Martin Slough Enhancement Project
2022 Monitoring Report

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INTRODUCTION

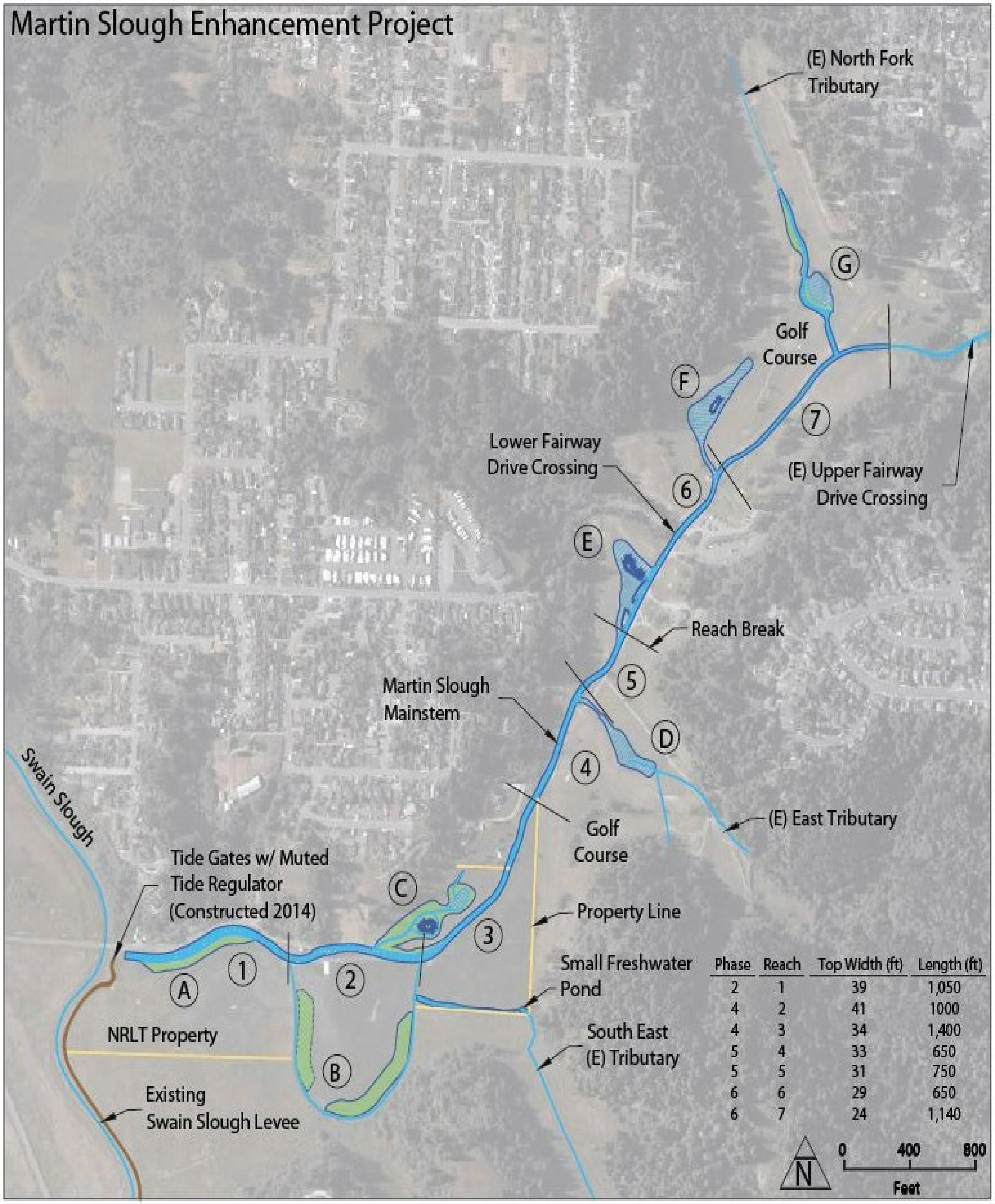
This report summarizes Year 2022 monitoring of the Martin Slough Enhancement Project (project). This report was prepared by the Natural Resources Services Division of Redwood Community Action Agency (RCAA) with information and support provided by partners and subcontractors and in accordance with the Martin Slough Monitoring Plan (Plan; RCAA 2021 revision).

Background

Martin Slough is a tributary of Elk River, a watershed that is part of the larger Humboldt Bay ecosystem. Martin Slough was identified by the California Department of Fish and Wildlife (CDFW) as playing a key role in the life cycle of coho salmon (*Oncorhynchus kisutch*) by providing ideal rearing habitat for juvenile coho. Juvenile coho occur in Martin Slough in relative abundance (see Fisheries Monitoring section below). The federally endangered tidewater goby (*Eucyclogobius newberryi*) also occurs in Martin Slough; the slough is within the HUM-3 Humboldt Bay tidewater goby critical habitat unit (Federal Register 2013). Nearly the entire project area is designated critical habitat for coho, Chinook salmon (*O. tshawytscha*) and steelhead trout (*O. mykiss*).

In 2006, the North Coast Regional Water Quality Control Board (NCRWQCB) and the U.S. Environmental Protection Agency (USEPA) listed the Elk River Watershed under Section 303(d) of the Clean Water Act as sediment-impaired, citing impaired water quality, impaired spawning habitat, and increased depth of flooding due to sediment. The project site is diked, former tideland degraded by previous management practices. Straight-line channels were excavated, riparian vegetation was removed, dikes were built, and tide gates were installed at the confluence of Martin Slough and Swain Slough. Tidal exclusion resulted in loss of sediment transport and natural fluvial geomorphic processes that maintained the tidal wetlands and channel capacity. In response to these stressors, the Martin Slough Enhancement Project was developed with the goal of enhancing fish habitat for endangered coho salmon and reducing the extent and duration of flooding in agricultural and urban recreational lands.

The project area encompasses 2 contiguous properties: 40 acres of pasture owned by the Northcoast Regional Land Trust (NRLT) and 120 acres owned by the City of Eureka (COE) and operated as the Eureka Municipal Golf Course (EMGC or golf course; Figure 1). The project was initiated in 2001 when RCAA and partners began preparing a feasibility study, completed in 2006. Between 2007 and 2014, RCAA contracted with Michael Love & Associates (MLA) and GHD, Inc., to develop designs for a new tide gate at the confluence of Martin Slough and Swain Slough, along with enhancements to the slough channel, new tidal marshes, and off-channel brackish and freshwater ponds. The tide gate replacement was completed in 2014, and enhancement work on the NRLT property was completed in 2019. Enhancement on the Golf Course began in 2019 and was completed in 2021.



Phase	Reach	Top Width (ft)	Length (ft)
2	1	39	1,050
4	2	41	1000
4	3	34	1,400
5	4	33	650
5	5	31	750
6	6	29	650
6	7	24	1,140

Figure 1. Martin Slough Enhancement Project area showing Northcoast Regional Land Trust and Eureka Municipal Golf Course properties plus design channel reaches and off-channel ponds.

Project Purpose

The purpose of the Martin Slough Enhancement Project was to improve aquatic and riparian habitat and reduce flooding of pasture and golf course greens and fairways throughout the project area. Specific goals of the project included the following:

1. Improve fish passage from Swain Slough into Martin Slough,
2. Reduce flood impacts to current land use,
3. Improve sediment transport,
4. Increase the amount of riparian corridor and riparian canopy,
5. Improve water quality (increase circulation, decrease nutrient inputs, decrease sedimentation),
6. Increase the extent of the estuarine ecotone in Martin Slough, providing a gradual transition from brackish water to freshwater habitats,
7. Enhance and create low-velocity off-channel/backwater habitats.

Project Phasing

The Martin Slough Enhancement Project was implemented in 5 phases. Table 1 summarizes each phase. These phases do not necessarily correspond to phasing as described in earlier compliance documents and reports, however, the project was implemented as described in Table 1.

Phase	Action	Year Completed
1	Replaced three dilapidated tides gates on Martin Slough at the confluence with Swain Slough with two 6’x 6’ side hinged gates, one 6’x 6’ top hinged gate, and one 2’x 2’ auxiliary gate, fitted with muted tidal regulators that allow a muted tide into Martin Slough	2014
2	Enlarged Martin Slough channel throughout NRLT property; built Marsh Plains A and B and off-channel Pond C; realigned the Southeast Tributary and constructed a freshwater pond; replaced two culvert crossings; installed a bridge to access agricultural land and a barn.	2018
3	Enlarged Martin Slough channel on the lower EMGC up to the East Tributary; enhanced Pond D; removed undersize culvert; installed new golf cart access bridge.	2019
4	Enlarged Martin Slough channel up to the North Fork tributary confluence; enhanced off-channel Pond E and constructed Pond F; replaced golf cart bridges.	2020
5	Enlarged remainder of the upper Martin Slough channel and the North Fork; constructed North Fork Pond G; installed temporary salinity barrier.	2021

MONITORING OVERVIEW

Purpose

The objectives of Martin Slough project monitoring are threefold:

1) Ensure implementation of the project according to established plans, including construction and schedules,
2) Document the effectiveness of the project in terms of its stated goals of improving wetland and riparian habitats and reducing flooding,
3) Adaptatively manage if project goals, objectives or success criteria are not being met.

The essential purpose of Martin Slough project monitoring is to indicate whether the enhancement component/current course of action is functioning as intended and to adaptively manage when and where necessary. Monitoring results should provide support for either continuation of current practices or making management adjustments. Thorough project evaluation will help provide information about sound design or design flaws, and effective or ineffective management techniques to apply or avoid by land managers, restoration designers and practitioners when planning or implementing similar estuarine restoration projects in and around Humboldt Bay.

Parameters

The Monitoring Plan (RCAA 2021) described 5 general post-construction parameters: topography, hydrology, water quality, fisheries and vegetation. These parameters are directly linked to individual long-term objectives established for the project and provide a multi-parameter basis for evaluating the final success of the project. These 5 parameters were selected to ensure that overlapping structural and functional components assessing both physical and biological characteristics of the site will be measured to evaluate project success.

This report covers post-construction monitoring for project Phases 2 through 5 and addresses all 5 parameters. Post-construction monitoring was conducted according to RCAA's 2021 Monitoring Plan and all project permits.

Performance and Success Criteria

Performance criteria are annual quantitative and qualitative benchmarks against which project progress is measured. Final success criteria will be used to determine if the project has substantially met its individual and overall objectives within the 5-year monitoring period. Attainment of final success criteria will indicate that the project is trending toward meeting long-term habitat goals with minimal chance of failure. While monitoring will continue for a 5-year period post-construction, if final success criteria are reached for a particular parameter in less than 5 years, monitoring of that parameter may be discontinued or reduced in scope and frequency.

There are separate annual performance and final success criteria for each parameter and parameter-specific monitoring methods and schedules. Specific performance and final success criteria are summarized for each parameter in Table 2.

Table 2. Topographic, hydrologic, water quality, fisheries and vegetation monitoring parameters, schedule, performance, and success criteria. (See text for MHHW and MLLW definitions.)

Parameter	Type of Monitoring	Frequency	Schedule	Performance Criteria	Success Criteria	Remedial Actions
Topography	Repeat surveys: - longitudinal channel profiles of mainstem Martin Slough - cross section of slough channels, marsh plains, and ponds	Surveys in: Year 1 Year 3 Year 5 post-construction	Once annually	- No high points restricting drainage of ebb tides in mainstem thalweg profile. - Less than 10% net change in cross sectional area below design MHHW of 5.5 feet (NAVD 88) at each cross section.	- No high points restricting drainage of ebb tides in mainstem thalweg profile. - Less than 20% net change in cross sectional areas below design MHHW of 5.5 feet (NAVD 88) at each cross section within project after 5 years.	- Identify cause(s) of high points restricting drainage. Remedial actions may include channel excavation or changes to tidal prism. - Analyze root cause(s) of excess aggradation or scour and address root cause(s).
Hydrology	Data logger used to continuously record water levels in Swain Slough and Martin Slough	Download data approximately every six weeks	Continuous through period where muted tide regulator (MTR) is being adjusted or, if funding is available, through the end of Year 5 after last construction phase completed	**Muted high tides sufficient during growing season to inundate constructed marsh plains**		Adjust 6'x 6' MTR gate and auxiliary MTR gate to increase time gate is open
				Tide gate is open ≥35% of the time (not including auxiliary door) Assume muted tide is only through auxiliary MTR gate.	Tide gate is open ≥50% of the time (not including auxiliary door).	
				Summer MLLW in Martin Slough >2.0 ft (NAVD 88)		Identify potential high points or channel aggradation. Actions may include channel excavation or changes to tidal prism.

Parameter	Type of Monitoring	Frequency	Schedule	Performance Criteria	Success Criteria	Remedial Actions
Water Quality	Surface and bottom salinity and temperature meters placed at the three Martin Slough water level monitoring stations. Spot measure dissolved oxygen, salinity and temperature during downloads. Additional spot measure w/fisheries monitoring.	Continuous, download every 6-8 weeks	Year round through Year 5 following final phase of implementation, as funding allows	- Average daily water temperature ≤18ºC during expected salmonid period of use - Maximum daily water temperature ≤21ºC during expected salmonid period of use - Pond G and Southeast Tributary Pond DO ≥4 ppm and salinity ≤4 ppt during expected salmonid period of use		- Adaptive management: meet and - - discuss water quality data with fisheries biologists and agency staff. Possible actions could include: - Increase circulation through MTR gate adjustments - Increase riparian vegetation for shading to cool water and reduce aquatic vegetation growth - Modify inlet/outlet of ponds to increase circulation.
Fisheries	**Salmonids**: Seining at selected locations consisting of varying habitat types (pond and channel) and longitudinal locations within the project area	One or more days per month during expected salmonid period of use, as funding allows	Post-construction for 3 years, or up to 8 years as funding allows	Annual average net increase of 50% over pre-project coho salmon numbers (combined total for juvenile young-of-the-year and one-year fish) recorded by CDFW	Annual average net increase of 50% over pre-project coho salmon numbers (combined total for juvenile young-of-the-year and one-year fish) recorded by CDFW	Performance and success may be subject to uncontrollable variables (i.e., ocean conditions, run size) affecting abundance. Follow water quality remedial actions.
	Tidewater goby: Seining	In conjunction with salmonid sampling	Post-construction for 5 years, as funding allows	Presence in new terminal ponds at upper end of new slough channels	Presence in new terminal ponds at upper end of new slough channels	Performance and success may be subject to uncontrollable variables. Follow water quality remedial actions.
Vegetation	Plant cover surveys and species composition	Years 2 and 5 each phase post-construction. Contingency Years 3 and 4	Spring/summer	Performance criteria shown in Tables 6 and 7 below	Success criteria shown in Tables 6 and 7 below	Replant, re-seed until criteria met; mechanically or manually remove invasive plants within revegetated areas of the project.

TOPOGRAPHY AND STRUCTURES

Overview

The objective of topographic monitoring is to evaluate post-construction topographic conditions. Monitoring objectives are to:

1) Assess channel bank stability and identify scour and/or aggradation within project reaches,
2) Assess aggradation in the constructed ponds,
3) Evaluate rates of scour or sediment aggradation on tidal marshes.

Topographic monitoring involves field survey and reoccupation of known benchmarks and includes a thalweg profile along the mainstem of Martin Slough and multiple channel cross sections along the main channel, tributary channels and across each of the ponds and marsh plains.

Topographic, hydrologic and water quality results are organized by water years that begin October 1 and end September 30. The topographic component of Martin Slough project monitoring is conducted every other year up to year 5 within each project phase. Topographic monitoring was completed for water year 2019 for the portions of the project constructed on NRLT (Phase 2) property. In 2021 topographic monitoring for Phase 2 Year 3 and Phases 3 and 4 Year 1 was conducted. Phase 5 Year 1 monitoring was delayed one year to consolidate all the topographic monitoring for all the phases to occur in odd years. This report provides monitoring results and findings for water year 2022, thus, does not include quantitative topographic monitoring.

Methods

Large wood features previously placed throughout the project were visually inspected at the conclusion of water year 2022. These included large wood cover structures on the North Fork tributary and log weirs installed in the mainstem at the upstream end of the project as part of Phase 5 construction. Topography was visually assessed on December 7, 2022 from the channel bank as part of the visual inspection of log weirs and large wood structures. The inspection focused on determining if any of the wood had moved, if any steel anchors were loose or corroded, and if any undesirable scour induced by the structure had occurred (MLA 2022).

Results and Discussion

Mainstem Channel Condition

Bank at Weirs, Upstream End of Project

Channel alignment at the upstream end of the project caused scour along the right bank of the upstream-most log weir, previously noted in the 2021 monitoring report. This condition appears to be improving as the upstream channel adjusts to the downstream weir elevations. Vegetation growing on the eroded bank is helping stabilize it and no active erosion was observed. This location should continue to be visually monitored. The downstream weirs have been partially buried by sediment, likely caused by backwater from the high-flow constriction created by the steel plates and brackets associated with the downstream salinity barrier.

Bank at Confluence with Pond F
During Phase 5 construction, there was bank sloughing into the channel on the left bank upstream of the confluence with Pond F. RCAA planted vegetation along the bank for stabilization and sedges have become well-established and a few willow stakes have established. The bank does not appear to have eroded further and the toe of the bank has not spread further into the channel.

Bank at NRLT Bridge
Immediately upstream of the new bridge and sheet pile retaining wall at the NRLT barn, a section of the right bank appears to be slumping into the channel at low tide. There are numerous seeps emerging from the adjacent hillside and high groundwater along the base of the adjoining hillslope appears to be driving the instability. Observations during low tide on December 7, 2022, confirmed that the extent of the slump appears to be relatively unchanged when compared to previous year's observations.

Large Wood Structures

The large wood structures were visually inspected from the bank on December 7, 2022. All structures (log cover structures, rood wad deflectors and habitat structures, log constrictors, log weirs) appeared stable and showed no signs of shifting since construction. No adverse scour along the banks was found in proximity to the structures. The complex wood structures located in the ponds' open water were partially or completely submerged during the low tide.

During the 2021 construction season RCAA staff filled and compacted voids that formed around the pile logs at the Pond D weirs. These areas appeared stable, and no additional erosion or scour was noted. Cattails have colonized the shallow section between Pond D and the most upstream weir where concrete mats are placed over the existing gas line crossing.

(See Appendix A, *Martin Slough Enhancement Project, 2022 Physical Monitoring Report,* Michael Love and Associates 2022.)

HYDROLOGY

Overview

The objectives of hydrologic monitoring are to measure water level fluctuations in amplitude and longitudinal extent relative to tidal influence within the project area. The objectives of hydrologic monitoring are to:

1) Evaluate the extent to which the project muted tides match the design muted tidal ranges
2) Assess flow conveyance (in both directions) through project reaches
3) Assess whether the higher muted tides (spring tides) during the dry season are remaining within acceptable ranges and not inundating adjacent NRLT pasture and/or greens and fairways of EMGC.

Results from hydrologic monitoring may be used to guide Muted Tide Regulator (MTR) adjustments and identify whether flow constrictions are affecting project performance.

Methods

The following sections were excerpted/adapted from the *Martin Slough Enhancement Project, 2022 Physical Monitoring Report,* Michael Love and Associates 2022 (Appendix A).

Water Level Monitoring

Four submersible water level loggers were installed: three on the mainstem of Martin Slough and one in the North Fork tributary. The loggers measure hydrostatic pressure above the sensor and are corrected using recorded atmospheric pressure to calculate the stage, or water level, in 15-minute intervals. A reference benchmark was established at each site and surveyed to determine water surface elevations in North American Vertical Datum (NAVD88). Data loggers were downloaded approximately every two months. At least one water level observation was made during each download period to calibrate the recorded data to the reference benchmark, placing all water level data into the NAVD88 vertical datum.

Stage data were recorded after Phase 1 completion starting in March 2017, expanded after Phase 2 completion and expanded further following Phases 3, 4, and 5 completions.

Property Line
Middle Reach of Martin Slough on NRLT property, near the property line with EMGC. A water level gage was installed on March 14, 2017, and was in operation through July 11, 2018, when it was removed for construction of Phase 2. This gage was discontinued and replaced by the Hole 18 (MS-18) gage after construction in 2018.

Swain Slough
A logger was installed in Swain Slough near the tide gate on February 11, 2018, and remains operational.

MS-Pond C
Lower Martin Slough on NRLT property. A logger was installed upstream of the confluence with Pond C on December 17, 2018, and remains operational.

MS-18 (Hole 18)
Middle reach of Martin Slough on EMGC. A logger was installed between Holes 17 and 18 downstream of Pond E on November 19, 2018, and removed on October 22, 2019, for Phase 3 construction. Following Phase 3 construction the logger was reinstalled on November 5, 2019; it was attached to the newly constructed vehicle bridge and remains operational.

MS-NF
Upper reach of Martin Slough downstream of the North Fork Tributary confluence on EMGC. A logger was installed on November 5, 2019, and removed on September 9, 2020 for Phase 4 construction. It was reinstalled in December 2020; however, the station was moved to a bridge on the North Fork Tributary just downstream of the existing irrigation pond and the future site of Pond G. The gage was removed from May 2021 to November 2021 for maintenance and construction of Phase 5. The gage remains in the North Fork tributary and is operational. See Table 1 in Appendix A for gaging station type and installation information.

Tidal Datums

Humboldt Bay experiences semidiurnal tides: two high tides and two low tides per day. The tidal datums of Mean Higher High Water (MHHW), Mean Lower High Water (MLHW), Mean Higher Low Water (MHLW), Mean Lower Low Water (MLLW), and sometimes Mean Tide Level (MTL) are used for designing and evaluating performance of tidal restoration projects. A key metric in sizing and maintaining tidal channel geometry is the average tidal prism, defined as the volume of water that drains between MHHW and MLLW.

The Humboldt Bay North Spit (NOAA Station No. 9418767) tidal datums converted to NAVD88 were used as a reference for unmuted tidal conditions. Tidal datums for each monitoring station were calculated on a per-month basis and seasonally using recorded water levels. A spreadsheet algorithm was used to identify the daily MHHW, MLHW, MLLW and MHLW and calculate the monthly averages.

Tidal Prism

The tidal prism is a key parameter in the design and self-sustainability of the project. Though Martin Slough receives freshwater inflows, the hydraulic geometry of the tidal channel of Martin Slough will be governed by the daily tidal flux created by the muted tide rather than less frequent high flow events from upstream. The daily tidal prism is a governing factor in the dimensions of the channel; a significant reduction in the tidal prism could cause sedimentation and a decrease in the channel cross-sectional area. MHHW or MLLW changes during the dry season, suggesting a change in tidal prism, could require changes in tide gate settings to restore the intended tidal prism and maintain geomorphic stability of the tidal channels. Tidal prism is calculated based on surveyed cross sections, thus, results are presented only for the years when a topographic survey is completed.

Results and Discussion

The following results and discussion were excerpted/adapted from the *Martin Slough Enhancement Project, 2022 Physical Monitoring Report,* Michael Love and Associates 2022 (Appendix A).

Muted Tide Regulator (MTR) Settings and Target Water Levels

During water year 2022 the muted tide in Martin Slough was controlled using the 6'x 6' side hinge gate and associated MTR in combination with the 2'x2' auxiliary door (slide gate) connected to its MTR. The 6-foot by 6-foot MTR gate was set to close when water levels in Martin Slough reached approximately 3.25 feet (NAVD88). The auxiliary gate closed when Martin Slough water levels approached 5.2 feet elevation. This elevation varied by several tenths of a foot from one tide cycle to the next.

Water Level

Water level data, combined with salinity and water temperature data, were plotted for each month of the 2022 water year (Appendix A, *MLA 2022, Appendix A*).

Swain Slough

Water levels fluctuated like those recorded at the NOAA North Spit tidal station (No. 9418767), except that the water level never dropped below 1.0 foot. Two conditions effected this: 1) the Swain Slough gage is in an outlet scour pool below a drainage flap gate, and the pool becomes disconnected from Swain Slough at the lowest tides; and 2) a tidal sill located on Elk River downstream of the confluence with Swain Slough results in the lowest tide levels being between elevation 0.5 to 1 foot (NAVD88).

Martin Slough near Pond C

Water levels at the Pond C gage showed water level fluctuating as expected, with the distinct signature of a muted tide that typically peaks just above elevation 5 feet (NAVD88) and does not drop below an elevation of 1 foot. Higher high tides appear to peak at about 5.5 feet, with an occasional peak just above 6 feet and the highest peak of 6.44 feet on December 23, of 2021. Peaks above 5.5 feet typically occurred over one or two days associated with elevated stream flows due to rainfall events.

Martin Slough near Hole 18

This monitoring station, MS-18, is located on the golf course vehicle bridge of the Martin Slough mainstem approximately 500 feet downstream of Fairway Drive, immediately downstream of the confluence with Pond E and a short distance upstream of the confluence with Pond D. Tidal influence extends past the Hole 18 gage; water level typically peaks at 5.0 feet with occasional peaks near 5.5 feet. Water level approaching 6 feet is usually associated with an exceptionally high tide or rainfall event. During water year 2022 the highest water level recorded at MS-18 was 6.29 feet on April 19, 2022, followed by 6.26 feet on December 23, 2021. During the dry weather monitoring period (June through September) the MS-18 is tidally influenced with a muted tide pattern fluctuating between 1 foot and 5.44 feet, closely corresponding to the water levels recorded at the Pond C gage.

North Fork Martin Slough

The North Fork Tributary gage was installed and operational on November 12, 2021 following Phase 5 construction. The baseflow water level during the period recorded was consistently between 2 and 5 feet elevation. The highest water level peak of 6.3 feet, was recorded on December 23, 2021. During the irrigation months (April to August) water level was controlled by the temporary salinity barrier (see Water Quality section below. From mid-April through early June high tide peaks were above elevation 4 feet, and the weirs were submerged during the peak high tide. From Early June through mid-August the barrier was raised to elevation 5.0 feet and flow was backed up behind it. Once the barrier was removed in mid-August water levels fluctuated daily with the tide between 2 feet and just above 5 feet.

Field Observations of Water Level Conditions

The brackish marsh around Pond C was observed during a low tide during the visual inspection on Dec 7, 2022 (see Appendix A, MLA 2022 Figure 9). The floodplain was wet from the previous high tide and brackish vegetation was established throughout the area indicating that brackish water is reaching the upper marsh plains as intended by design. Wood structures on the marsh plains were partially submerged during high tide, creating cover habitat.

Tidal Datums

Stage data was analyzed and tidal datums were calculated relative to the NAVD88 vertical datum. Monthly values are provided in Appendix A (MLA 2022, Appendix C), and averages for the dry season of July through September are provided in Table 3 below. This represents the period of minimal freshwater influence on the tidal channel. The yearly tidal datums calculated at the North Spit from 1983 to 2001, July through September datums for water year 2022, and the design muted tidal datums also are included. Tidal datums for the North Fork Tributary gage were not determined due to data collection interrupted by construction activities and by installation of the salinity barrier.

Table 3. Tidal datums for dry period of July through September 2022 and (2021) at each gage station.

Location	Water Level (NAVD88)			
	MLLW	MTL	MHHW	Ave. Diurnal Range
North Spit epoch 1983-2001)	-0.34 ft	3.36 ft	6.51 ft	6.85 ft
North Spit (July -Sept. WY 2022)	0.27 ft	3.95 ft	7.13 ft	6.86 ft
Swain Slough	1.48 ft (1.55 ft)	3.95 ft (3.98 ft)	6.69 ft (6.79 ft)	5.21 ft (5.24 ft)
Martin Slough				
MS Design	1.50 ft	Not Provided	5.50 ft	4.00 ft
MS at Pond C	1.46 ft (1.39 ft)	3.43 ft (3.45 ft)	5.11 ft (5.19 ft)	3.65 ft (3.80 ft)
MS at Hole 18	1.32 ft (1.22 ft)	3.26 ft (3.26 ft)	4.92 ft (5.01 ft)	3.61 ft (3.79 ft)

(From MLA 2022, p. 17)

Except for MLLW, which is influenced by a tidal sill in the Elk River Slough that limits draining of the tide, the Swain Slough data collected during this monitoring period are similar to North Spit, although higher. This is likely due to periods of elevated flows in Elk River that raise water levels in Swain Slough. When compared to the previous water year (2021) the MLLW, MTL and MHHW decreased by 0.07 feet, 0.03 ft and 0.10 feet, respectively. At the Pond C gage, when compared to the water year 2021 datums, the MTL and MHHW decreased by 0.02 and 0.08 ft, respectively while the MLLW increased by 0.07 feet. At the Hole 18 gage, the tidal datums for MLLW increased by 0.10 feet, MTL stayed the same, and the MHHW decreased by 0.09 compared to the previous year.

The tidal datums can be used to determine the inundation frequency of areas that have been revegetated with brackish-tolerant plant species. With completion of Phase 5 in 2021, the tide gate settings were no longer operated based on interim conditions. However, the tidal range increase to 5.5 feet to meet MHHW design criteria was not implemented due to concerns with tidal flooding of low-lying golf course greens and increased salinity in the upstream ponds and channel reaches, intended to provide seasonal freshwater habitat.

(See Appendix A, *Martin Slough Enhancement Project, 2022 Physical Monitoring Report,* Michael Love and Associates 2022.)

WATER QUALITY

Overview

The objectives of water quality monitoring are to:

1) Assess the parameters of salinity, dissolved oxygen (DO) and temperature in terms of suitability for target species and habitat,
2) Ensure that salinity does not extend upstream to the golf course irrigation pump intake when in use.

Performance Criteria

The project monitoring plan (RCAA 2021) defines performance criteria for salinity, water temperature, and dissolved oxygen. The performance criterion for DO concentrations is $\geq$4 mg/l when salmonid presence is expected. This metric is mainly applied to surface DO concentrations, as bottom concentrations can be substantially lower when fish are present. For Pond G and the North Fork tributary this applies year-round, as Pond G and the North Fork were intended to provide over-summering habitat for rearing juvenile salmonids. Ponds C, D, E and F and the mainstem channel are expected to provide seasonal over-wintering salmonid habitat and the water quality criteria apply from late fall into mid to late spring.

Water temperature performance criteria were based on daily values. Water temperature should maintain a daily average of <18°C and daily maximum of <21°C during periods when salmonids are expected to be present.

The salinity threshold is 4 ppt and generally applied to surface salinity concentrations due to higher DO and lower concentrations near the surface where fish are expected to mainly occur.

The project, once completed, was intended to create a longitudinal gradient of salinity, with the highest salinity near the tide gate transitioning to freshwater conditions at the upstream end and each pond having different concentrations of brackish water. Additionally, stratification is expected to provide a vertical gradient from more saline waters at the bottom to less brackish water near the surface. During rainfall-runoff events the entire project channel length and all the ponds are anticipated to be predominately freshwater. With completion of the project's upstream reach in 2021, the water year 2022 salinity data show brackish conditions have moved upstream as expected.

Temporary Salinity Barrier

The EMGC currently diverts surface water from Martin Slough for irrigation of turf using their riparian water right. The irrigation diversion is in the North Fork channel of Martin Slough, approximately 265 feet upstream from the confluence with the mainstem. The water pumped from the channel originates from both the North Fork and mainstem of Martin Slough due to the low gradient of the slough and resulting backwatering of the pond from the mainstem. In mid-April, a temporary salinity barrier was installed in the mainstem just downstream of the confluence with the North Fork to isolate the municipal golf course irrigation intake from the tidal prism (Figure 2). At that time salinity in water pumped for irrigation was too high for watering greens and fairways. The salinity barrier was intended to allow for a year-round muted tidal regime downstream of the North Fork confluence with the Martin Slough mainstem following construction completion in 2021 (MLA 2022). The salinity barrier's intended operation period was the irrigation season with removal by the end of 2026, unless golf course irrigation system upgrades were completed beforehand.

Figure 2. Temporary salinity barrier installed to isolate the EMGC irrigation intake from the tidal prism. Located on the Martin Slough mainstem just downstream of the confluence with the North Fork.

Methods

The following methods section was excerpted/adapted from the *Martin Slough Enhancement Project, 2022 Physical Monitoring Report,* Michael Love and Associates 2022 (Appendix A).

Temperature and salinity data loggers were installed at the same locations as the water level loggers, except at Swain Slough. Salinity data loggers also recorded water temperature and were installed in each perforated standpipe, one at the bottom coupled to the water level logger and one attached to a float that traveled the height of the standpipe and measured conditions approximately 10 inches below the surface. At the MS-NF site only surface salinity was recorded. Salinity and temperature were recorded continuously on the same 15-minute interval as the stage data loggers. Salinity data loggers were not installed at the Swain Slough station, but Swain Slough water temperatures were recorded by the water level logger placed at the bottom of the water column. Spot measurements of salinity, temperature and dissolved oxygen were also taken using a YSI handheld meter and recorded on data sheets as the data loggers were downloaded, typically at a low tide. Additional water quality measurements were taken during fisheries monitoring and covered in the Annual Fishery Monitoring Report (Appendix B).

Surface and bottom salinity concentrations and water temperatures recorded at each gaging station in water year 2022 were plotted with water level (Appendix A, *MLA 2022*, *Appendix A)*. The plots included daily rainfall totals measured at the National Weather Service (NWS) office on Woodley Island, Humboldt Bay, for reference. A table of water quality spot measurements recorded during each data download is presented in Appendix A, *MLA 2022*, *Appendix B*. Spot measurements include water temperature, salinity, and DO concentrations. Plots of daily average and daily maximum water temperatures are shown in Figure 3.

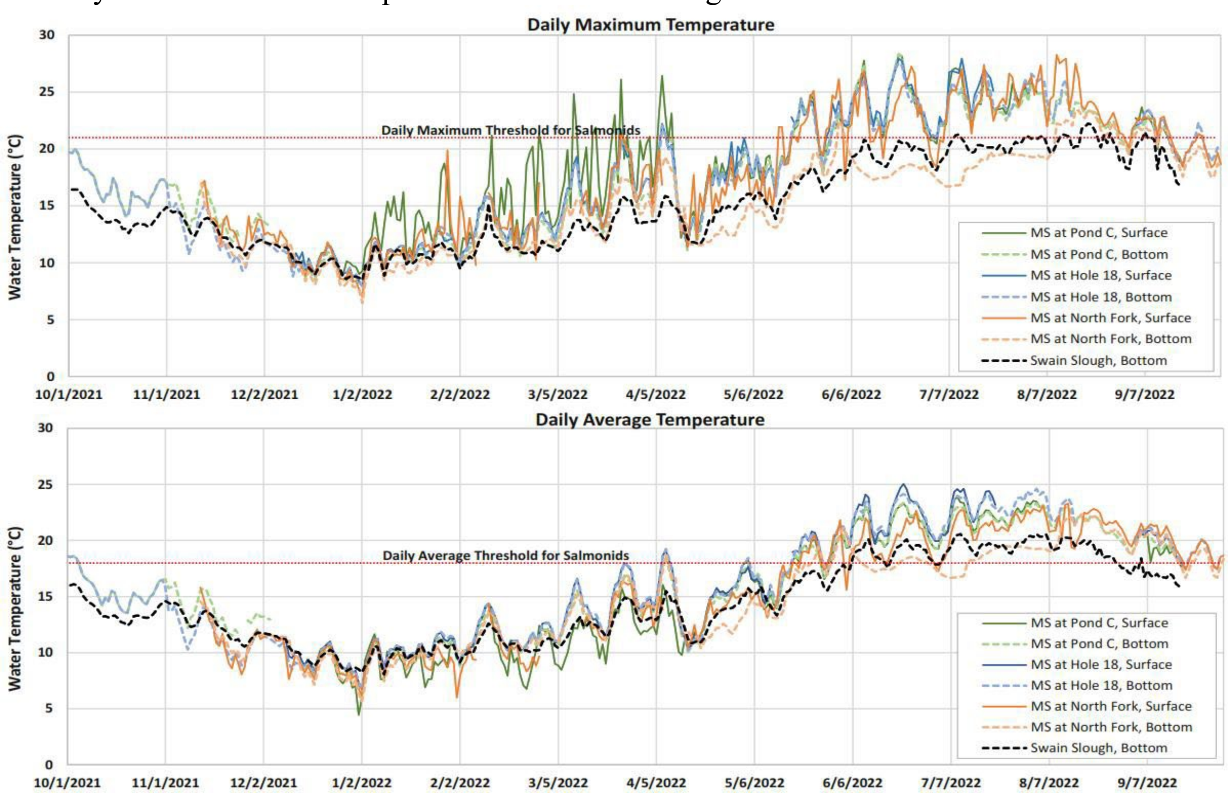


Figure 3. Daily maximum and daily average water temperatures for water year 2022 recorded at the Swain Slough, Martin Slough at Pond C, Martin Slough at Hole 18 and the North Fork Tributary gaging stations.

Results and Discussion

The following results and discussion were excerpted/adapted from the *Martin Slough Enhancement Project, 2022 Physical Monitoring Report,* Michael Love and Associates 2022 (Appendix A).

Salinity and Water Temperature

Water temperatures within the project area are dependent on air temperature, temperature of freshwater inflow from upstream, and temperature of inflow from Swain Slough. During winter months temperatures are expected to be similar to freshwater streams around Humboldt Bay. During the dry season, areas with brackish water should experience higher water temperatures due to influence from Humboldt Bay and Swain Slough. These can readily exceed 20°C due to shallow inundation of mudflats during rising tides in the daytime. Water temperature data from water year 2019 through 2022 show these trends.

A Note Regarding Data Loggers

At the end of water year 2021 and beginning of water year 2022, many data loggers that had been in use for the duration of the project began to fail. Loggers were returned to the manufacturer and data were recovered when possible. Data not recovered created a gap in the data plots. Periodically the surface salinity data loggers, attached to a float, would become tangled in the standpipe and remain stuck when water receded. Downloading the data and reinstalling a logger resets the logger's position and it can be difficult to parse the data to determine when the logger became stuck. Data for those time periods were removed from the data set whenever possible.

Swain Slough

Water temperatures in Swain Slough during the fall of 2021 and early winter of 2022 were similar to those measured in the freshwater reach of Martin Slough near MS-18 and upstream at the North Fork Tributary gage, with small diurnal temperature fluctuations (Figure 3**)**. However, by mid-April 2022, water temperatures became elevated and both diurnal and tidal influenced temperature fluctuations became more apparent.

Salinity was not recorded in Swain Slough.

Martin Slough near Pond C

In Martin Slough at Pond C, the salinity was highly correlated with precipitation, and stratification was present during periods not dominated by freshwater inflows. During periods between rainfall events the bottom salinity would fluctuate dramatically with incoming and outgoing tides, while the surface salinity generally fluctuated less and was less brackish. During periods with precipitation, salinity concentrations were close to zero for days at a time. Several days following the cessation of rainfall, the bottom salinity increased relatively rapidly, while the surface salinity slowly increased with each tide cycle. This pattern was most pronounced in January 2022.

Water temperatures in Martin Slough near Pond C remained low throughout the fall and early winter months. Surface and bottom temperatures were nearly identical much of the time, with periods where the surface water temperature was colder and fluctuated much more with tidal cycles than along the bottom. This seemed to be associated with stratification during flood tide and mixing during ebb tide. By May 2022, temperatures at this location began to rise, as did salinity, due to lack of rainfall. During the summer months water temperatures were between 18° and 22°C and were consistently warmer than Swain Slough.

Martin Slough near Hole 18
Salinity measurements in Martin Slough near Hole 18 showed that during winter and early spring both surface and bottom salinity fluctuated between 0 and 22 ppt almost daily with the tidal cycle. However, starting in April, salinity decreased dramatically with the onset of rainfall. Water temperatures in Martin Slough near Hole 18 fluctuated with tides and showed diurnal fluctuation with changes in precipitation and ambient air temperature. These fluctuations grew more exaggerated in the warmer months starting in April and continued through September.

North Fork Martin Slough
Salinity measurements were recorded at the surface at the North Fork Tributary gage, located just upstream of the confluence with the mainstem. Data showed that saline water is reaching the upper reach of the Martin Slough project area. When the temporary salinity barrier was installed surface salinity dropped to less than 0.5 ppt. With its removal in August the salinity fluctuated with the tide between 0 and 18 ppt.

Temperature values showed normal diurnal fluctuations, with warming during the summer months. Water temperature performance criteria are applied year-round due to the goal of providing year-round conditions suitable for rearing salmonids in this section of the project. The salinity barrier installation influenced water temperatures by increasing surface temperature and decreasing bottom temperatures, presumably due to lack of mixing that occurred after the barrier was installed.

Comparison to Performance Criteria

Salinity
Spot measurements of salinity were almost always above the 4 ppt threshold unless there was rainfall, with the exception of the North Fork tributary that recorded low values of 0.1 and 0.4 ppt during the salinity barrier installation period. The continuous data (Appendix A, *MLA 2022, Appendix B*) showed that during the winter months surface salinity at all three gage stations fluctuated with the tide cycle, often dropping below the 4 ppt threshold during low tide and for extended periods during precipitation events. During the warmer and drier summer months Pond C and Hole 18 surface salinity levels showed less fluctuation. Salinity generally remained above 16 ppt and 12 ppt in Pond C and Hole 18 beginning in May and June, respectively.

In the spring, prior to installation of the salinity barrier, North Fork Tributary gage salinity levels periodically exceeded 4 ppt. Despite the barrier, salinity remained too high for irrigation with the pump and in August the salinity barrier was removed by EMGC staff in an attempt to flush the upstream ponds and capture freshwater. Following its removal salinity climbed to between 12 and 18 ppt. Concentrations far exceeded those suitable for rearing salmonids due to the substantial amount of tidal inflow to the North Fork combined with a lack of freshwater inflow to keep the reach fresh.

The 2022 water year experienced 25.48 inches of rainfall based on the NWS Woodley Island gage in Eureka, CA. The Eureka 20-year average rainfall for 1991 to 2020 was 41.40 inches. The 2022 water year was 62% of normal; this drier than normal year is one likely cause of high salinity levels due to lack of freshwater flowing through the project area or entering from Elk River via Swain Slough.

Water Temperature

Temperature values recorded during the water year are shown in Figure 3. During the months of October through April maximum daily and average daily water temperatures were below the thresholds of 21°C and 18°C, respectively, for juvenile salmonids. During the summer months the daily average temperature increased to between 18°C and 25°C. From June to August, Swain Slough temperatures were also above the daily average threshold of 18°C. The North Fork gage recorded the lowest values of the four gage stations during the summer months, however, the North Fork data set was incomplete due to construction in fall of 2021. The data suggest the inflow of tidal water from Swain Slough governs the water temperatures in Martin Slough due to the large degree of tidal cycling. The drier than normal water year and resulting low base flow is one likely cause of the higher temperatures in the 2022 water year.

Dissolved Oxygen Spot Measurements

Spot measurements of DO by RCAA staff during each data logger download are provided in Appendix A (*MLA 2022*, *Appendix C)*. The measured DO levels at the four sites were generally above the minimum performance criteria of 4 mg/l on the surface, and were often substantially higher. The DO levels were considered acceptable for rearing salmonids and other aquatic organisms.

(See the *Martin Slough Enhancement Project, 2022 Physical Monitoring Report,* Michael Love and Associates 2022, Appendix A.)

TOPOGRAPHY, HYDROLOGY AND WATER QUALITY RECOMMENDATIONS

The following recommendations were excerpted from the *Martin Slough Enhancement Project, 2022 Physical Monitoring Report* (Michael Love and Associates 2022).

The Martin Slough Enhancement Project was implemented in phases with the final construction phase completed in 2021. While the restoration project was completed, the EMGC is still working on establishing an alternative irrigation supply. In the interim the golf course used the temporary salinity barrier, attempting to maintain freshwater at its screened pump intake on the

North Fork. The salinity barrier affected the upstream hydrologic and water quality conditions. However, it did not appear to influence downstream water quality.

Channel Conditions

The high point identified along the thalweg profile near the NRLT bridge is still present. It originated from a slumping bank associated with high groundwater and saturated soils close to the base of the adjoining hillslope. Material may continue to slump at this location, but currently is not significantly constricting the channel or influencing the tidal amplitude. The project manager and project engineer should continue to inspect this site to detect if any additional slumping occurs, and/or if the channel is scouring this material.

The second area of sedimentation noted in the 2019 survey at the property line near the previous grade control should also continue to be monitored to see if this material scours-out or causes a reduction in tidal exchange or outflow of freshwater. This will be evaluated as part of the topographic monitoring in 2023.

The previously noted eroding bank at the upstream end of the project may continue to adjust and should be monitored to ensure the upstream-most log weir adjacent to this location remains stable. Minor bank armoring might be needed to protect the upstream weir and piles. Future channel surveys should include the channel immediately upstream of the project on the mainstem to assess changes to bed elevation and width.

Water Levels

The 2022 water level data show that the tidal amplitude and MHHW in Martin Slough are both less than the design values (Table 3 above). Further increasing the muted high tide by adjusting the tide gate settings to better achieve the design condition was discussed but considered undesirable, as it would further increase salinity concentrations in the upper portions of the project, the area intended to provide low salinity aquatic habitat during the dry season. Additionally, there are low areas on the golf course adjacent to the channel that could become inundated during spring tides if the gate is adjusted to increase tidal amplitude. Even with the current lower than design setting, the tidal amplitude and MHHW water levels are inundating the constructed surfaces (i.e., marsh plains) and vegetation is becoming established as intended.

Water Quality Conditions

The water quality monitoring shows that water temperatures and salinity concentrations in the North Fork are exceeding the performance thresholds during summer and early fall. When the salinity barrier was in place, the salinity concentrations were within criteria, but the water temperature remained above the performance thresholds (Figure 3 above). The higher salinity concentrations are likely due to lower summer stream flows and more tidal-freshwater mixing than assumed during the design. Drought conditions resulting in below average stream flows during 2022 likely further influenced water quality. Adaptive management options to reduce salinity and water temperatures in the upper reaches of the project should be explored but appear to be limited at this time.

Monitoring Protocols
The water quality and stage monitoring equipment has been in operation since 2017. Some equipment likely requires servicing or replacement, especially given the project's corrosive brackish water environment. Battery levels should continue to be monitored and replaced when the voltage is consistently falling below 3.4 to 3.3 volts.

Monitoring stations should be examined to ensure that the t-posts are sufficiently embedded and the straps holding each pipe are sound. Stainless steel cables inside the standpipes have corroded and were replaced with nylon cord and should be examined during each download.

Access to the Pond C gage is along a log that extends from the toe of the bank into the channel (Appendix A; *MLA 2022*, *Appendix C Figure 7*). An additional length of metal safety grating should be installed along the log to provide sure footing when accessing the standpipe. A rope staked into the bank would also be helpful for traversing the steep bank.

Increasingly, the floats in the standpipes that keep the upper salinity data logger at the water surface have become stuck after high tides, leaving them dry until the next high tide event. This unfortunately leaves portions of the upper salinity dataset unusable. The floats should be replaced with a smaller spherical float that allows for unfettered movement as the tide rises and falls. The standpipes are 4-inch diameter, and a 3-inch diameter or smaller ball float should improve the performance. Additional weight applied to the existing data loggers may also help.

FISHERIES

Overview

The objectives of fisheries monitoring include documenting fish presence, species diversity and associated water quality within a variety of sampling locations in all habitat types within the Martin Slough project area. Beginning in 2019, Ross Taylor and Associates (RTA) and graduate students from Cal Poly Humboldt conducted work including Passive Integrative Transponder (PIT) tagging juvenile coho salmon (*Oncorhynchus kisutch*), generating growth rates from recaptures of previously tagged fish, determining coho residency times and timing of smolt out-migrations and assessing off-channel habitat use by juvenile coho.

Methods and Materials

The following section was excerpted/adapted from the *Martin Slough Enhancement Project- Coho Salmon Monitoring Report for Fall/Winter/Spring of 2021-2022*, Ross Taylor and Associates 2023), attached as Appendix B.

Fisheries monitoring occurred 2 days per month, starting in November 2021 and ending in June 2022, thus, all references to '2022' fish monitoring include November and December of 2021. Sampling sites were distributed throughout the project area (Figure 4). On the NRLT property, established monitoring sites were located at Pond C, Southeast Tributary and the Oxbow Channel. On EMGC property monitoring sites were located at Ponds D, E, F and G, and the mainstem below and above Fairway Drive. The number of sites monitored per month ranged from 5 to 11.

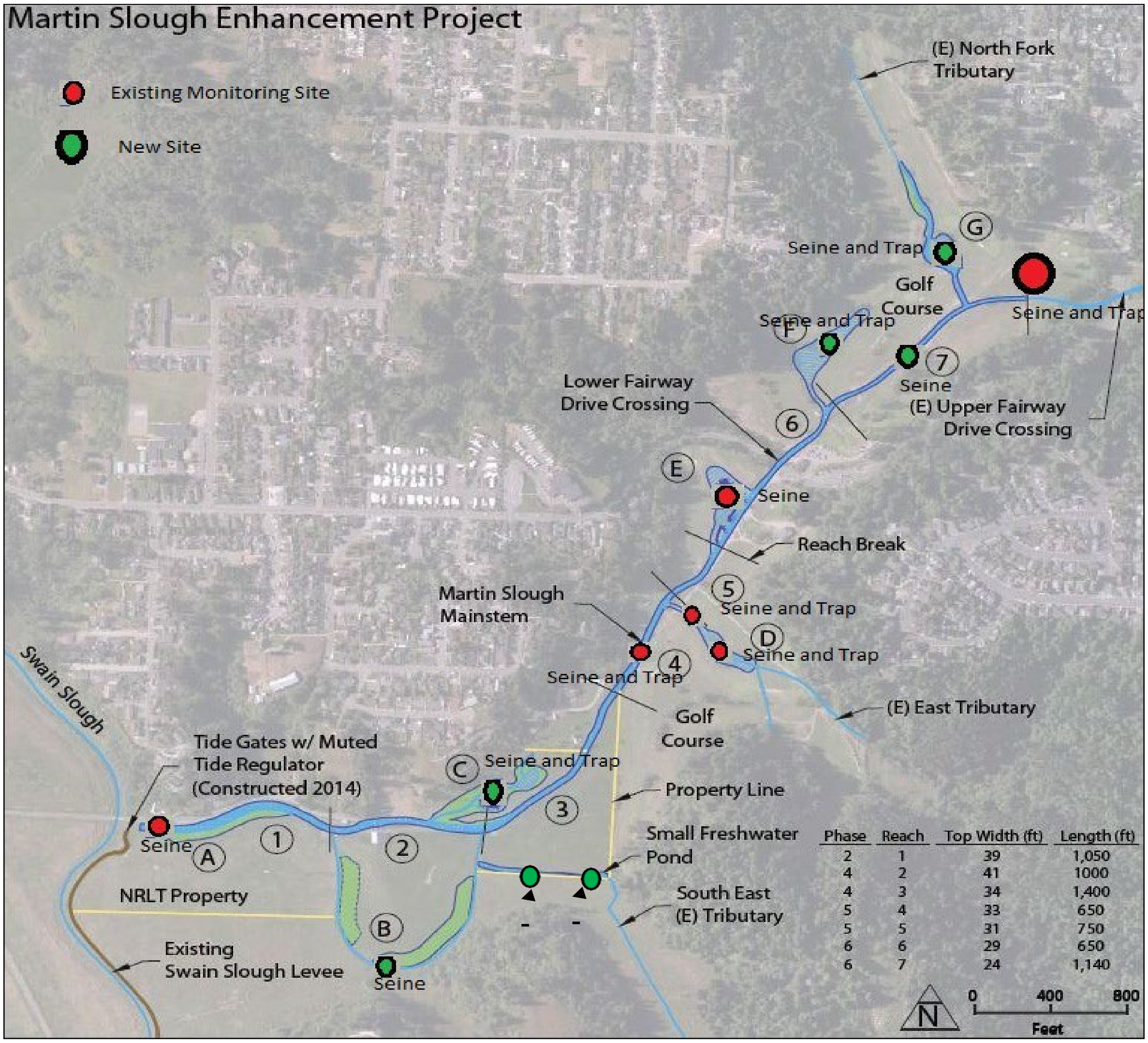


Figure 4. Martin Slough Enhancement Project reaches, ponds and fisheries monitoring locations.

A variety of seine net sizes (lengths of 10, 20, 22, 30, 80 and 100 feet) was used, depending on the site, tide levels and water depths. The 10-foot through 30-foot nets were 4 feet tall and the 80-foot and 100-foot nets were 6 feet tall. When sampling most locations a net with ¼-inch mesh was used, however, for areas known to support tidewater goby, nets used were 1/8-inch mesh.

The method of fish capture processing depended on the species caught and location. For example, threespine stickleback (*Gasterosteus aculeatus*) and Pacific staghorn sculpin (*Leptocottus armatus*) were counted out of the seine net and immediately released. When large numbers of stickleback were encountered, they were batch-counted in visual estimates of 25 fish per aquarium net-scoop. Tidewater goby (*Eucyclogobius newberryi*) and smelt species were not held in buckets due to Endangered Species Act status (goby) or fragility (smelt). All coho and other salmonids were temporarily held in dark-colored 5-gallon pails with lids and battery-powered aerators. Processing salmonids involved anesthetizing, measuring, weighing, scanning and/or tagging.

Captured salmonids were anesthetized using Alka-Seltzer Gold. The lowest concentration of the medication (1 fully dissolved aspirin-free tablet) that permitted safe handling was used. Fork length (FL) to the nearest mm and weight to the nearest 0.01 g were recorded for each fish captured. Each fish was scanned for a PIT tag. Anesthetized fish >75 mm FL were surgically implanted with 12-mm or smaller PIT tags; fish 65-75 mm FL were implanted with 9-mm PIT tags or smaller; and fish <60-mm FL were not tagged.

A PIT tag antenna array was previously established in the main channel of lower Martin Slough to record outmigration.

Processed juvenile coho were allowed to recover in an aerated bucket and monitored until all fish appeared upright and swimming. Fish were released back into their capture locations and were carefully observed during their post-surgery release. When large numbers of fish were processed, both the anesthetizing bath and recovery container water were changed to avoid subjecting fish to increased water temperatures.

At each sampling location, water quality measurements were taken with handheld YSI water quality meters that included dissolved oxygen, temperature, and salinity taken at near-surface to a maximum depth in 1-foot intervals. Survey start and end times were also recorded.

Data Storage/Processing

Data from the handheld PIT tag reader and notebook were downloaded in the RTA office and entered into Excel. Spreadsheets were created for juvenile coho salmon catch, growth rate calculations of recaptured coho, tidewater goby catch, general fish catch, and water quality measurements. Growth rates were computed for recaptures of previously tagged fish by subtracting the fish’s most recent length and weight from its previously recorded length and weight, then dividing the difference by the number of days between capture events (days at large). When individual fish were recaptured multiple times, the month-to-month growth rates depicted how growth changed over the course of the fall/winter/spring season.

Another objective of fish monitoring was documenting the out-migration timing of coho salmon smolts in Martin Slough. A PIT tag antenna array and data logger system were installed in the lower reach of Martin Slough near the barn on the property owned and managed by the NRLT (Figure 5). This system consisted of a Biomark® IS1001 Multiplexing Transceiver system and two 10’x 3’ pass-through antennas. The antennas were arranged side-by-side to cover the channel cross-section. This side-by-side arrangement provided better coverage of tagged fish migrating downstream, at the expense of having the antennas set above and below each other to detect direction of movement (direction is documented by a fish passing by one antenna and then the next antenna). All juvenile coho were tagged upstream of the array, therefore, all tag detections consisted of out-migrating coho smolts. Unknown tags or fish tagged in other Humboldt Bay drainages were assumed to be moving in an upstream direction through the array, having entered Martin Slough through the tide gate located approximately 1,200 feet downstream. The side-by-side orientation of the antennas provided better coverage during the wide variations in channel depth and width because of tide changes (Figures 5 and 6). Biomark® auto-tuned the antennas, which is important in a tidally influenced area with changes in water depths and salinity levels.

Figure 5. PIT tag antenna array system in lower Martin Slough at low tide on April 25, 2022.

Figure 6. PIT tag antenna array system in lower Martin Slough at high tide on April 27, 2022.

Due to technical problems associated with electrical interference and delays in obtaining equipment to address the problem a fully functioning system with two antennas was operational by late April 2022, probably a month after the commencement of the coho smolt out-migrations. PIT tag detection data from the IS1001 unit were downloaded in approximately one-month intervals and the site was visited 2 or 3 times monthly to clear debris off the antennas and make sure the IS1001 unit was running properly.

Results and Discussion

The results section was excerpted/adapted from the *Martin Slough Enhancement Project- Coho Salmon Monitoring Report for Fall/Winter/Spring of 2021-2022*, Ross Taylor and Associates 2023, Appendix B.

Sampling Dates and Locations

Fourteen sites within Martin Slough were sampled during the 2021-2022 season (Figure 4). Sampling typically occurred 1 day per month in the upper reaches of Martin Slough, followed by a day lower in the watershed. Between 3 and 8 sites were sampled per day depending on tides, ease of access, and/or numbers of juvenile coho captured.

Species Numbers and Capture Sites

Fourteen fish, 2 crustacean, 2 amphibian and 1 reptile species were captured during the 2022 season (see Appendix B for specific capture information). Juvenile coho and tidewater goby captured numbered 1,691 and 1, 355, respectively. The 14 fish species captured varied in distribution. Threespine stickleback was the most abundant species encountered and present at all 14 sampling locations. Tidewater goby was abundant; its distribution increased over the four years of project construction as the upstream extent of brackish water increased. Tidewater goby were captured in 12 of the 14 sampling locations; they were absent from the 2 sites upstream of brackish water intrusion. The upstream distribution of Pacific staghorn sculpin increased similarly to tidewater goby; as the brackish water extended farther upstream, so did the presence of staghorn sculpin. Eighty-five percent of fish species were captured in Pond F. In contrast, just 2 species (14%) were captured in the East Tributary Pond D.

Coho Salmon Catch and Growth Rates

Out of 1,691 juvenile coho salmon caught in 2022, 1,519 (90%) were fry caught in May and June and suspected progeny of adults successfully spawning in Martin Slough. There were 173 captures of age-0 and age-1+ fish that most likely migrated into Martin Slough from the Elk River during the late-fall/early-winter juvenile redistribution period. Most of the newly emerged fry were caught in the main channel, above or near the confluence with the North Fork of Martin Slough. In May 2022, a sub-sample of these fish were measured and weighed and were between 46 and 54 mm in FL and 0.6 to 1.6 g (too small to tag; Figure 7).

Figure 7. Coho salmon smolt and 6 fry caught at the Upper Fairway Drive site on May 19, 2022.

RTA implanted 133 PIT tags in coho and recaptured 36 (169 coho captured). Two smolts that failed to out migrate in 2021 were captured in Pond D in November and December of 2021. Most (89%; 117 tagged and 34 recaptured) of the juvenile coho were in pools at Upper Fairway Drive sampling locations. The remaining tags were implanted in juvenile coho captured at Pond G (18 fish), North Fork Channel below Pond G (8), main channel near the North Fork confluence (8), Pond E (7), Pond F (6), and the main channel near the East Fork confluence (3). The two recaptures outside the Upper Fairway Drive sites occurred in Pond G and the North Fork channel immediately below Pond G.

Daily growth rates were computed for all previously PIT tagged fish, recaptured in February, March, April and May. In February, computing daily growth rates of recaptured fish was straightforward because recaptures were only from the previous month. In March through May, fish were recaptured with varying numbers of days at large and some fish were recaptured multiple times. (For tables with all of the daily growth computations from PIT tag recaptures see Appendix B, *Martin Slough Enhancement Project- Coho Salmon Monitoring Report for Fall/Winter/Spring of 2021-2022*, Ross Taylor and Associates 2023.)

Growth rates tended to increase as the rearing season progressed and water temperatures generally increased (Table 44. The individual fish with the highest growth rate was tagged and recaptured in a brackish water location of the North Fork, just below Pond G, and provided our only documentation of growth rates in brackish water. At this location, the salinity measurements on February 24 equaled 2.2 ppt at the near-surface and 8.8 ppt at a depth of 1.0 feet. On the day of its recapture on March 28, the salinity measurements were 0.5 ppt at the near-surface, 0.7 ppt at a depth of 1 foot, and 1.8 ppt at a bottom depth of 1.5 feet.

Table 3. Average month-to-month growth rates for juvenile coho salmon in Martin Slough, January through May of 2022. Water temperature measured in the lower pool at Upper Fairway Drive when coho salmon were sampled.

Growth Period	Number of Recaps	Average Growth - length	Average Growth - weight	Water Temp at Upper FW Drive
January to February	6 fish	0.16 mm/day	0.08 g/day	Jan = 9.0ºC
February to March	11 fish	0.32 mm/day	0.11 g/day	Feb = 5.9ºC
March to April	8 fish	0.55 mm/day	0.14 g/day	March = 8.8ºC
March to May	3 fish	0.51 mm/day	0.15 g/day	April = 10.3ºC
April to May	2 fish	0.35 mm/day	0.14 g/day	May = 13.0ºC

Recaptures of previously tagged juvenile coho indicated minimal movement of fish between capture events. All but one fish recaptured were in the location of initial capture. Length of residency in the Upper Fairway Drive pools varied from 113 to 59 days. A fish with 3 recaptures, tagged on January 25, experienced increased growth rates each time it was recaptured: 0.20 mm/day between January and February, 0.40 mm/day between February and March, and 0.56 mm/day between March and April.

Coho Salmon Out-Migration and Antenna Array Detections

The PIT tag antenna array system located in lower Martin Slough was operating with one functional antenna on April 8 and was fully operational (two antennas) on April 25. Between April 8 and June 21, 50 individual tags were detected by the array; 49 tags were in juvenile coho salmon including 1 coho from Freshwater Creek. Of the 133 fish tagged in Martin Slough, 37% were detected by the array. In April, 13 tagged fish were detected; in May, 29 fish were detected; and in June, 8 fish were detected. The final download of the array's data logger occurred on July 27, after the final tag was detected on June 21. As stated previously, a portion of the out-migration season was missed due to equipment malfunction prior to April 8 and partial function prior to late April. Research spanning nearly a 70-year period confirmed that April and May are the peak months in California for coho salmon smolt out-migration (Shapovalov and Taft 1954; Drucker 1972; Ettlinger et al. 2021).

Most of the Martin Slough array detections (33 of 49) occurred during periods of darkness. Of the 16 detections that occurred during daylight hours, 7 were between 6:00 AM and 7:00 AM and 3 were after 4:00 PM. Twenty of the 49 detections (41%) occurred between 10:00 PM and 4:00 AM. RTA's results regarding diel timing of out-migration movement were consistent with other studies that documented most movement occurring at night. Meehan and Siniff (1962) found that on the Taku River the peak migration of coho smolts occurred between 11:00 PM and 3:00 AM. Mace (1983) reported that coho smolts were rarely observed out-migrating during daylight hours, and they appeared in the transition zone between freshwater and the estuary only in the afternoon and evening hours.

Water Quality Measurements

The overall trend observed in 2022 monitoring was the persistently high salinity readings in all of the off-channel ponds, including Pond G, the uppermost pond on the EMGC. During the 4 years of project construction, salinity in the Martin Slough ponds increased each year as more of the channel was excavated, the muted tide gate became fully operational in the fall of 2020, and the upstream extent of high tides increased (Table 5). Ponds D, E, F, and G were all constructed with high tailwater controls which prevented the ponds from fully draining, including more dense brackish water from draining out of the ponds. It also appeared that rain events created a low-salinity lens on the near-surface to one-to-two feet of depth. Deeper than 2 feet, the waters remained highly brackish, too salty to support over-winter rearing of juvenile Coho Salmon.

Table 5. Salinity readings in parts per thousand (ppt) in 4 off-channel ponds. The 2021 data were collected by Cahill/CPH and the 2020 and 2022 data were collected by RTA. The first value is near-surface and second value is salinity at the pond's maximum depth.

Sampling Date	Pond D	Pond E	Pond F	Pond G
4/23/20	0.2 – 0.2	0.2 – 0.2	Not sampled	Not constructed
5/26/20	0.2 – 0.2	0.2 – 0.2	Not sampled	Not constructed
1/31/21	0.3 - 5.1	0.1 – 0.4	0.1 – 0.2	Not constructed
2/24/21	0.1 – 0.7	0.2 – 0.2	0.2 – 0.8	Not constructed
3/17/21	0.1 – 0.1	0.2 – 0.7	Not sampled	Not constructed
4/14/21	0.2 – 0.4	1.4 – 1.8	2.5 – 4.6	Not constructed
5/17/21	0.3 – 0.3	5.5 – 6.2	7.4 – 8.1	Not constructed
1/25-26/22	0.3 – 18.3	11.1 – 15.7	7.1 – 15.3	1.0 – 19.1
2/24/22	Not sampled	Not sampled	7.1 – 20.2	Not sampled
3/28/22	0.3 – 11.8	21.7 – 22.8	3.4 – 20.3	5.3 – 16.2
4/25-26/22	Not sampled	1.9 – 3.6	0.6 – 15.2	0.8 – 14.8
5/19-20/22	10.3 – 11.1	10.3 – 11.1	7.6 – 11.2	2.0 – 15.2

Dissolved oxygen, water temperature and salinity measurements are provided in Appendix B, *Martin Slough Enhancement Project- Coho Salmon Monitoring Report for Fall/Winter/Spring of 2021-2022*, Ross Taylor and Associates 2023.

Recommendations

The following section was excerpted/adapted from the *Martin Slough Enhancement Project- Coho Salmon Monitoring Report for Fall/Winter/Spring of 2021-2022,* Ross Taylor and Associates 2023, Appendix B.

During the 2022 8-month sampling period 14 sites within the project area were sampled and each site was sampled multiple times. During the second sampling season in the fall/winter/spring of 2022-2023 RTA intends to sample at similar frequency and effort. In an attempt to tag as many fish as possible, sampling intensity may increase in freshwater and low-salinity areas where more juvenile coho are likely to be present. Less frequent sampling is planned in areas with high densities of tidewater gobies, specifically to reduce potential impacts to this endangered species. These areas include Pond C and the Pond C terminal channel.

One juvenile coho detected in Martin Slough originated in Freshwater Creek. This fish was captured and tagged at the Freshwater Creek downstream outmigrant trap on June 5 and 12 days later it was detected in Martin Slough. The distance between these 2 locations is approximately 11 miles; the fish's path through Humboldt Bay was unknown but assumed to be a pathway hugging the eastern shore of the bay, which may not be the preferred pathway of out-migrating smolts (Pinnix et al. 2013). Movements of juvenile coho between various tributaries within Humboldt Bay were previously documented, however, this is a relatively rare occurrence (Halloran 2020). Acoustic tagging and tracking of coho smolts in Humboldt Bay determined that smolts spent between 15-22 days in the bay prior to out migrating to the ocean (Pinnix et al. 2013). This study found that coho smolts used deep channels with narrow intertidal margins, as opposed to shallow channels, intertidal mudflats or eelgrass meadows (Pinnix et al. 2013). This study determined that out migrating coho smolts spent from less than 1 to up to 4 days in the lower estuary of Freshwater Creek; this could explain the multiple detections over several days with some tagged fish in lower Martin Slough. A second pair of antennas would allow for better determining movement patterns of coho smolts in lower Martin Slough, however, budget currently is lacking for additional equipment purchases.

The presence of newly emerged coho salmon fry in Martin Slough in May and June of 2022 was a surprise. CDFW biologists who conducted numerous years of sampling in Martin Slough prior to the channel enhancement project stated that large numbers of newly emerged fry were never documented (M. Wallace, pers. comm.). RTA assumed that these fish were the result of successful spawning of adult coho salmon in upper Martin Slough during the winter of 2021-2022. As far as is known, this is the first-time adult salmon have recently spawned in Martin Slough.

The persistently high salinity levels in the off-channel ponds during the fall/winter/spring of 2021-2022 coincided with very few juvenile coho sampled in off-channel habitats. Between December 2021 and April 2022, 140 juvenile coho were caught and 29 (21%) of these were in off-channel ponds. The numbers of fish captured by pond were: Pond D,2; Pond E, 7; Pond F, 1; and Pond G, 19. In 2021 the salinity levels were relatively low in Ponds D, E, and F when sampling occurred in off-channel habitats. At this time, the muted tide gate was fully operational, yet these ponds remained only slightly brackish. Catches in 2021 included relatively high numbers of juvenile coho. For example, on March 17 the coho catch was 36 in Pond D, 26 in Pond E and 41 in Pond F; all when maximum salinity readings were less than 1.0 ppt. The channel excavation work was completed during the summer of 2021, and it appears that this further deepening (and lowering) of the channel elevation allowed further upstream penetration of higher-salinity water. After the 2021 construction season, in March of 2022, the same ponds had maximum salinity values of 11.8, 22.8 and 20.3 ppt, respectively.

The project's Biological Assessment listed 9 purposes and goals, including "*provide habitat and benefits to multiple species by improving and increasing the diversity and amount of fresh and saltwater wetland/estuarine habitat****, particularly off-channel and side channel juvenile salmonid rearing and overwintering habitat***" (GHD 2017). Based on our biological sampling and water quality monitoring in 2021-2022 (including November and December of 2022), the persistently high salinity readings in the off-channel ponds have failed to improve or increase the amount of off-channel habitat for juvenile salmonid rearing. If anything, there has been a substantial decrease in the quantity and quality of off-channel salmonid rearing and overwintering habitat in Martin Slough. In addition, pre-construction relocations in 2020 and 2021 documented ample amphibian breeding and rearing in Ponds D and G when these ponds were wholly freshwater. Significant loss of breeding and rearing habitat for red-legged frog, Pacific treefrog, rough-skinned newt, northwestern salamander, and coastal giant salamander has occurred post-construction.

RTA recommended that a meeting be convened with project partners and regulatory agencies to discuss the persistently high salinities in the Martin Slough off-channel ponds and feasible means to limit the upstream extent of brackish water; at a minimum allowing Pond G to function as high-quality overwintering habitat for juvenile coho. The pre-project water quality modeling predicted that salinities in the upper ponds (F and G) during the rainy season would be under 8 ppt and suitable for overwintering juvenile coho, yet on-the-ground monitoring has documented unsuitable conditions based on high salinities and the relative lack of coho presence in the ponds.

(See the *Martin Slough Enhancement Project-Coho Salmon Monitoring Report for Fall/Winter/Spring of 2021-2022*, Ross Taylor and Associates 2023. The complete report is attached as Appendix B.)

VEGETATION

Overview

The principal revegetation goal of the Martin Slough Enhancement Project is, through passive and active revegetation, to establish, rehabilitate, or re-establish native plant communities within the project area, including within tidal marsh, brackish marsh, freshwater marsh, riparian, and coastal prairie plant habitat zones. The active revegetation effort for this project originally included installation of >50,000 individual plants and direct seeding of approximately 1 acre of disturbed ground. Fifty species were planted including 18 obligate and facultative wetland species, 21 riparian tree and shrub species and 11 grass and forb species. Active planting occurred in upper channel banks, pond fringes and top of bank riparian areas. Grasses reseeding occurred in pastures and golf course rough. Passive revegetation was anticipated in salt and brackish wetlands in the mid- and lower channel where native seed and propagules move in the tidal water column and are naturally recruited (RCAA 2018).

Monitoring was designed to validate revegetation success considering total vascular plant cover (conversely the amount of bare earth) and native to non-native vascular plant ratios as well as species richness and diversity. Criteria also were developed specifically for 2 target invasive plants identified in the Annual Monitoring Plan (RCAA 2021, rev.), *Spartina densiflora* (dense-flowered cord grass) and *Phalaris arundinacea* (reed canary grass).

With all project phases vegetation monitoring began second-year post-construction, or Year 2. In 2020, construction occurred in project Phase 3, on the EMGC, from the eastern boundary of Phase 2 at the NRLT/golf course property line to immediately below Martin Slough mainstem/Pond E and including the East Tributary/Pond D (Figure 1). In 2022, Phase 3 Year 2, revegetation was monitored by RCAA staff. When success criteria are met in Year 2 (first year monitoring) in a particular project phase, then monitoring of that phase should occur next in Year 5. However, if success criteria are not entirely met in Year 2 then monitoring should occur again in Year 3 and possibly Year 4 in that particular project phase. Tables 6 and 7 summarize success criteria for wetland and riparian plant communities.

Table 6. Revegetation success criteria in the Martin Slough Enhancement Project wetland zone.

Tidal, Brackish, and Freshwater Marsh Success Criteria	
Year 2	30 percent or greater total absolute vegetation cover 35 percent or greater relative cover of native wetland species. No more than 20 percent absolute cover of target invasive plants.
Year 3 (contingency)	40 percent or greater total absolute vegetation cover 40 percent or greater relative cover of native wetland species. No more than 15 percent absolute cover of target invasive plants.
Year 4 (contingency)	50 percent or greater total absolute vegetation cover 45 percent or greater relative cover of native wetland species. No more than 10 percent absolute cover of target invasive plants.
Year 5	60 percent or greater total absolute vegetation cover 50 percent or greater absolute cover of native wetland species. No more than 10 percent relative cover of target invasive plants. Plant vigor shall be "good" per the qualitative score for assessing the health and vigor of planted stock
All Years	Native wetland species consist of hydrophytic OBL/FACW/FAC species. No major erosional areas

Table 7. Revegetation success criteria in the Martin Slough Enhancement Project riparian zone.

Riparian Success Criteria	
Year 2	30 percent or greater total absolute vegetation cover 35 percent or greater relative cover of native riparian species No more than 20 percent absolute cover of target invasive plants.
Year 3 (contingency)	40 percent or greater total absolute vegetation cover 40 percent or greater relative cover of native species No more than 15 percent absolute cover of target invasive plants
Year 4 (contingency)	50 percent or greater total absolute vegetation cover 45 percent or greater relative cover of native species No more than 10 percent absolute cover of target invasive plants.
Year 5	60 percent or greater total absolute vegetation cover 50 percent or greater relative cover of native species No more than 10 percent absolute cover of target invasive plants. 90 percent total vegetation cover for areas within Golf Course more than 25 feet away from the channel and ponds planted using nonnative species
All years	Plant vigor shall be "good" per the qualitative score for assessing the health and vigor of planted stock No major erosional areas

Methods

Macroplots (polygons) were established in the Phase 3 project area that included ground directly disturbed by construction activities and adjacent channel top of bank areas. Within the macroplots 34 sample units were randomly established, with 17 in the wetland (tidal, brackish and freshwater marsh) zone and 17 in the riparian habitat zone (Figure 8). Vegetation was sampled using 1-m^2 quadrats and 3-m radius circular plots centered on the random point in wetland and riparian delineated zones, respectively.

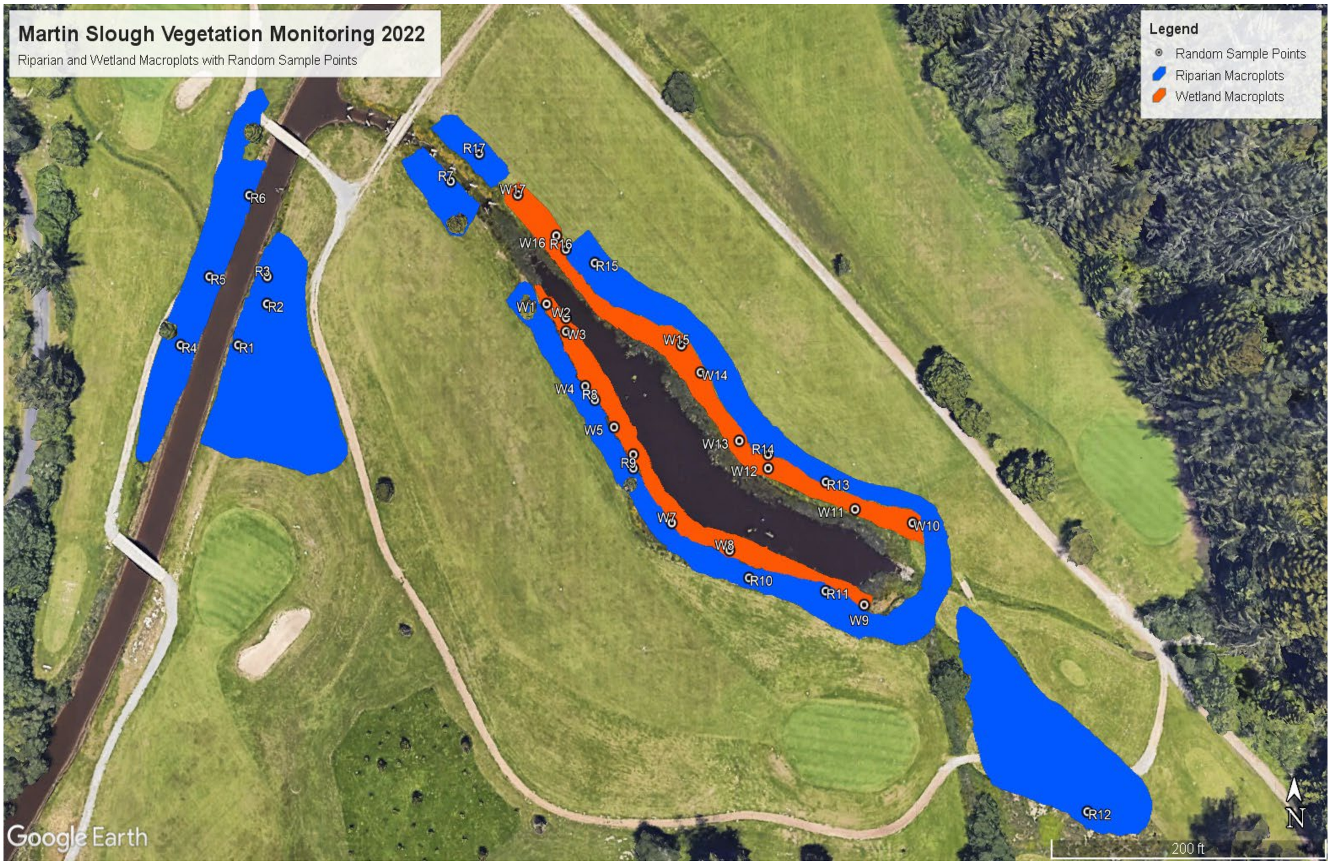


Figure 8. Macroplots in the Phase 3 area with wetland and riparian monitoring sample plots randomly located.

The RCAA (2021) Monitoring Plan included 3 vegetation strata: tree, shrub and herbaceous. The intent is to sample each of these strata separately over time as woody vegetation grows and cover increases to above 5% in each stratum. Currently, neither the tree nor shrub stratum meet the 5% standard, thus, cover estimates consist predominantly of herbaceous species within riparian plots.

Percent cover was visually estimated for each species within each sample unit. Each species was classified according to its native/nonnative status within its historic range and, in the wetland zone, wetland designation (OBL, FACW, FAC, FACU or UPL; USWS 1988). Absolute cover, relative cover, and species richness and diversity were calculated for both zones. Relative native wetland (FAC, FACW, and OBL) cover was calculated for the wetland (tidal, brackish and freshwater marsh) zone. Species richness and diversity were calculated using the Shannon-Weiner Diversity Index (Omayio and Mzungu 2019).

Planted trees and shrubs in riparian zones were maintained (weeded, mulched, watered and caged with deer fence) by RCAA staff throughout the entire project area. Although no plant viability success criteria were identified in the revegetation plan (RCAA 2018), field crews documented tree and shrub mortality throughout the project area in 2022. Replacements planting began in the riparian zone in December 2022.

Results and Discussion

Absolute Cover

Generally, plant cover was high throughout the Phase 3 area. Mean absolute cover was 72.4% (± 22.7 SD; range 43-129%) in the wetland zone and 93.1% (± 19.5 SD; range 58-115%) in the riparian zone. In the wetland zone, mean cover for wetland indicator species was estimated at 35% (± 22.7; range 13-90%). In the riparian zone, tree and shrub strata combined cover averaged 6.7%. Both zones surpassed the Year 2 success criteria of ≥30% absolute vegetation cover, however, the cover estimates in the riparian zone included all 3 strata, thus, represents primarily herbaceous vegetation.

Relative Cover

In the wetland zone relative cover of native wetland indicator species was 62.1% versus 36.8% relative cover for nonnative species (plants not identified to genus accounted for 1.1%). In the riparian zone, relative cover of native and nonnative species was 47.2% and 52.6%, respectively. Both zones surpassed the success criteria of in the wetland zone of ≥35% relative cover of native species. Only one sample unit, in the wetland zone, contained a target invasive species, reed canary grass, with 15% cover of the invasive species in that plot.

Table 8 below summarizes absolute and relative cover estimates.

Table 8. Cover estimates and success criteria for wetland and riparian zone vegetation and bare earth. (WI=wetland indicator; T&S=tree and shrub.) All values are percents.

Habitat Zone	Mean Absolute Percent Cover All Vegetation	Absolute Cover Success Criteria	Mean Relative Cover Native Vegetation	Relative Cover Success Criteria	Mean Cover Bare Earth
Wetland	**72** (35 WI)	**≥30**	**62**	**≥35**	**41**
Riparian	**93** (7 T&S)	**≥30**	**47**	**≥35**	**35**

Plant Vigor

Plant vigor was qualitatively assessed as good in the herbaceous stratum in both the wetland and riparian zones. However, at the time of sampling at least 2-dozen planted tree and shrub saplings in the riparian zone lacked vigor or were dead within the Phase 3 project area. Plant vigor was inventoried across the entire project area in the fall and actual mortality turned out to be significantly greater in the Phase 3 area than was documented during sampling. Plant mortality likely was due to the dry summer conditions in recent years, coupled with insufficient watering.

Bare Earth

Bare earth was recorded in 41% (6) of wetland plots, averaging 20% in area per plot, or 6.9% of the area sampled. Bare earth was recorded in 35% (7) of riparian plots and averaged 19% in area per plot, or 7.6% of the area sampled.

Species Richness and Diversity

Wetlands

Plant species richness was moderate in the wetland zone, with 29 species identified; roughly 2/3 were native and 1/3 were nonnative. Eighty-seven percent of the wetland native species were classified as either obligate- or facultative wetland. One obligate native species, wire rush (*Juncus balticus)*, occurred in 94% of the plots, ranging from 5 to 90% cover and averaging 22% cover. Lyngbye's sedge (*Carex lyngbyei)* was recorded in 41% of plots with cover ranging from 3-15%. The naturalized nonnative birdsfoot trefoil (*Lotus corniculatus)* occurred in 59% of the plots, although cover was relatively low, ranging from 1-22%. A target invasive species, reed canary grass, occurred in one plot with 15% cover; cord grass, the second target invasive, was not detected in any of the wetland plots.

Riparian

Plant species richness was high in the riparian zone with 54 species identified, with approximately half native and half nonnative species. Native red fescue (*Festuca rubra*) occurred in 82% of plots with cover generally 20% or above. When combined with fescue recorded but not identified to species, this grass dominated plant cover in most riparian plots. Wire rush occurred in 59% of plots, although cover was minimal with about 5% per plot. Highly invasive Yorkshire grass (*Holcus lanatus*) occurred consistently, within 94% of plots; nonnative clover (*Trifolium* sp.) occurred in 88% of plots. Sixty-five percent of the plots contained either highly invasive grasses and/or species in the Asteraceae.

Species diversity was calculated for each zone using the Shannon-Wiener Diversity Index (Omayio and Mzungu 2019):

Diversity $=H/\ln(S)$, where:

$H = \Sigma[(p_i) \times \ln(p_i)]$,

p_i = proportion of the sample represented by the species $_i$

S = the total number of species

Species diversity was relatively high, well above 0 (when only 1 species is detected), in both zones. Diversity was higher in the riparian zone than in the wetland zone, with diversity indices at 3.55 and 2.42 in the riparian and wetland zones, respectively. However, between roughly ½-2/3 of the plots contained nonnative and, in some cases, highly invasive species. A species list of all species recorded during monitoring in the riparian and wetland zones is in Appendix C.

Recommendations

Revegetation of previously disturbed ground appears to be progressing rapidly and has either met or is close to meeting performance criteria as outlined in RCAA's Monitoring Plan (RCAA 2021, rev. and Tables 6 and 7 above). This is especially the case in the wetland zone where percent cover was 72%, of which 38% consisted of wetland indicator species and the ratio of native to non-native was approximately 2:1.

Vegetation in the riparian zone, although meeting performance criteria, is threatened with becoming dominated by invasive nonnative species, the ratio of native to nonnative species in the riparian zone hovering around 1:1. This threat is likely to persist until riparian tree and shrub saplings are able to grow enough to shade out undesirable understory species. As was evident from the mortality inventory in fall 2022, tree and shrub saplings require more frequent weeding, cage repair and regular watering to ensure survival. Although the RCAA field crew spent a fair amount of time weeding and watering over the course of 2022, it apparently wasn't enough to compensate for the recent seasonal drought. Additional watering, ideally via irrigation, is what is required during drought to promote survivability of tree and shrub plantings across the project area.

To a lesser extent, deer browsing caused mortality or reduced plant vigor. Regular inspections to ensure plants are properly caged with deer fence to protect them from browsing is important. Some of the mortality in 2022 was caused by damaged cages allowing deer and small mammalian herbivores to access plants. Gopher activity also appeared responsible for plant mortality, particularly in localized areas. RCAA suggests an ultrasonic pest repellant or other non-lethal form of gopher control where gopher activity is threatening the well-being of young plants.

The Hydrologic, Water Quality and Fisheries sections of this report describe monitoring results indicating that project modeling relative to salinity levels in the upper ponds and mainstem proved somewhat inaccurate. Reconstructing the channel allowed the muted tide to enter farther upstream than was predicted and the increased salinity was not diluted by freshwater inflow. Thus, salinity levels are currently too high in the upper reaches to function as juvenile salmonid rearing and amphibian habitat. In January of 2023, the project team met via teleconference to discuss this situation and agreed that lowering the tide gates and further restricting the muted tide is warranted as the only potential near-term solution to reducing the salinity levels within the slough. The tradeoff is likely to have negative impacts on the brackish wetland plant community due to less saltwater flowing into the upper ponds and main stem. Continued vegetation monitoring is important to determine impacts of a reduced muted tide to wetland vegetation and habitat in the near future.

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APPENDICES

Appendix A. *Martin Slough Enhancement Project, 2022 Physical Monitoring Report,* Michael Love and Associates 2022.

Appendix B. *Martin Slough Enhancement Project- Coho Salmon Monitoring Report for Fall/Winter/Spring of 2021-2022*, Ross Taylor and Associates 2023.

Appendix C. 2022 Martin Slough vegetation monitoring plant species list.