water from 13 fish hatcheries, 2001–03. Intern J Environ Anal Chem 85:1141–1152.

Eicholzer M and Gutzwiller F. 1990. Dietary nitrates, nitrites and *N*-nitroso compounds and cancer risk: a review of the epidemiologic evidence. Nutr Rev 56:95–105.

Evans, RO, Westerman PW, Overcash MR. 1984. Subsurface drainage water quality from land application of swine lagoon effluent. Trans Am Soc Agric Eng 27:473–480.

Extension Toxicology Network. 2003. Exotoxnet—A Pesticide Information Project of the Cooperative Extension Offices of Cornell University, Michigan State University, Oregon State University, and the University of California at Davis. U.S. Department of Agriculture, Extension Service, and the National Agricultural Pesticide Impact Assessment Program. Available: http://ace.orst.edu/info/extoxnet/ [accessed 26 September 2005].

Fernandez C, Alonso C, Babin MM, Pro J, Carbonell G, Tarazona JV. 2004. Ecotoxicological assessment of doxycycline in aged pig manure using multispecies soil systems. Sci Total Environ 323:63–69.

Gaskins HR, Collier CT, Anderson DB. 2002. Antibiotics as growth promoters: mode of action. Anim Biotechnol 13:29–42.

Gerba CP, Smith JE Jr. 2005. Sources of pathogenic microorganisms and their fate during land application of wastes. J Environ Qual 34:42–48.

Glassmeyer ST, Furlong ET, Kolpin DW, Cahill JD, Werner SL, Meyer MT, et al. 2005. Transport of chemical and microbial contaminants from known wastewater discharges: Potential for use as indicators of human fecal contamination. Environ Sci Technol 39:5157–5169.

Halling-Sorensen B, Sengelov G, Ingerslev F, Jensen LB. 2003. Reduced antimicrobial potencies of oxytetracycline, tylosin, sulfadiazine, streptomycin, ciprofloxacin, and olaquindox due to environmental processes. Arch Environ Contam Toxicol 44:7–16.

Ham JM, DeSutter TM. 2000. Toward site-specific design standards for animal-waste lagoons: protecting ground water quality. J Environ Qual 29:1721–1732.

Hanselman TA, Graetz DA, WIlkie AC. 2003. Manure-borne estrogens as potential environmental contaminants: a review. Environ Sci Technol 37:5471–5478.

Hirsch R, Ternes T, Haberer K, Kratz KL. 1999. Occurrence of antibiotics in the aquatic environment. Sci Total Environ 225:109–118.

Hitzfield BC, Hoger SJ, Dietrich DR. 2000. Cyanobacterial toxins: Removal during drinking water treatment, and human risk assessment. Environ Health Perspect 108:113–122.

Huddleston JH. 1996. How Soil Properties Affect Groundwater Vulnerability to Pesticides Contamination. Oregon State Extension Service. Available: http://wwwagcomm.ads.orst.edu/AgComWebFile/EdMat/EM8559.pdf [accessed 26 September 2005].

Huffman RL, Westerman PW. 1995. Estimated seepage losses from established swine waste lagoons in the lower coastal plain of North Carolina. Transact Am Soc Agric Eng 38:449–453.

Jensen K, Krogh PH, Sverdup LE. 2003. Effects of the antibacterial agents tiamulin, olanquindox and metronidazole and the antihelminthic ivermectin on the soil invertebrate species *Folsomia fimeteria* (Collembola) and *Enchytraeus crypticus* (Enchytraeidae). Chemosphere 50:437–443.

Jensen OM. 1982. Nitrate in drinking water and cancer in northern Jutland, Denmark, with special reference to stomach cancer. Ecotoxicol Environ Saf 9:258–267.

Jongbloed AW, Lenis NP. 1998. Environmental concerns about animal manure. J Anim Sci 76:2641–2648.

Khachatourians GG. 1998. Agricultural use of antibiotics and the evolution and transfer of antibiotic-resistant bacteria. Can Med Assoc J 159:1129–1136.

Kolpin DW, Furlong ET, Meyer MT, Thurman EM, Zaugg SD, Barber LB, et al. 2002. Pharmaceuticals, hormones and other organic wastewater contaminants in U.S. streams, 1999–2000: a national reconnaissance. Environ Sci Technol 36:1202–1211.

Kostraba JN, Gay EC, Rewers M, Hamman RF. 1992. Nitrate levels in community drinking waters and risk of IDDM: an ecological analysis. Diabetes Care 15:1505–1508.

Kummerer K. 2004. Resistance in the environment. J Antimicrob Chemother 54:311–320.

Liu X, Miller GY, McNamara PE. 2005. Do antibiotics reduce production risk for U.S. pork producers? J Agric Appl Econ 37:565–575.

Mallin MA. 2000. Impacts of industrial-scale swine and poultry production on rivers and estuaries. Am Sci 88:26–37.

Mallin, MA, Burkholder JM, Shank GC, McIver MR, Glasgow HB, Springer J, et al. 1997. Comparative impacts of effluent from poultry and swine waste holding lagoon spills on receiving rivers and tidal creeks. J Environ Qual 26:1622–1631.

McGechan MB, Lewis DR, Hooda PS. 2005. Modelling through-soil transport of phosphorous to surface waters from livestock agriculture at the field and catchment scale. Sci Total Environ 344:185–199.

McLachlan JA, Korach KS. 1995. Symposium on Estrogens in the Environment, III. Environ Health Perspect 103:3–4.

Mellon MC, Benbrook C, Benbrook KL. 2001. Estimates of antimicrobial abuse in livestock. Cambridge, MA:Union of Concerned Scientists.

Meyer MT. 2004. Use and Environmental Occurrence of Veterinary Pharmaceuticals in the United States. In: Pharmaceuticals in the Environment: Sources, Fate, Effects, and Risks (Kummerer K, ed). New York:Springer-Verlag,155–163.

Morales-Suarez-Varela M, Llopis-Gonzales A, Tejerizo-Perez ML, Ferrandiz Ferragud J. 1993. Concentration of nitrates in drinking water and its relationship with bladder cancer. J Environ Pathol Toxicol Oncol 12:229–236.

Morales-Suarez-Varela MM, Llopis-Gonzalez A, Tejerizo-Perez ML. 1995. Impact of nitrates in drinking water on cancer mortality in Valencia, Spain. Eur J Epidemiol 11:15–21.

Morbidity and Mortality Weekly Report (MMWR). 1996. Spontaneous abortions possibly related to ingestion of nitrate-contaminated well water—LaGrange County, Indiana, 1991–1994. MMWR 45:569–572.

Mueller BA, Newton, K, Holly EA, Preston-Martin S. 2001. Residential water source and the risk of childhood brain tumors. Environ Health Perspect 109:551–556.

Mueller DK, Hamilton PA, Helsel DR, Hitt KJ, Ruddy BC. 1995.

Nutrients in groundwater and surface water of the United States—an analysis of data through 1992. US Geological Survey Water Resour Invest Rep 95–4031.

Parslow RC, McKinney PA, Law GR, Staines A, Williams B, Bodansky HJ. 1997. Incidence of childhood diabetes mellitus in Yorkshire, northern England, is associated with nitrate in drinking water: an ecological analysis. Diabetologia 40(5):550–556.

Rademacher JJ, Young TB, Kanarek MS. 1992. Gastric cancer mortality and nitrate levels in Wisconsin drinking water. Arch Environ Health 47:292–294.

Raman DR, Williams EL, Layton AC, Burns RT, Easter JP, Daugherty AS, et al. 2004. Estrogen content of dairy and swine wastes. Environ Sci Technol 38:3567–3573.

Rao PV, Gupta N, Bhaskar AS, Jayaraj R. 2002. Toxins and bioactive compounds from cyanobacteria and their implications on human health. J Environ Biol 23:215–224.

Rapala J, Lahti K, Rasanen LA, Esala AL, Niemela SI, Sivonen K. 2002. Endotoxins associated with cyanobacteria and their removal during drinking water treatment. Water Res 36:2627–2635.

Schets FM, During M, Italiaander R, Heijnen L, Rutjes SA, van der Zwaluw WK, et al. 2005. *Escherichia coli* O157:H7 in drinking water from private water supplies in the Netherlands. Water Res 39:4485–4493.

Seffner W. 1995. Natural water contents and endemic goiter. Zantralblatt Hyg Umwelt 196:381–398.

Sengelov G, Agerso Y, Halling-Sorensen B, Baloda SB, Andersen JS, Jensen LB. 2003. Bacterial antibiotic resistance levels in Danish farmland as a result of treatment with pig manure slurry. Environ Int 28:587–595.

Sharpe RR and Harper LA. 1997. Ammonia and nitrous oxide emissions from sprinkler irrigation applications of swine effluent. J Environ Qual 26:1703–1706.

Sharpley A, Moyer B. 2000. Phosphorus forms in manure and compost and their release during simulated rainfall. J Environ Qual 29:1462–1469.

Soto AM, Calabro JM, Prechtl NV, Yau AY, Orlando EF, Daxenberger A, et al. 2004. Androgenic and estrogenic activity in water bodies receiving cattle feedlot effluent in eastern Nebraska, USA. Environ Health Perspect 112:346–352.

Steindorf K, Schlehofer B, Becher H, Hornig G, Wahrendorf J. 1994. Nitrate in drinking water: a case-control study on primary brain tumours with an embedded drinking water survey in Germany. Int J Epidemiol 23:451–457.

Stone KC, Hunt PG, Coffey SW, Matheny TA. 1995. Water quality status of A USDA water quality demonstration project in the Eastern Coastal Plain. J Soil Wat Conserv 50:567–571.

Sumpter JP, Johnston AC. 2005. Lessons from endocrine disruption and their application to other issues concerning trace organics in the aquatic environment. Environ Sci Technol 39:4321–4332.

Tajtakova M, Semanova Z, Tomkova Z, Szokeova E, Majoroa J, Radikova Z, et al. 2006. Increased thyroid volume and frequency of thyroid disorders signs in schoolchildren from nitrate polluted area. Chemosphere 62:559–564.

Thiele-Bruhn S, Beck IC. 2005. Effects of sulfonamide and tetracycline antibiotics on soil microbial activity and microbial biomass. Chemosphere 59:457–465.

Thouez J-P, Beauchamp Y, Simard A. 1981. Cancer and the physicochemical quality of drinking water in Quebec. Soc Sci Med 15D:213–223.

University of Iowa and Iowa State Study Group. 2002. Iowa Concentrated Animal Feeding Operations Air Quality Study. Iowa City, IA:The University of Iowa College of Public Health.

U.S. EPA. 1998. Environmental Impacts of Animal Feeding Operations. Washington, DC:U.S. Environmental Protection Agency, Office of Water, Standards and Applied Sciences Division. Available: http://www.epa.gov/ostwater/guide/feedlots/envimpct.pdf [accessed 26 September 2005].

U.S. EPA. 2000. Deposition of Air Pollutants to the Great Waters. 3rd Report to the U.S. Congress. (1) Section A. Washington, DC:U.S. Environmental Protection Agency.

U.S. EPA. 2006. Approved Methods for Unregulated Contaminants. U.S. Environmental Protection Agency. Available: http://www.epa.gov/ogwdw/methods/unregtbl.html [accessed 5 January 2007].

Van Loon AJM, Botterweck AAM, Goldbohm RA, Brants HAM, van Klaveren JD, van den Brandt PA. 1998. Intake of nitrate and nitrite and the risk of gastric cancer: a prospective cohort study. Br J Cancer 7:129–135.

Van Maanen JM, Albering HJ, de Kok TM, van Breda SG, Curfs DM, Vermeer IT, et al. 2000. Does the risk of childhood diabetes mellitus require revision of the guideline values for nitrate in drinking water? Environ Health Perspect 108(5):457–461.

Ward MH, Cantor KP, Riley D, Merkle S, Lynch CF. 2003. Nitrate in public water supplies and risk of bladder cancer. Epidemiology 14:183–190.

Ward MH, deKok TM, Levallois P, Brender J, Gulis G, Nolan BT, et al. 2005. Workgroup report: drinking-water nitrate and health—recent findings and research needs. Environ Health Perspect 113:1607–1614.

Ward MH, Mark SD, Cantor KP, Weisenburger DD, Correa-Villasenore A, Zahm SH. 1996. Drinking water and the risk of non-Hodgkin's lymphoma. Epidemiology 7:465–471.

Webb J, Archer JR. 1994. Pollution of soils and watercourses by wastes from livestock production systems. In: Pollution in Livestock Production Systems (Dewi IA, Axford RFE, Marai IFM, Omed HM, eds). Oxfordshire, UK:CABI Publishing, 189–204.

Webb S, Ternes T, Gibert M, Olejniczak K. 2003. Indirect human exposure to pharmaceuticals via drinking water. Toxicol Lett 142:157–167.

Weisenburger D. 1993. Potential health consequences of ground-water contamination of nitrates in Nebraska. Nebr Med J 78:7–10.

Westerman PW, Huffman RL, Feng JS. 1995. Swine-lagoon seepage in sandy soil. Transact ASAE 38(6):1749–1760.

Weyer P, Riley D. 2001. Endocrine Disruptors and Pharmaceuticals in Drinking Water. Denver, CO:AWWA Research Foundation and the American Water Works Association.

Weyer PJ, Cerhan JR, Kross BC, Hallberg GR, Kantamneni J, Breuer G, et al. 2001. Municipal drinking water nitrate level and cancer risk in older women: the Iowa Women's Health Study. Epidemiology 11:327–338.

WHO. 2003. Algae and cyanobacteria in fresh water. In: Guidelines for Safe Recreational Water Environments. Vol 1: Coastal and Fresh Waters. Geneva:World Health Organization, 136–138.

Wing S, Freedman S, Band, L. 2002. The potential impact of flooding on confined animal feeding operations in eastern North Carolina. Environ Health Perspect 110:387–391.

Wollenberger L, Halling-Sorensen B, Kusk KO. 2000. Acute and chronic toxicity of veterinary antibiotics to *Daphnia magna*. Chemosphere 40:723–730.

Yang C-Y, Cheng M-F, Tsai S-S, Hsieh Y-L. 1998. Calcium, magnesium, and nitrate in drinking water and gastric cancer mortality. Jpn J Cancer Res 89:124–130.

Zahn JA, Hatfield JL, Do YS. 1997. Characterization of volatile organic emissions and wastes from a swine production facility. J Environ Qual 26:1687–1696.

Hydrobiologia (2013) 704:293–309
DOI 10.1007/s10750-012-1266-y

WATER BODIES IN EUROPE

Water clarity and eelgrass responses to nitrogen reductions in the eutrophic Skive Fjord, Denmark

Jacob Carstensen · Dorte Krause-Jensen · Stiig Markager · Karen Timmermann · Jørgen Windolf

Received: 28 February 2012 / Accepted: 21 July 2012 / Published online: 30 August 2012

Abstract Eelgrass depth limits and water clarity in the Skive Fjord estuarine system have not improved despite nutrient input reductions of 30%. Long-term monitoring data (1989–2010) were used to investigate the underlying causes. Dissolved inorganic and organic nitrogen concentrations decreased significantly over time, whereas particulate organic nitrogen concentration, assumed to consist primarily of phytoplankton and phytoplankton detritus and calculated as a proportional factor to chlorophyll *a*, did not change. Total organic carbon, mostly of autochthonous origin, remained constant despite reduced nitrogen concentrations, resulting in an increasing C:N ratio of the organic material in the water column. Phytoplankton primary production also remained constant suggesting that phytoplankton growth was only limited by nitrogen to a minor degree. Alleviated grazing pressure caused by a reduction in the blue mussel standing stock and a pelagic food web dominated by jellyfish may have contributed to the constantly high phytoplankton levels. Particulate inorganic matter, likely reflecting sediment resuspension, increased over time, most probably in response to removal of blue mussels and declining eelgrass cover. The Skive Fjord estuarine system is affected by multiple pressures—nutrient enrichment, mussel dredging and climate change that must be addressed together for water clarity to improve and eelgrass to recover.

Keywords Eelgrass depth limit · Eutrophication · Light attenuation · Nutrients · Oligotrophication · Secchi depth

Guest editors: C. K. Feld, A. Borja, L. Carvalho & D. Hering / Water bodies in Europe: integrative systems to assess ecological status and recovery

J. Carstensen (✉) · S. Markager · K. Timmermann
Department of Bioscience, Aarhus University,
Frederiksborgvej 399, 4000 Roskilde, Denmark
e-mail: jac@dmu.dk

D. Krause-Jensen · J. Windolf
Department of Bioscience, Aarhus University,
Vejlsøvej 25, 8600 Silkeborg, Denmark

Introduction

Seagrass meadows are productive coastal ecosystems that constitute important habitats for fish, birds and invertebrates (Hemminga & Duarte, 2000). Seagrasses provide physical structure on otherwise largely bare sediments, enhancing habitat- and biodiversity, biomass, and primary and secondary production (Duffy, 2006). Seagrasses also increase water clarity by enhancing the sedimentation of particles and stabilising the sediments, which along with burial of refractory seagrass material contribute to carbon sequestration (Terrados & Duarte, 2000; Gacia et al., 2002; Carr et al., 2010; Fourqurean et al., 2012). Seagrass meadows thereby provide valuable ecosystem services to the benefit of humans as well (Duffy, 2006). However, large-scale losses of seagrasses have occurred worldwide over the last century, mainly due to eutrophication enhancing phytoplankton production leading to out shading of the seagrass community at deeper depths leading to a structural shift in dominance from benthic to pelagic plants (Short & Wyllie-Echeverria, 1996; Duarte, 2002; Green & Short, 2003; Orth et al., 2006a; Waycott et al., 2009; Krause-Jensen et al., 2012). Additional eutrophication effects such as increased risk of water column anoxia and organic over-enrichment of sediments can further hamper the occurrence of eelgrass (Pulido & Borum, 2010; Krause-Jensen et al., 2011). Global warming may accentuate these effects and may also increase respiration rates and, thus, light demands of seagrasses (Stæhr & Borum, 2011). At shallow depths with suitable substrate, the governing factors for the eelgrass distribution are the physical exposure from waves and currents (Fonseca et al., 2002; Krause-Jensen et al., 2003). All these factors lead to habitat compression that potentially erodes the resilience of seagrass meadows in shallow and turbid coastal ecosystems to absorb natural perturbations.

Eelgrass (*Zostera marina*) is the most common seagrass species in northern and western Europe with widespread distributions along the Atlantic coast from Spain to northern Norway, and reaching far into the brackish Baltic Sea (Green & Short, 2003). It often constitutes a monoculture in sandy coastal ecosystems, probably making seagrass habitats more vulnerable to perturbations such as herbivory and disease (Orth et al., 2006a). Whereas physical exposure, sediment characteristics, and to some extent also herbivory, are important factors for the overall distribution of eelgrass, the depth limit is considered a sentinel to eutrophication since light limitation is the major factor controlling the depth limit (Duarte, 1991, but see also Balsby et al., 2012). The depth limit represents a balance between primary production and loss processes, and eelgrass depth limits provide a proxy integral of the changing light condition, provided that loss processes for the deepest growing plants are constant. Therefore, the depth limit of seagrasses is also a key indicator under the European Water Framework Directive (WFD) for the biological quality element ′Macroalgae and angiosperms′ (Marbà et al., 2012).

Many studies have documented the decline of eelgrass and seagrasses in general (e.g. Orth et al., 2006a; Waycott et al., 2009), but there are few studies about their recovery. Orth et al. (2006b) reported the relatively rapid spread of eelgrass over two decades in coastal lagoons on the American East Coast, following the nearly complete disappearance after the wasting disease and a destructive hurricane. In some of the coastal lagoons, the recovery process was enhanced by restoration efforts. In Mumford Cove, an embayment on the Long Island Sound that previously received large nutrient inputs from point sources, eelgrass fully recovered 15 years after the wastewater treatment was improved (Vaudrey et al., 2010) and in Tampa Bay, Florida, seagrasses have also expanded upon nutrient load reductions (Greening & Janicki, 2006; Greening et al., 2011). Thus, there is evidence to support the hypothesis that reducing nutrient inputs will gradually lead to the recovery of eelgrass.

In Denmark, nutrient inputs and concentrations have declined significantly since 1990 (Carstensen et al., 2006) following several action plans targeting both diffuse and point sources. It was therefore anticipated that eelgrass meadows, which had been decimated during the twentieth century (Boström et al., 2003; Krause-Jensen et al., 2012) would recover in response to lower nutrient levels, in particular nitrogen levels, since nitrogen is the main limiting nutrient of phytoplankton growth throughout most of the eelgrass growing season although phosphorous is also important as limiting nutrient from March to June in Limfjorden (Conley et al., 2000; Markager et al., 2006). This expectation was based on a study by Nielsen et al. (2002), who documented a significant correlation between concentrations of total nitrogen (TN) and eelgrass depth limit, based on a spatially and temporally distributed data set covering 27 estuaries and 7 years (1985–1991). Although this data did not really cover a period with decreasing nutrient concentrations, it was believed that the relationship could be used for predicting the response of eelgrass depth limit to changing TN concentrations, assuming that space could substitute for time. Historical records of eelgrass depth limit from ca 1900 have shown that eelgrass could be found at 6–8 m depth in Danish estuaries and at 10–12 m depth in coastal areas, with a spatial distribution about four times larger than at present (Boström et al., 2003). Nitrogen inputs from land were also much lower around 1900, increasing by factor of 6–7 up to the 1980s before the action plans lowered nitrogen inputs to a level about three times above that a century ago (Conley et al., 2007). For implementation of the WFD, targets have been defined as 74% of the depth limit around 1900 and the relationship of Nielsen et al. (2002) has been used to link these to a target for TN concentrations. However, to the surprise of environmental managers and scientists eelgrass has not, in general, expanded to deeper waters in Denmark, despite substantially reduced TN levels (~45%) in estuaries and coastal areas (Hansen & Petersen, 2011).

The objective of the present study was to investigate this apparent discrepancy between decreasing TN concentrations and unaltered eelgrass depth limits, rendering the use of a simple empirical relationship between these variables inapplicable in practice for nutrient management. We partitioned the nitrogen pool into different fractions (dissolved inorganic, dissolved organic and particulate organic) and examined their trends over time and estimated their contribution to light attenuation together with other attenuating substances. Finally, we discuss potential feedback mechanisms between eelgrass and resuspension/sedimentation.

Materials and methods

Study site and data

Limfjorden is a large estuarine complex in northwestern Denmark, consisting of several connected shallow basins and a total surface area of 1500 km^2 (Fig. 1). In this study, we focus on three of these basins in the southern inner most eutrophic part of Limfjorden that have been intensively monitored for more than two decades: (1) Risgårde Bredning, (2) Skive Fjord, and (3) Lovns Bredning (in Danish: Fjord and Bredning are equivalent to Estuary and Broad). These basins are referred to as the Skive Fjord estuarine system and constitute the most eutrophic part of Limfjorden. The Skive Fjord estuarine system has an average depth of about 5 m with little tidal mixing (tidal amplitude = 0.15 m). Mean salinities range from 21 in Lovns Bredning to 25 in Risgårde Bredning. Due to the shallowness and the wind-exposed character of the inlet, the water column is only stratified about 40% of the time (Carstensen et al., 2007). Phytoplankton primary production is limited by phosphorous from March to June and then by nitrogen (Conley et al., 2000; Markager et al., 2006). However,

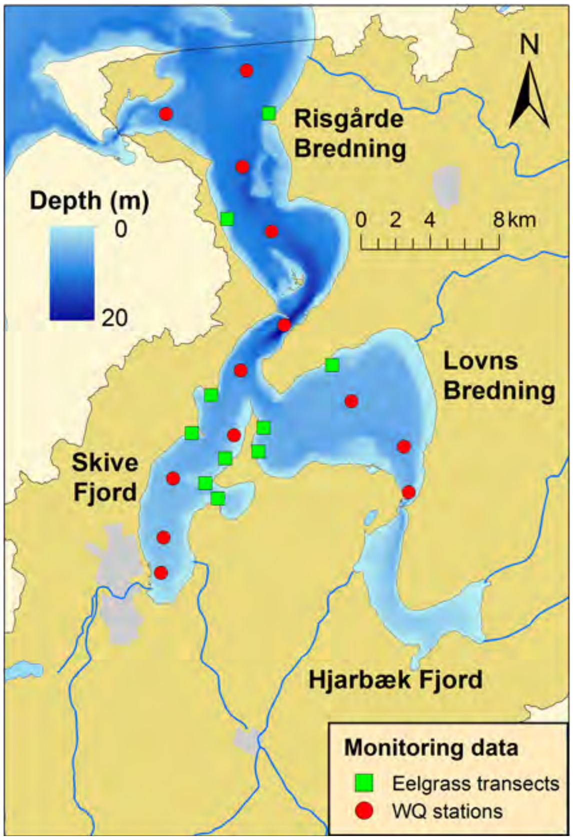


Fig. 1 Map of the study area with the location of the 13 water quality stations and 10 eelgrass transects. The three studied inter-connected basins are Risgårde Bredning (outer basin to the north), Skive Fjord (inner basin to the southwest), and Lovns Bredning (inner basin to the east). Hjarbæk Fjord (to the southeast) is a dammed brackish reservoir that is not regularly monitored and therefore not included in this study

in this study we will consider the derived effects on eelgrass from nitrogen inputs only.

The marine area of the Skive Fjord complex is 248 km^2 and the catchment area is 2620 km^2, of which 67% is intensively farmed and having a high livestock density (1.38 livestock unit per hectare in 2005). Freshwater discharges and nitrogen concentrations have been measured at a number of monitoring stations in various streams, covering 73 and 67% of the catchment area and nitrogen input, respectively. Freshwater discharges were monitored continuously using a calibrated flow versus water level relationships and samples for nutrients were normally collected every 2 weeks. Nutrient inputs were calculated using linear interpolation of nutrient concentrations and multiplying these with the discharge (Kronvang &

Table 1 Overview of periods with data and number of observations (in parentheses) for the studied monitoring variables in the different basins of the Skive Fjord estuarine system

Monitoring variable	Risgårde Bredning	Skive Fjord	Lovns Bredning
Eelgrass depth limit	1989–2008, 2010 (24)	1989–2008, 2010 (58)	1996–2008, 2010 (29)
Secchi depth	1989–2010 (3432)	1989–2010 (1687)	1989–2010 (1516)
K_d	1998–2008[a] (478)	1998–2010 (595)	1998–2009 (365)
DIN	1989–2008[a] (620)	1989–2010 (744)	1989–2006 (716)
TN	1989–2008[a] (620)	1989–2010 (744)	1989–2006 (716)
Chl*a*	1989–2008[a] (617)	1989–2010 (733)	1989–2006 (697)
TSS	1989–2008[a] (613)	1989–2010 (744)	1989–2006 (716)
OrgSS	1989–2008[a] (610)	1989–2010 (742)	1989–2006 (605)
POC		1999–2003 (224)	
TOC	1989–1997 (155)	1989–2003 (490)	1989–1997 (145)
Primary production		1989–2008 (535)	1989–1997 (200)

Eelgrass was not monitored in 2009

[a] Data from 2008 available for January–March only

Bruhn, 1996). Nutrient inputs from point sources were calculated in a similar manner from measured freshwater discharges and nitrogen concentrations, whereas nutrient inputs from the ungauged catchment were modelled according to Windolf et al. (2011). Finally, atmospheric depositions of nitrogen were measured at several monitoring stations in Denmark and the average annual deposition at the two nearest stations (Ulborg and Tange) was scaled up with the area of the study site and adjusted for lower depositions on a water surface. Consistent nutrient input data were available from 1990 to 2010, whereas estimates using a different method were available for specific years in the 1980s.

Eelgrass monitoring began in 1989 and 10 transects (Fig. 1) have been monitored during the study period (1989–2010), following the standard procedures laid out in the guidelines for the Danish National Aquatic Monitoring and Assessment Program (DNAMAP). A diver swims along a line transect from the coast towards deeper waters assessing eelgrass cover until the maximum depth limit, i.e. the deepest occurring shoot is reached. The diver then swims perpendicular to the transect line and records a total of 5–7 observations of the maximum depth limit. The number of transects monitored every year in each of the basins varied from 1 to 6 with most observations from the Skive Fjord basin (Table 1).

Water quality has been sampled at 13 stations, mostly in the deeper parts of the basins (Fig. 1). Water quality monitoring began in 1980 but we only used data from the period corresponding to the eelgrass monitoring data (1989–2010). Skive Fjord has been monitored for the entire study period, whereas standard water quality monitoring ceased in Lovns Bredning in 2006 and in Risgårde Bredning in March 2008 (Table 1). In each basin, one station has been monitored all years during the period, but in general data were heterogeneously distributed over months and across stations. Nutrients, DIN calculated as the sum of measured ammonium, nitrite and nitrate and TN, were measured by standard chemical techniques (Grasshoff, 1976). Chlorophyll *a* (Chl*a*) was extracted in 90% acetone and measured by trichromatic spectrophotometry (Strickland & Parsons, 1972), total suspended solids (TSS) and loss on ignition of total suspended solids (OrgSS) were measured after filtering the particles of a water sample onto a Whatman GF/C filter, and TOC and POC were measured using infrared spectrophotometry (ISO-CEN EN 1484) on acid-treated samples (filtered for POC). Samples from the top 5 m (either 1 or 2 samples representing the water column above the eelgrass) were averaged before the statistical analyses. Primary production was measured using standard ^{14}C techniques for surface water samples incubated in the dark and at various irradiance levels (Steemann Nielsen, 1952; Markager et al., 1999). The light attenuation coefficient (K_d) was calculated from irradiance profiles (recorded every 0.2 m) measured with a spherical PAR sensor from

Table 2 Trend analysis by linear regression of yearly mean values (1989–2010) for March to September of nitrogen and suspended solids fractions as well as Secchi depth and eelgrass depth limit (cf. Fig. 3)

Monitoring variable	Risgårde Bredning	Skive Fjord	Lovns Bredning
DIN (μmol l^{-1})	**−0.518 (0.0002)**	**−0.365 (0.0389)**	−0.619 (0.1658)
DON (μmol l^{-1})	**−1.323 (0.0002)**	**−1.519 (<0.0001)**	**−1.661 (0.0001)**
PON (μmol l^{-1})	−0.034 (0.4542)	−0.061 (0.1731)	−0.214 (0.0639)
TN (μmol l^{-1})	**−2.052 (<0.0001)**	**−2.140 (<0.0001)**	**−2.714 (0.0026)**
TSS (mg l^{-1})	0.011 (0.9130)	0.081 (0.3195)	−0.088 (0.4944)
OrgSS (mg l^{-1})	−0.051 (0.0886)	−0.047 (0.0620)	**−0.107 (0.0062)**
InorgSS (mg l^{-1})	0.133 (0.0699)	**0.174 (0.0033)**	0.123 (0.0785)
Secchi depth (m)	**−0.031 (0.0343)**	−0.005 (0.6770)	−0.005 (0.7014)
Eelgrass depth limit (m)	**−0.102 (<0.0001)**	0.005 (0.6802)	−0.024 (0.6477)

Slopes (unit × year^{-1}) and their significance (P value in parentheses) are listed for each trend analysis, and significant trends ($P < 0.05$) are highlighted in bold

1998 and onwards. Before 1998 and in case of technical problems, Secchi depth was measured only (Table 2). The marine monitoring data can be downloaded from http://mads.dmu.dk.

Statistical analyses

The concentration of organic nitrogen (ON) was calculated as ON = TN − DIN, but to partition this pool further into a dissolved and particulate fraction, which were not measured directly, it was assumed that most of the particulate fraction would be constituted by phytoplankton and phytoplankton detritus. The particulate organic nitrogen (PON) was therefore approximated by scaling the Chl*a* concentration with factor 0.43, determined as the average ratio between measurements of POC and Chl*a* (weight ratio of 34.3), divided by the molar weight of C (12) and the Redfield ratio (C:N = 106:16). The dissolved organic nitrogen (DON) was consequently found as DON = ON − PON. The inorganic fraction of the total suspended solids (InorgSS) were found as InorgSS = TSS − OrgSS.

For each basin separately, yearly means (1989–2010) of eelgrass depth limits, nitrogen (DIN, DON, PON and TN) and suspended solids (TSS, OrgSS and InorgSS) concentrations from March through September were computed through use of a general linear model (GLM) that described variations between transects/stations, years, and months after log-transformation of the observations (see Carstensen & Henriksen, 2009 for details). The specific months (Mar–Sep) were chosen as the period where sufficient light for eelgrass growth can be expected. Nitrogen and suspended solid concentrations were log-transformed before applying the model. The GLM resolved the spatial and temporal heterogeneity of monitoring data to produce yearly estimates (computed as marginal means), unbiased by differences in the months and stations sampled across years (Searle et al., 1980). The yearly means for nitrogen and suspended solid fractions were back-transformed to their original scale using the exponential function, thus providing estimates of the geometric means (i.e. the medians). Due to the shallowness of the different basins the Secchi disc occasionally reached the bottom (about 0.5, 13 and 5% of the observations in Risgårde Bredning, Skive Fjord and Lovns Bredning, respectively), and therefore the statistical method in Carstensen (2010) was used to analyse these censored observations and derive yearly means of Secchi depth (Mar–Sep) unbiased by the censoring. Trends in the yearly means were tested using linear regression.

The chain of cause-effect relationships from nutrient inputs to eelgrass depth limit was broken down into three separate hypotheses: (1) nutrient concentrations in the estuarine system were mainly controlled by nutrient inputs, (2) Secchi depth and light attenuation were mainly governed by the nitrogen and TSS fractions in the water, and (3) eelgrass depth limit was mainly controlled by light. These hypotheses were investigated separately using the raw observations (hypothesis 2) or annual means (hypotheses 1 and 3).

First, annual means of DIN, DON, PON and TN (Mar–Sep) were related to nitrogen inputs (Jan–Sep) by a regression model with both common and basin-specific intercepts and slopes:

$$\text{N-conc.} = \mu + a_i + b \times \text{N-input} + c_i \times \text{N-input} \quad (1)$$

where μ is the common intercept, a_i are basin-specific differences from the common intercept, b is the common slope, and c_i are basin-specific differences from the common slopes. Non-significant terms in the full model (Eq. 1) were removed and the model re-estimated, until all terms were significant ($P < 0.05$).

Second, light is generally assumed to decrease exponentially with depth and the exponential factor in this relationships (K_d = diffuse light attenuation coefficient) is controlled by light absorbing and scattering substances in the water. Water and dissolved organic matter ($\sim$DON) absorb light, whereas particulate matter ($\sim$PON and InorgSS) both scatter and absorb light. An empirical model was employed to estimate the relative importance of these substances for the diffuse light attenuation coefficient:

$$K_d = K_b + K_{DON} \times \text{DON} + K_{PON} \times \text{PON} + K_{InorgSS} \times \text{InorgSS} \quad (2)$$

where K_b is the background absorption by water itself and other substances not included with the other terms, and K_{DON}, K_{PON}, and $K_{InorgSS}$ are coefficients for the absorption and scattering of light by DON, PON and InorgSS, respectively. The inorganic fraction of TSS was used in the equation while the organic fraction (OrgSS) was already implicit included in the PON concentration. This partitioning of attenuating substances is similar to that of Olesen (1996) and Gallegos (2001). The parameters of Eq. 2 were estimated by linear regression with both common and basin-specific parameters for K_{DON}, K_{PON}, and $K_{InorgSS}$. Yearly means of DON, PON and InorgSS were subsequently inserted into Eq. 2 to calculate changes over time in their relative contribution to the light attenuation.

The diffuse light attenuation coefficient was related to Secchi depth (Z_{SD}) according to the law of Lambert–Beer and Preisendorfer (1986):

$$Z_{SD} = \frac{-\ln(I_{SD}/I_0)}{(\alpha + K_d)} \quad (3)$$

where I_{SD} is the irradiance at the Secchi depth, I_0 is the surface irradiance and α is the beam attenuation. The beam attenuation coefficient was estimated as a parameter scaled with a harmonic function for the daily max solar angle. Parameters in Eq. 3 were estimated by non-linear regression.

Third, eelgrass depth limit was assumed to be controlled mainly by light and proportional to Secchi depth (Krause-Jensen et al., 2011). Yearly means of eelgrass depth limit ($DL_{eelgrass}$) were therefore related to yearly means of Secchi depth, ideally yielding a common straight proportional relationship. However, Secchi depths were generally measured at stations with deeper water (5–10 m) than the areas with eelgrass (<2.5 m, Fig. 3h) that may not adequately represent light conditions at the eelgrass transects. Secchi depths measured at water quality stations and the presumed light conditions at the eelgrass transects were assumed to deviate by a constant, but basin-specific, difference and consequently, a linear regression with basin-specific intercepts (a_i) was analysed:

$$DL_{eelgrass} = a_i + b \times Z_{SD} \quad (4)$$

where b is the common slope. All statistics were carried out in SAS version 9.2 using PROC GLM and PROC MODEL.

Results

The annual freshwater discharge (Q) to the Skive Fjord estuarine system varied between 0.62 and 1.02 km^3 with an average of 0.84 km^3 (Fig. 2). Variations in the freshwater discharge were also clearly visible in the nitrogen loading from diffuse sources that co-varied significantly with Q ($r = 0.87$; $P < 0.0001$), although flow-weighted TN concentrations for the diffuse source decreased by almost 30% over the study period from about 360 to 260 μmol l^{-1}. Over the same period atmospheric nitrogen deposition and nitrogen input from point sources decreased by approximately 40 and 60%, respectively. However, nutrient inputs to the estuarine system were dominated by diffuse sources (88%) and with relatively minor contributions from atmosphere and point sources (both around 6%).

All nitrogen fractions declined over time (Fig. 3; Table 2). DIN concentrations decreased about 0.5 μmol l^{-1} year^{-1} in all three basins, although the decrease was not significant in Lovns Bredning due to elevated levels in 1994 and 1995 (Fig. 3a), both years with high Q and nitrogen input. Declines in DON

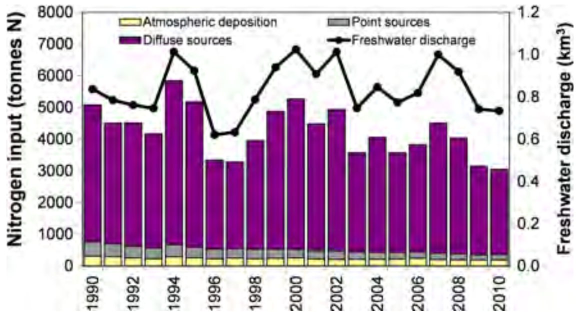


Fig. 2 Trends in annual freshwater discharge and nitrogen inputs from atmosphere point, and diffuse sources to the Skive Fjord estuarine system

concentrations were even larger ($\sim$1.5 μmol l^{-1} year^{-1}) and significant. However, the estimated PON concentration, which was scaled from measured Chl*a*, remained stable. Thus, the large decreases in TN (Fig. 3d) were mainly caused by lower DIN and DON levels.

TSS generally remained unaltered over the study period (Table 2) although lower concentrations were observed in the second half of the 1990s, but the constant TSS level over time was the combination of decreasing OrgSS (about -0.05 mg l^{-1} year^{-1}) and increasing InorgSS (about 0.15 mg l^{-1} year^{-1}) (Fig. 3e, f; Table 2). Most pronounced was the doubling in InorgSS after 2001 (Fig. 3f). Secchi depth and eelgrass depth limit did not change over the study period in the more nutrient-rich Skive Fjord and Lovns Bredning, whereas both of them decreased significantly in Risgårde Bredning (Table 2) such that all basins now have similar levels of about 3 m for Secchi depth and 1.5 m for eelgrass depth limit (Fig. 3g, h). Depth limits in Lovns Bredning did, however, show an immediate positive response to the marked increase in water clarity in 1998 (Fig. 3g, h), although a similar response was not seen in neither Skive Fjord nor Risgårde Bredning.

For all four nitrogen fractions, Eq. 1 was reduced to basin-specific proportional responses (i.e. all intercepts were not significantly different from zero but slopes were significant and basin-specific) with the steepest slope for Lovns Bredning, followed by Skive Fjord and Risgårde Bredning (Fig. 4). Both nitrogen inputs and concentrations varied by a factor of 2 over the study period. However, in absolute numbers the largest change was observed for DON (10–13 μmol l^{-1} per 1000 tons) and then DIN (2–6 μmol l^{-1} per 1000 tons), whereas the smallest change was observed for PON (1–2 μmol l^{-1} per 1000 tons). Thus, all nitrogen fractions decreased significantly with nitrogen reductions.

All four parameters in the empirical model for light attenuation (Eq. 2) were significantly different from zero, both as common and basin-specific parameters (Table 3), demonstrating that light attenuation increased, as expected, with increasing concentrations of DON, PON and InorgSS (Fig. 5). The model with common parameters for all basins explained 50% ($R^2 = 0.50$) of the variation. The variation described by basin-specific parameters was only marginally larger ($R^2 = 0.54$) and none of the four parameters differed significantly among basins or from the estimates with a common model. Only the background attenuation (K_b) tended to differ with a lower value in Risgårde Bredning compared to Skive Fjord and Lovns Bredning. This indicated that the optical properties of DON, PON and InorgSS were indeed similar across the three basins as expected if the sources were the same. There was a large unexplained variation in K_d ($\pm$0.21 m^{-1}; Fig. 5a–c) and the values of K_b of 0.25 (Table 3) were about ten times higher than K_d for pure water (Smith & Baker, 1978, 1981). Within the ranges of the observations, PON and DON had similar effects on K_d, whereas the effect of InorgSS was considerably lower (Fig. 5a–c).

Variations in Secchi depth were well described by Eq. 3 ($R^2 = 0.79$; Fig. 5d), suggesting that Secchi depth represents on average 12.9% of the surface light (I_{SD}/I_0). Beam attenuation (α) varied from 0.036 m^{-1} during spring and autumn to 0.109 m^{-1} during summer, indicating a higher scattering of light during summer where phytoplankton and hence particle concentrations were high. The decreasing DON levels (Fig. 3) resulted in a lower relative contribution to the attenuation of light over time (Fig. 6) according to the empirical relation in Eq. 2. In the beginning of the study period 40–50% of the diffuse light attenuation could be attributed to DON levels and this relative proportion decreased to 20–30% in the most recent years, with the highest overall contribution in Lovns Bredning. PON levels did not change significantly over time and the relative contribution of PON to the diffuse light attenuation was about 20% throughout the study period. Finally, the relative contribution of InorgSS to light attenuation increased from about 5 to 10–20% in response to the increasing trends and was

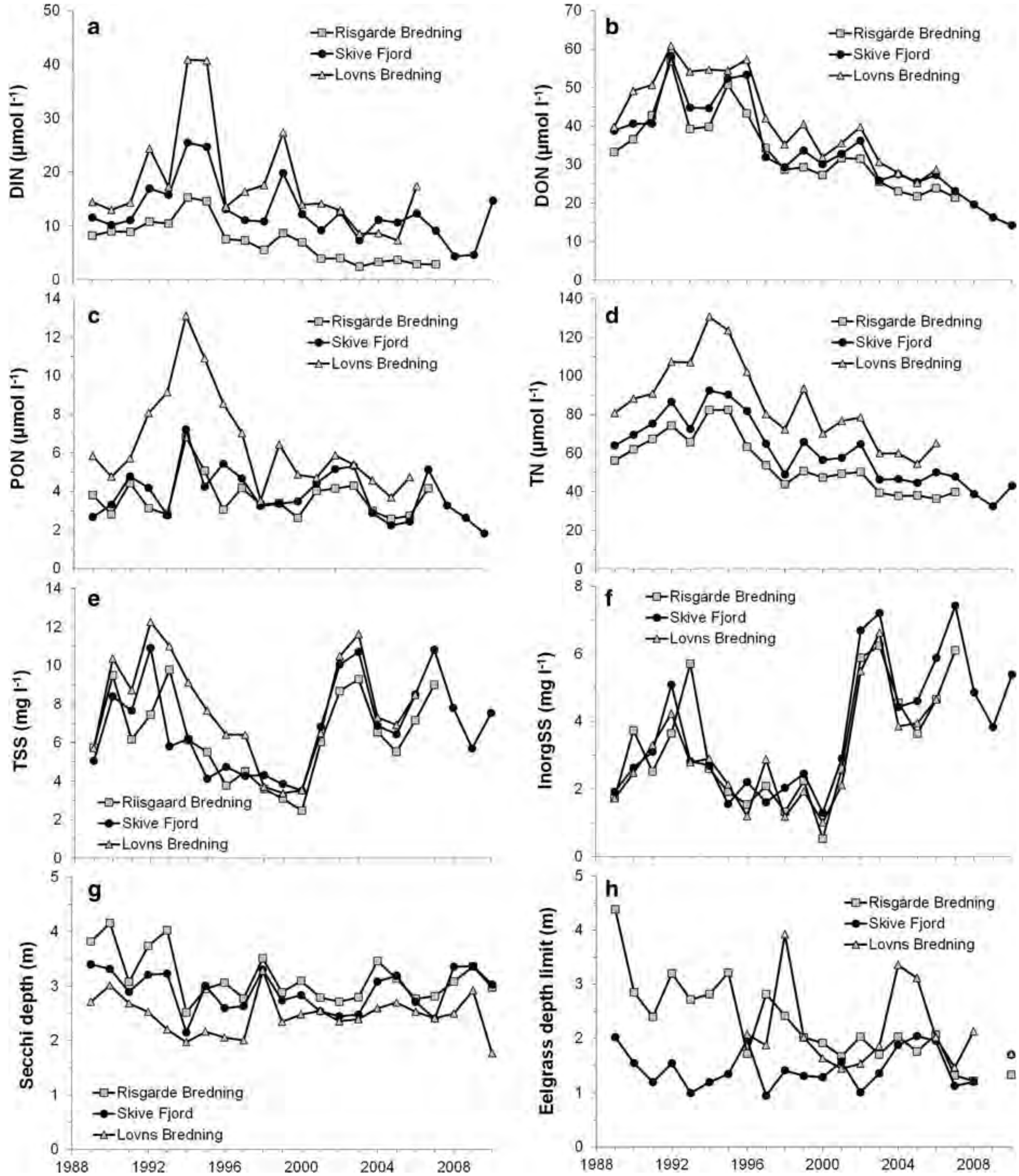


Fig. 3 Yearly means of the nitrogen and suspended solids fractions as well as Secchi depth and eelgrass depth limit (Mar–Sep) for the three basins in the Skive Fjord estuarine system

generally highest in Skive Fjord (Fig. 3). The relative background contribution, including water, other attenuating substances and interactions between absorption and scattering that were not accounted for in the DON, PON or InorgSS pools, varied between 30 and 50% for the different basins. The expected Secchi depth

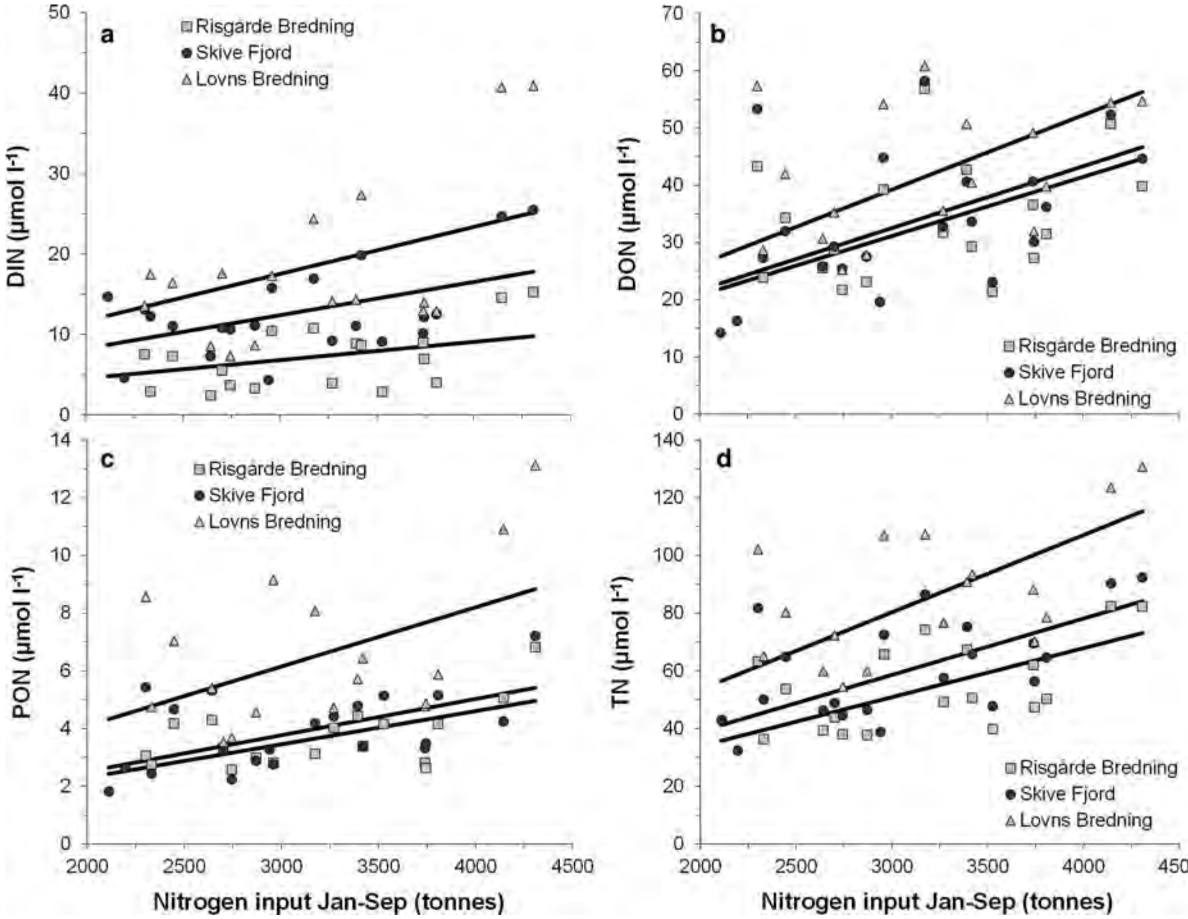


Fig. 4 Mean concentrations of different nitrogen fractions (Mar–Sep) versus nitrogen input from land and atmosphere (Jan–Sep). *Lines* show the basin-specific relationships with the steepest slope obtained for Lovns Bredning, followed by Skive Fjord and Risgårde Bredning in all *plots*. All regressions were significant ($P < 0.05$)

Table 3 Parameter estimates from Eq. 2 ($K_d = K_b + K_{DON} \times DON + K_{PON} \times PON + K_{InorgSS} \times InorgSS$) and their standard errors using common parameters for all basins and basin-specific parameters using data from March to September ($n = 750$)

Parameter	All basins	Risgårde Bredning	Skive Fjord	Lovns Bredning
K_b	0.2487 (±0.0276)	0.2238 (±0.0816)	0.3079 (±0.0402)	0.2813 (±0.0484)
K_{DON}	0.0094 (±0.0007)	0.0087 (±0.0024)	0.0090 (±0.0009)	0.0086 (±0.0012)
K_{PON}	0.0340 (±0.0014)	0.0318 (±0.0032)	0.0341 (±0.0027)	0.0350 (±0.0020)
$K_{InorgSS}$	0.0207 (±0.0023)	0.0175 (±0.0048)	0.0225 (±0.0036)	0.0201 (±0.0038)

All parameter estimates were significant ($P < 0.05$)

predicted from yearly means of DON, PON and InorgSS (Fig. 6) all had significantly increasing trends ($P < 0.01$), in contrast to the observed yearly means (Table 2). This suggests that other attenuating substances and probably in particular scattering may have increased over time.

Despite the large scatter, yearly means of eelgrass depth limits were significantly related to Secchi depths ($P = 0.0002$ for the common slope in Fig. 7) and there were significant differences between basin-specific intercepts ($F_{2,52} = 10.47$; $P = 0.0002$) with the depth limit at a given Secchi depth generally being deepest

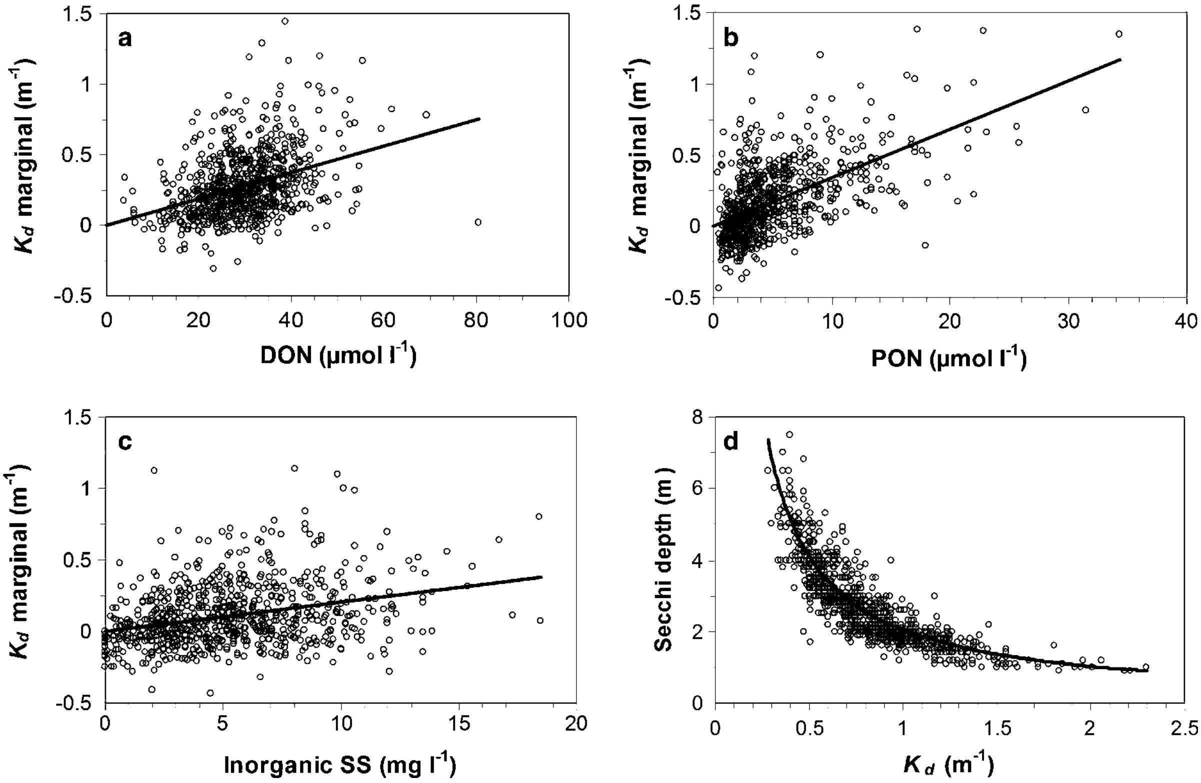


Fig. 5 Light attenuation coefficient as function of **a** DON, **b** PON, and **c** InorgSS ($n = 750$) estimated from Eq. 2. K_d marginal is the observed K_d with other effects subtracted, i.e. in **a** the predicted effects from PON and InorgSS have been subtracted from the observed K_d. **d** Relationship between Secchi depth and K_d estimated from Eq. 3

in Risgårde Bredning and shallowest in Skive Fjord. The slope from the regression suggested that eelgrass should grow to approximately 80% of the Secchi depth. The relationship between eelgrass depth limit and Secchi depth is also consistent with the declining trends for both variables in Risgårde Bredning (Fig. 3g, h). Such corresponding trends were also apparent for Lovns Bredning (Fig. 3g, h), whereas interannual variations for eelgrass depth limits in Skive Fjord had smaller ranges and was less tightly coupled to Secchi depth (Fig. 7).

Discussion

Our results confirm that light is the main governing factor for eelgrass depth limit, but light conditions are not necessarily related to nutrient concentrations in a simple manner. Reduced nitrogen inputs over the last two decades from land and atmosphere has resulted in declines for TN levels across many Danish coastal systems (Carstensen et al., 2006; Carstensen & Henriksen, 2009) as well as across the different nitrogen fractions (this study). For all basins in Limfjorden both nutrient and chlorophyll concentrations have responded with decreasing trends over the period from 1985 to 2008 (Markager et al., 2006; Krause-Jensen et al., 2012). However, light attenuation has not improved accordingly, and shows a significant decreasing trend for Limfjorden as such despite the reduction in nutrient loadings (Krause-Jensen et al., 2012) indicating that other factors than nutrient concentrations are governing light attenuation. This is also confirmed with our empirical model (Eq. 2) where DON, PON and InOrgSS were only able to explain about half of the variation in K_d. The unexplained variation in K_d and the fact that K_b is about ten times higher than the attenuation by pure water suggest that other factors are important for light attenuation and we hypothesise that two effects are important.

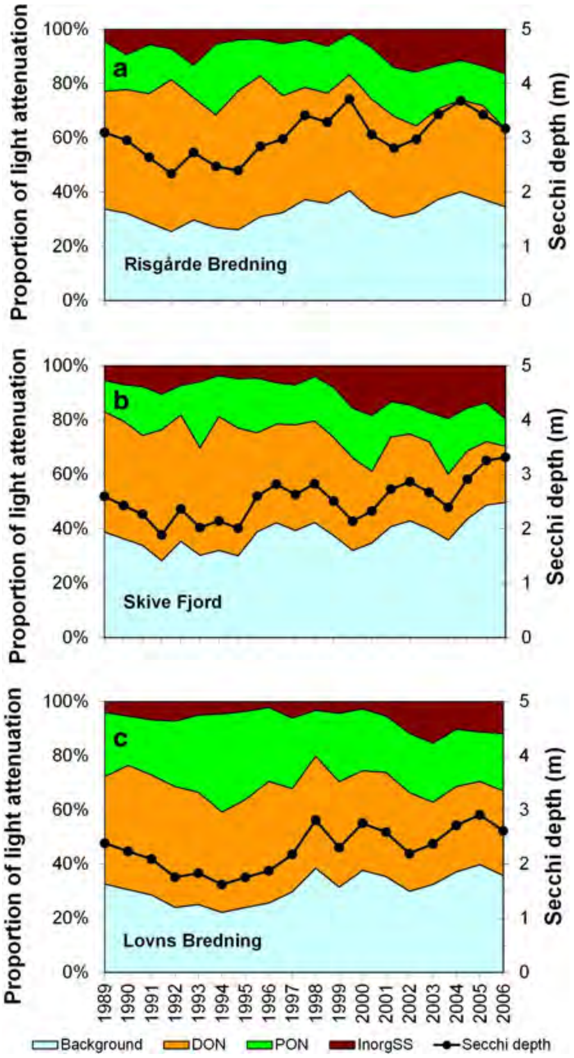


Fig. 6 The relative contribution of water, DON, PON and InorgSS to the diffuse attenuation of light (Mar–Sep) over time in the three basins calculated from the trends of the different substances (Fig. 3) and the parameter estimates from Eq. 2 (Table 3). Secchi depth is modelled from trends of DON, PON and InorgSS using Eqs. 2 and 3

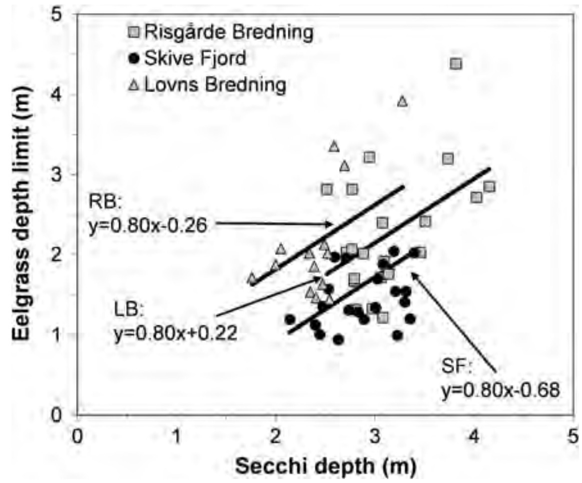


Fig. 7 Relationships between annual means (Mar–Sep) of Secchi depth and eelgrass depth limit by use of Eq. 4

First, Eq. 2 is only an empirical model for light attenuation where the effects are assumed to be additive. In reality, particles, both organic as represented by PON and InOrgSS, will cause an increase in the scattering of light which in turn will enhance the effective light absorption due to a longer effective pathway for the photons (Kirk, 1994). An improved description of the light attenuation could potentially improve the explanatory power of the model. Second, DON and PON may not fully account for the light absorbing fractions of dissolved and particulate organic matter in the water column. If the C:N ratio of the organic pools has increased over time then the attenuation of organic matter would be larger than predicted by DON and PON concentrations.

Although there were fewer TOC observations over time and monitoring stopped in 2003, TOC trends support that there is not a strong link between organic carbon and ON (Fig. 8). Despite large decreases in ON (Fig. 3b, c) the amount of TOC has remained relatively constant over the study period (Fig. 8a), and this has consequently led to changes in the C:N ratio of the organic material from around the Redfield ratio (C:N = 6.6) in the early 1990s to about 10 in the early 2000s (Fig. 8b). The unaltered TOC concentrations could explain the similarly unaltered Secchi depths, highlighting that the link between TN and Secchi depth is weak.

Why has organic matter not decreased?

Eutrophication has been defined as an increase in the rate of supply of organic matter to an ecosystem (Nixon, 1995), and increasing nutrient inputs have been attributed as the major cause by enhancing the autochthonous production of organic material. Oligotrophication, the reverse of eutrophication implying a reduction in the supply of organic matter (Nixon, 2009), has apparently not yet taken place in the Skive Fjord estuarine system despite large reductions in nutrient inputs. In addition to exchanges across the

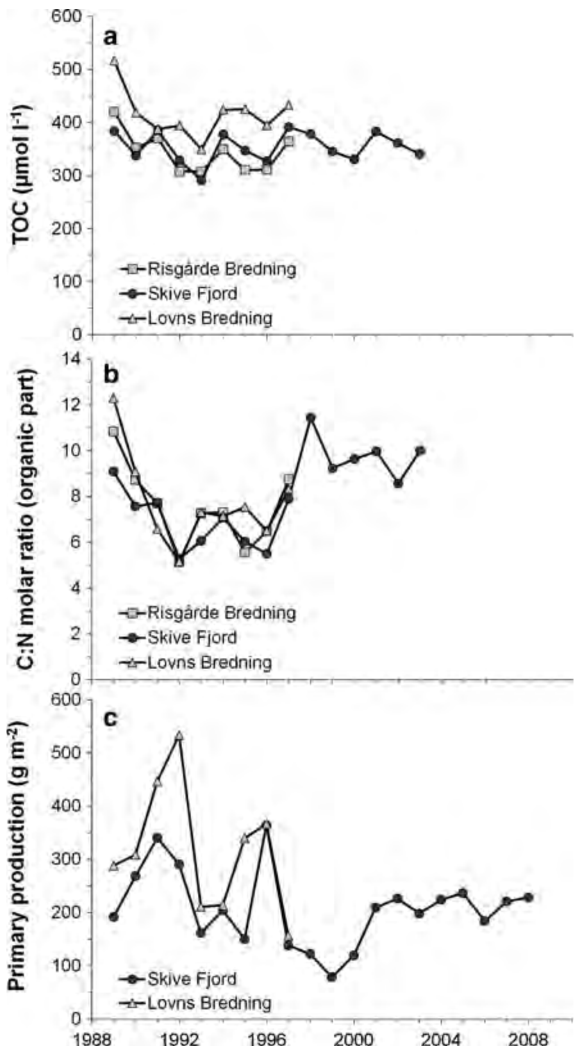


Fig. 8 Yearly geometric means (Mar–Sep) of TOC and C/N molar ratio of the organic matter in the water column as well as primary production

open boundary, organic matter in the water column originates from freshwater discharge, production by photosynthesis, as well as reintroduction from sediments e.g. enhanced by resuspension, whereas it is lost by respiration, benthic grazing, sedimentation and export.

Salinities have decreased by approximately 1.5 over the study period in all three basins (data not shown), indicating a potential larger influence of organic matter from terrestrial sources and less dilution by exchange. Organic matter in freshwater is mostly dissolved (DOC:TOC = 0.66; B. Kronvang, personal communication) with DOC concentrations around 500–600 µmol l^{-1} (Markager et al., 2011 from a similar estuary). Thus, with a presumed freshwater TOC concentration of 800 µmol l^{-1}, the lower salinity during the most recent years would correspond to an increase in TOC of $\sim$25 µmol l^{-1} from a linear mixing relationship of freshwater with a marine water mass having 400 µmol l^{-1} TOC (Fig. 8) and a salinity of 24. On the other hand, nitrogen concentrations (mostly nitrate) in the freshwater discharge to the Skive Fjord estuarine system is high ($\sim$300 µmol l^{-1}; cf. Fig. 2), which on a stoichiometric basis using Redfield ratios converts to almost 2000 µmol C l^{-1}, a concentration 3–4 times higher than measured DOC concentrations in the freshwater discharge, and presumably 2–2.5 times higher than TOC. This is in accordance with Markager et al. (2011) estimating that 30% of DOC was allochthonous and 70% derived from marine production. Assuming proportionality through mixing between TOC input from freshwater and TOC derived from freshwater nitrogen, the reduced nitrogen input over the study period should lead to a reduced TOC concentration by 20% (equivalent to 80 µmol C l^{-1}) in the estuarine system.

However, primary production by phytoplankton remained high throughout the study period (Fig. 8c) despite a presumably lower availability of nutrients. DIN concentrations were generally above levels considered to limit phytoplankton growth ($\sim$2 µmol l^{-1}) from March to May, but suggested potential nitrogen limitation from June to September. Spring primary production was limited by phosphorus (Markager et al., 2006), although phosphate concentrations (not shown) were also generally higher than those considered to limit phytoplankton growth ($\sim$0.2 µmol l^{-1}). However, it is possible that phytoplankton growth was essentially not nutrient limited during the productive season due to high nutrient turnover and therefore, reduced nitrogen levels may only have had a minor effect on phytoplankton production. This is supported by the observation that phytoplankton primary production has decreased in all other basins in Limfjorden by about 30% from the 1980s (Krause-Jensen et al., 2012). In these basins nutrients loadings and concentrations are lower and are now reduced to levels there are limiting for phytoplankton growth. The shallow Skive Fjord estuarine system has extensive areas covered with blue mussels having the capacity to clear the water column several times per day during mixed conditions

(Møhlenberg, 1995; Riisgaard et al., 2004). Intensive mussel dredging is taking place in the study area removing about 20% of the standing stock every year (Dolmer et al., 1999), but mussel landings in the Limfjorden area have declined to less than half in the last decade after peaking in the mid 1990s (Ministry for food and agriculture). Overfishing, oxygen depletion and reduced recruitment are believed to be the main causes for an almost 50% reduction in the blue mussel standing stock from 1993 to 2004 (Kristensen & Hoffmann, 2004). Moreover, the pelagic food web has become dominated by jellyfish which are important predators on the zooplankton (Riisgaard et al., 2012). Thus, the unaltered primary production could also result from alleviated grazing control.

Inorganic suspended matter has earlier been found to constitute an important part of light attenuation in Limfjorden (Olesen, 1996). The trend of increasing InorgSS in the Skive Fjord suggests an increased sediment resuspension over time, potentially enhancing the mobilisation of organic material from the sediments to the water column. Particularly important are the dissolved forms that may remain in the water column after release from the sediments. Organic material in the sediment may have a relatively high C:N ratio, because of preferential N mineralisation (Schneider et al., 2003). Thus, increased resuspension associated with wind mixing, enhances the release of organic particles from the sediments and enriches the water column with an increasing C:N ratio as a result (Fig. 8b). Another consequence of this mechanism might be that the permanent burial of organic matter is reduced e.g. as a consequence of the reduced extent of seagrasses (Fourqurean et al., 2012), such that a larger amount of organic matter remains active within the system.

Why is there an increased resuspension?

The increased resuspension could potentially be caused by a change in the wind regimes. However, this is unlikely since average wind speeds over Denmark generally have declined over the study period (Hansen & Petersen, 2011). It is more likely that the increased resuspension is linked to reduced ability of the sediments to sustain windy conditions. The sediment composition is unlikely to have changed substantially, since TOC and PON concentrations in the water column, feeding the sediments, have been rather constant over time. Therefore, it is more likely that the sediments have become more exposed to wind-induced resuspension over time.

The removal of blue mussels from the system, by harvesting and oxygen depletion, has a double-sided effect on the resuspension. Blue mussels filter the water column for both organic and inorganic particles, the latter deposited as pseudo-faeces. A reduced standing stock of blue mussels consequently results in more turbid waters because of reduced ′water cleaning′ ability. In addition to harvesting mussels, dredging also removes stones, empty shells and other features that help to stabilise the sediments (Widdows et al., 2002), reduce currents along the bottom and enhance the sedimentation of particulate matter. The large increase of InorgSS after 2000 (Fig. 3f) is largely consistent with the reduction in the standing stock of blue mussels (Kristensen & Hoffmann, 2004).

In the Skive Fjord estuarine system eelgrass typically grows at depths where mussel dredging is prohibited (<2 m), but this depth limit may also impose a constraint on the eelgrass depth limit due to the continuous physical disturbance from the intensive mussel dredging. Like mussels and other large substrate features on the seafloor, eelgrass enhances the sedimentation of particles (Terrados & Duarte, 2000; Carr et al., 2010). Although eelgrass depth limits have not changed over the study period except for Risgårde Bredning (Fig. 3h), there has been a thinning of the eelgrass meadows at the same time in Limfjorden in general (Hansen & Petersen, 2011) and in Risgårde Bredning and Lovns Bredning (Fig. 9). It is plausible that this loss of eelgrass, in addition to the aforementioned factors, could lead to increased resuspension of sediments and thus provide a feedback mechanism that maintains a turbid state and prevents eelgrass from establishing sound populations at deeper depths (Hiratsuka et al., 2007; Carr et al., 2010). In both Risgårde Bredning and Lovns Bredning, the decrease in eelgrass cover was associated with increasing InorgSS, believed to be mostly clay particles (Fig. 9). Eelgrass was most dense at the 1–2 m depth interval, which accounts for about 10% of the total fjord area. Hence, the total loss of eelgrass cover was roughly 1%. The overall increase in InorgSS of approximately 3 mg l^{-1} after 2001 in an average water column of 5 m corresponded to an increased resuspension of 1.5 mm sediment from those areas, where eelgrass was lost. Thus, it is possible that the

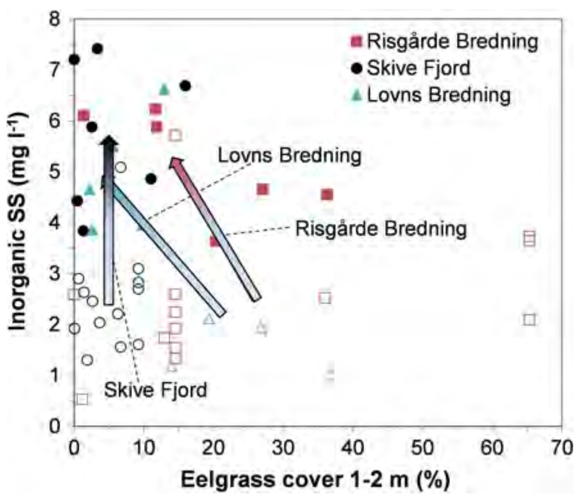


Fig. 9 Yearly means of eelgrass cover versus InorgSS in the three basins (marked with different *colours*). Means from 1989 to 2001 are shown with *open symbols* and means from 2002 to 2010 are shown with *filled symbols*. The *thick lines* connect the pair of means for these two periods (1989–2001 and 2002–2010) with *arrows* indicating the change in each of the three basins

losses of eelgrass, even at a small scale ($\sim$1% of the total area), could contribute to the increased turbidity, as these eelgrass belts occur in the shallow water most prone to resuspension.

An eelgrass population restricted to depths less than 2 m is naturally more vulnerable to physical exposure, compared to eelgrass with a stable mother population at deeper depths, from where it can colonise the more dynamic shallow areas. This could suggest the existence of a depth threshold for maintaining a resilient eelgrass population, and the reduced eelgrass coverage (Hansen & Petersen, 2011) could indicate that this critical threshold might have been exceeded such that eelgrass in the Skive Fjord estuarine system does not constitute a stable population.

Management implications

The expectation that eutrophication is fully reversible, suggesting that coastal ecosystems return to a previous state when pressures upon the system are released, has been challenged recently (Duarte et al., 2009). The pathway of ecosystem recovery is clearly not identical to that of ecosystem degradation, and ecosystem managers may need to release pressures below those that led to the collapse, due to internal feedbacks of the system leading to hysteresis responses (Scheffer et al., 2001). Our results document high primary production and organic matter concentrations in the water column despite decreasing nitrogen concentrations. These results are consistent with a large-scale study of 28 ecosystems across four regions showing an almost doubling in the chlorophyll yield to TN (Carstensen et al., 2011). Our study suggests that other factors than nutrients, such as resuspension of bottom material, mussel dredging and altered top-down control, maintain an unclear and turbid system with high concentrations of light-attenuating substances in the water column. Such factors appear to have counterbalanced improvements in nutrient concentrations and shifted the baseline (see Duarte et al., 2009 for discussion) for the light conditions, and consequently the depth distribution of eelgrass. The presence of shifting baselines essentially implies that single-pressure–response relationships based on historical data are unable to predict the response when managing that single pressure over relative short time scales, e.g. less than 20 years. On longer time scales the ecosystem might switch back to its previous state with a dominance of benthic primary producers (Krause-Jensen et al., 2012). Our results also show that better and more insightful relationships can be obtained by investigating the sequence of cause-effect relationships rather than simple correlation analyses and may help to understand the resistance and time lag in the improvement of the ecological conditions.

The Skive Fjord estuarine system is affected by multiple pressures, and it is unlikely that eelgrass will recover to a historical extent by managing nutrients only over short times scales. The key to restore widespread and stable populations of eelgrass is to improve light conditions, such that deeper and denser populations can be established, and to reduce occurrence of anoxia in the deeper parts. This requires a combination of further reduction of nutrient levels such that phytoplankton growth becomes nutrient limited and reduced mussel dredging such that blue mussels can exert a “natural” benthic grazing pressure on the phytoplankton. Mussel dredging is also a stress factors as much of the spreading of eelgrass occur by seeds, but pioneering seedlings inhabiting new areas could be removed by mussel dredging. Temperature increases will counteract these restoration efforts by increased turnover rates for nutrients and increased eelgrass respiration losses reducing the theoretical eelgrass depth limit, albeit not drastically (Stæhr &

Borum, 2011). Thus, the direct effect of temperature increase on eelgrass respiration cannot account for the shift in baseline. Transplanting activities can speed up the recovery of eelgrass, but efforts to restore seagrasses have had mixed results owing to unsuitability of sites and uncertainties associated with establishing resilient populations (Thom et al., 2012). Additional studies are needed to assess if eelgrass has the potential to grow deeper than present levels in the Skive Fjord estuarine system, or whether light conditions in the eelgrass meadows or mussel dredging at depths above 2 m impose the depth limit.

This study has shown the value of long-term monitoring data for understanding responses of coastal ecosystems to changing nutrient inputs. Measurements of TSS, OrgSS, POC, TOC and primary production, which are not standard monitoring parameters within the DNAMAP, have been essential for understanding why eelgrass did not respond to significant reductions in nitrogen levels. We recommend that these additional measurements become standard in monitoring programs to better understand and predict the outcome of measures aiming to restore coastal ecosystems.

Acknowledgments This research is a contribution to the WISER project (contract #FP7-226273), funded by the European Commission, and the REELGRASS project (contract #09-063190), funded by the Danish Agency for Science, Technology and Innovation. Additional founding was provided by the Danish Council for Strategic Research to the project IMAGE (Integrated Management of Agriculture, Fishery, Environment and Economy, Grant No. 09-067259). We are grateful to the Danish Environmental Centers responsible for data collection under the Danish Nationwide Aquatic Monitoring and Assessment Program. This is a contribution from the Baltic Nest Institute.

References

Balsby, T. J. S., J. Carstensen & D. Krause-Jensen, 2012. Sources of uncertainty in estimation of eelgrass depth limits. Hydrobiologia (this issue).

Boström, C., S. P. Baden & D. Krause-Jensen, 2003. The seagrasses of Scandinavia and the Baltic Sea. In Green, E. P. & F. T. Short (eds), World Atlas of Seagrasses. University of California Press, Berkeley: 27–37.

Carr, J., P. D'Odorico, K. McGlathery & P. Wiberg, 2010. Stability and bistability of seagrass ecosystems in shallow coastal lagoons: role of feedbacks with sediment resuspension and light attenuation. Journal of Geophysical Research 115: G03011.

Carstensen, J., 2010. Censored data regression: statistical methods for analyzing Secchi transparency in shallow systems. Limnology & Oceanography: Methods 8: 376–385.

Carstensen, J. & P. Henriksen, 2009. Phytoplankton biomass response to nitrogen inputs: a method for WFD boundary setting applied to Danish coastal waters. Hydrobiologia 633: 137–149.

Carstensen, J., D. J. Conley, J. H. Andersen & G. Ærtebjerg, 2006. Coastal eutrophication and trend reversal: a Danish case study. Limnology & Oceanography 51: 398–408.

Carstensen, J., P. Henriksen & A.-S. Heiskanen, 2007. Summer algal blooms in shallow estuaries: definition, mechanisms, and link to eutrophication. Limnology & Oceanography 52: 370–384.

Carstensen, J., M. Sánchez-Camacho, C. M. Duarte, D. Krause-Jensen & N. Marbà, 2011. Connecting the dots: downscaling responses of coastal ecosystems to changing nutrient concentrations. Environmental Science & Technology 45: 9122–9132.

Conley, D. J., H. Kaas, F. Møhlenberg, B. Rasmussen & J. Windolf, 2000. Characteristics of Danish estuaries. Estuaries 23: 820–837.

Conley, D. J., J. Carstensen, G. Ærtebjerg, P. B. Christensen, T. Dalsgaard, J. L. S. Hansen & A. B. Josefson, 2007. Long-term changes and impacts of hypoxia in Danish coastal waters. Ecological Applications 17: S165–S184.

Dolmer, P., P. S. Kristensen & E. Hoffmann, 1999. Dredging of blue mussels (*Mytilus edulis* L.) in a Danish sound: stock sizes and fishery-effects on mussel population dynamic. Fisheries Research 40: 73–80.

Duarte, C. M., 1991. Seagrass depth limits. Aquatic Botany 40: 363–377.

Duarte, C. M., 2002. The future of seagrass meadows. Environmental Conservation 29: 192–206.

Duarte, C. M., D. J. Conley, J. Carstensen & M. Sánchez-Camacho, 2009. Return to Neverland: shifting baselines affect ecosystem restoration targets. Estuaries and Coasts 32: 29–36.

Duffy, J. E., 2006. Biodiversity and the functioning of seagrass ecosystems. Marine Ecology Progress Series 311: 233–250.

Fonseca, M. S., P. E. Whitfield, N. M. Kelly & S. S. Bell, 2002. Modelling seagrass landscape pattern and associated ecological attributes. Ecological Applications 12: 218–237.

Fourqurean, J. W., C. M. Duarte, H. Kennedy, N. Marbà, M. Holmer, M. A. Mateo, E. T. Apostolaki, G. A. Kendrick, D. Krause-Jensen, K. J. McGlathery & O. Serrano, 2012. Seagrass ecosystems as a globally significant carbon stock. Nature Geoscience 5: 505–509.

Gacia, E., C. M. Duarte & J. J. Middelburg, 2002. Carbon and nutrient deposition in a Mediterranean seagrass (*Posidonia oceanica*) meadow. Limnology & Oceanography 47: 23–32.

Gallegos, C. L., 2001. Calculating optical water quality targets to restore and protect submersed aquatic vegetation: overcoming problems in partitioning the diffuse attenuation coefficient for photosynthetically active radiation. Estuaries 24: 381–397.

Grasshoff, K., 1976. Methods in Seawater Analysis. Verlag Chemie, Weinheim.

Green, E. P. & F. T. Short, 2003. World Atlas of Seagrasses. University of California Press, Berkeley.

Greening, H. & A. Janicki, 2006. Toward reversal of eutrophic conditions in a subtropical estuary: water quality and seagrass response to nitrogen loading reductions in Tampa Bay, Florida, USA. Environmental Management 38: 163–178.

Greening, H. S., L. M. Cross & E. T. Sherwood, 2011. A multiscale approach to seagrass recovery in Tampa Bay, Florida. Ecological Restoration 29: 1–2.

Hansen, J. W. & D. L. J. Petersen, 2011. Marine areas 2010. NOVANA. Status and trends in the natural and environmental quality (in Danish). Scientific Report No. 6, DCE, National Centre for Environment and Energy, Aarhus University, Silkeborg.

Hemminga, M. A. & C. M. Duarte, 2000. Seagrass Ecology. Cambridge University Press, Cambridge.

Hiratsuka, J., M. Yamamuro & Y. Ishitobi, 2007. Long-term change in water transparency before and after the loss of eelgrass beds in an estuarine lagoon, Lake Nakaumi, Japan. Limnology 8: 53–58.

Kirk, J. T. O., 1994. Light and Photosynthesis in Aquatic Ecosystems. Cambridge University Press, Cambridge.

Krause-Jensen, D., M. F. Pedersen & C. Jensen, 2003. Regulation of eelgrass (*Zostera marina*) cover along depth gradients in Danish coastal waters. Estuaries 26: 866–877.

Krause-Jensen, D., J. Carstensen, S. L. Nielsen, T. Dalsgaard, P. B. Christensen, H. Fossing & M. B. Rasmussen, 2011. Sea bottom characteristics affect depth limits of eelgrass *Zostera marina*. Marine Ecology Progress Series 425: 91–102.

Krause-Jensen, D., S. Markager & T. Dalsgaard, 2012. Benthic and pelagic primary production in different nutrient regimes. Estuaries and Coasts 35: 527–545.

Kristensen, P. S. & E. Hoffmann, 2004. Standing stock of blue mussels in Limfjorden 1993–2003 (in Danish). Report No. 130 from DTU-Aqua. www.aqua.dtu.dk.

Kronvang, B. & J. A. Bruhn, 1996. Choice of sampling strategy and estimation method when calculating nitrogen and phosphorus transport in small lowland streams. Hydrological Processes 10: 1483–1501.

Marbà, N., D. Krause-Jensen, T. Alcoverro, S. Birk, A. Pedersen, J. M. Neto, S. Orfanidis, J. M. Garmendia, I. Muxika, A. Borja, K. Dencheva, & C. M. Duarte, 2012. Diversity of European seagrass indicators – patterns within and across regions. Hydrobiologia (this issue).

Markager, S., W. Vincent & E. Y. Tang, 1999. Carbon fixation by phytoplankton in high Arctic lakes: implications of low temperature for photosynthesis. Limnology & Oceanography 44: 597–607.

Markager, S., L. M. Storm, & C. A. Stedmon, 2006. Limfjorden state of the environment from 1985 to 2003 – empirical models relating nutrients to climate and hydrography (in Danish). Report No. 577, National Environmental Research Institute, Silkeborg. www.dce.au.dk.

Markager, S., C. A. Stedmon & M. Søndergaard, 2011. Seasonal dynamics and conservative mixing of dissolved organic matter in the temperate eutrophic estuary Horsens Fjord. Estuarine Coastal Shelf Science 92: 376–388.

Møhlenberg, F., 1995. Regulating mechanisms of phytoplankton growth and biomass in a shallow estuary. Ophelia 42: 239–256.

Nielsen, S. L., K. Sand-Jensen, J. Borum & O. Geertz-Hansen, 2002. Depth colonization of eelgrass (*Zostera marina*) and macroalgae as determined by water transparency in Danish coastal waters. Estuaries 25: 1025–1032.

Nixon, S. W., 1995. Coastal marine eutrophication: a definition, social causes, and future concerns. Ophelia 41: 199–219.

Nixon, S. W., 2009. Eutrophication and the macroscope. Hydrobiologia 629: 5–19.

Olesen, B., 1996. Regulation of light attenuation and eelgrass *Zostera marina* depth distribution in a Danish embayment. Marine Ecology Progress Series 134: 187–194.

Orth, R. J., T. J. B. Carruthers, W. C. Dennison, C. M. Duarte, J. W. Fourqurean, K. L. Heck Jr, A. R. Hughes, G. A. Kendrick, W. J. Kenworthy, S. Olyarnik, F. T. Short, M. Waycott & S. L. Williams, 2006a. A global crisis for seagrass ecosystems. Bioscience 56: 987–996.

Orth, R. J., M. L. Luckenbach, S. R. Marion, K. A. Moore & D. J. Wilcox, 2006b. Seagrass recovery in the Delmarva Coastal Bays, USA. Aquatic Botany 84: 26–36.

Preisendorfer, R. W., 1986. Secchi disk science: visual optics of natural waters. Limnology & Oceanography 31: 909–926.

Pulido, C. & J. Borum, 2010. Eelgrass (*Zostera marina*) tolerance to anoxia. Journal of experimental Marine Biology and Ecology 385: 8–13.

Riisgaard, H. U., D. F. Seerup, M. H. Jensen, E. Glob & P. S. Larsen, 2004. Grazing impact of filter-feeding zoobenthos in a Danish fjord. Journal of Experimental Marine Biology and Ecology 307: 261–271.

Riisgaard, H. U., P. Andersen, & E. Hoffmann, 2012. From fish to jellyfish in the eutrophicated Limfjorden (Denmark). Estuaries and Coasts 35, doi:10.1007/s12237-012-9480-4.

Scheffer, M., S. Carpenter, S. A. Foley, C. Folke & B. Walker, 2001. Catastrophic shifts in ecosystems. Nature 413: 591–596.

Schneider, B., R. Schlitzer, G. Fischer & E. M. Nothig, 2003. Depth-dependent elemental compositions of particulate organic matter (POM) in the ocean. Global Biogeochemical Cycles 17: 1032.

Searle, S. R., F. M. Speed & G. A. Milliken, 1980. Populations marginal means in the linear model: an alternative to least squares means. American Statistician 34: 216–221.

Short, F. T. & S. Wyllie-Echeverria, 1996. Natural and human induced disturbances of seagrass. Environmental Conservation 23: 17–27.

Smith, R. C. & K. S. Baker, 1978. The bio-optical state of ocean waters and remote sensing. Limnology & Oceanography 23: 247–259.

Smith, R. C. & K. S. Baker, 1981. Optical properties of the clearest natural waters (200–800 nm). Applied Optics 20: 177–184.

Stæhr, P. A. & J. Borum, 2011. Seasonal acclimation in metabolism reduces light requirements of eelgrass (*Zostera marina*). Journal of Experimental Marine Biology and Ecology 407: 139–146.

Steemann Nielsen, E., 1952. The use of radio-active carbon (C14) for measuring organic production in the sea. Journal Conseil International pour l'Exploration de la Mer 18: 117–140.

Strickland, J. D. & T. R. Parsons, 1972. A Practical Handbook of Seawater Analysis. Fisheries Research Board of Canada, Ottawa: 1–310.

Terrados, J. & C. M. Duarte, 2000. Experimental evidence of reduced particle resuspension within a seagrass (*Posidonia oceanica* L.) meadow. Journal of Experimental Marine Biology and Ecology 243: 45–53.

Thom, R. M., H. L. Diefenderfer, J. Vavrinec & A. B. Borde, 2012. Restoring resiliency: case studies from Pacific Northwest estuarine eelgrass (*Zostera marina* L.) ecosystems. Estuaries and Coasts 35: 78–91.

Vaudrey, J. M. P., J. N. Kremer, B. F. Branco & F. T. Short, 2010. Eelgrass recovery and nutrient enrichment reversal. Aquatic Botany 93: 237–243.

Waycott, M., C. M. Duarte, T. J. B. Carruthers, R. J. Orth, W. C. Dennison, S. Olyarnik, A. Calladine, J. W. Fourqurean, K. L. Heck Jr, A. R. Hughes, G. A. Kendrick, W. J. Kenworthy, F. T. Short & S. L. Williams, 2009. Accelerating loss of seagrasses across the globe threatens coastal ecosystems. Proceedings of the National Academy of Sciences of the United States of America 106: 12377–12381.

Widdows, J., J. S. Lucas, M. D. Brinsley, P. N. Salkeld & F. J. Staff, 2002. Investigation of the effects of current velocity on mussel feeding and mussel bed stability using an annular flume. Helgoland Marine Research 56: 3–12.

Windolf, J., H. Thodsen, L. Troldborg, S. E. Larsen, J. Bøgestrand, N. B. Ovesen & B. Kronvang, 2011. A distributed modelling system for simulation of monthly runoff and nitrogen sources, loads and sinks for ungauged catchments in Denmark. Journal of Environmental Monitoring 13: 2645–2658.