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Humboldt Bay Harbor, Recreation and Conservation District
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Date: 5/3/23

To: Whom it may concern

From: Rob Holmlund, Development Director, Humboldt Bay Harbor District

Re: Cover Letter and Summary of Key Findings of the 5/1/23 Report "Intake Assessment of the Potential Effects on Ichthyoplankton and other Meroplankton Due to Entrainment at Proposed Samoa Peninsula Water Intakes" by Tenera Environmental

Background

The Humboldt Bay Harbor District is actively working to design and permit a baywater intake system. As a part of the permitting process, the consulting firm Tenera Environmental analyzed the potential impacts of the proposed intake system that would occur due to the entrainment[1] of ichthyoplankton using a modeling approach (the Empirical Transport model [ETM]) with data from 12 months of sampling. The ETM has been used on larger intake systems throughout California and is the standard approach in California for assessing impacts from power plant and desalination ocean intakes. As is required under state policy, the results from the ETM are used to calculate appropriate mitigation for the impacts to ichthyoplankton (also known as Area of Production Foregone [APF]). The results of the study are also used to estimate any required mitigation for estimated entrainment effects on Longfin Smelt (*Spirinchus thaleichthys*) larvae, a species listed as threatened under the California Endangered Species Act. The initial ETM can be found as Appendixes P and Q of the Final Environmental Impact Report (FEIR) for the Samoa Peninsula Land-based Aquaculture Project, which can be found here: https://humboldtgov.org/3218/Nordic-Aquafarms-Project. The FEIR was certified by Humboldt County on September 28, 2022.

Attached is the report "Intake Assessment of the Potential Effects on Ichthyoplankton and other Meroplankton Due to Entrainment at Proposed Samoa Peninsula Water Intakes" (Intake Assessment Report). The Intake Assessment Report was authored by Tenera Environmental and finalized on 5/1/23. The Intake Assessment Report presents the results of a sampling and modeling study that builds on the ETM to assess the potential for impacts to marine organisms that could occur due to the operation of the proposed intake system. The design and operation of intakes in ocean and estuarine waters in California are required to minimize effects on marine life. The findings of the Intake Assessment Report are relevant to several of the permits required for the intake system.

[1] Entrainment is when small planktonic organisms, including the eggs and larvae of fishes (ichthyoplankton) and invertebrates, pass through screens into a water-intake system.

The FEIR referenced above included the following relevant mitigation measure and compensatory restoration:

- Mitigation Measure 6a-Protection of Longfin Smelt.
- The EIR analyzed the proposed pile pulling at "Kramer Dock" which is proposed for compensatory restoration for APF.

The remainder of this cover letter outlines the key findings from the Intake Assessment Report.

Key Findings of the Intake Assessment Report

- The calculated Area of Production Foregone (APF) in the Intake Assessment Report is consistent with the key findings in Appendices N, P, and Q of the FEIR referenced above.
- The Intake Assessment Report verified the ETM, the above cited mitigation measures, and the above cited compensatory restoration.
- In line with the bullets above, the proposed mitigation/restoration at Kramer Dock (which consists of the removal of derelict creosote piles) as described in Appendix N of the FEIR is sufficient to mitigate for APF.

Clarification Regarding Conservative Nature of Intake Assessment Report

It is important to note that the attached Intake Assessment Report is very conservative, for the following reasons:

- The report does not apply the allowable 1% impact reduction factor as allowed by the 2019 California Ocean Plan (page 51), even though the screen slot size of the proposed intake system is 1mm (less than the required 1.75mm). The Ocean Plan can be found here: https://www.waterboards.ca.gov/water_issues/programs/ocean/docs/oceanplan2019.pdf).
- While the project is impacting the relatively low-value habitat of "open water" and utilizing the much higher-value of "near shore" habitat for mitigation, the report does not apply the 1:10 "out-of-kind" mitigation ratio as allowed on page 52 of the Ocean Plan.
- When calculating the value of the Kramer Dock pile removal as mitigation, the report does not consider the fact that the proposed pile removal will remove an estimated 308 tons of contamination from the Bay.
- The APF calculated from the ETM model is likely overestimated and conservative because:
  - It uses the entire volume of Humboldt Bay as its source water even though the actual spawning habitat for the species that were analyzed is much more limited.
  - It does not take into account the efficiency or effectiveness of the intake screen design at reducing entrainment, and the orientation and behavior of larvae that would likely considerably decrease the actual entrainment at the intake.
  - It does not consider that the screens are located in a dynamic tidal channel that brings nutrient-rich, coastal waters into the bay.

Attachments:

A – "Intake Assessment of the Potential Effects on Ichthyoplankton and other Meroplankton Due to Entrainment at Proposed Samoa Peninsula Water Intakes" by Tenera Environmental (5/3/23)

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

May 1, 2023

ESLO2023-001.2

Submitted to:
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Humboldt Bay Harbor
Recreation and Conservation District
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List of Abbreviations and Acronyms

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

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

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Executive Summary

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

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

The design of ETM studies requires sampling at entrainment locations that provide data used to estimate the concentrations of fish larvae potentially subject to entrainment and sampling at locations throughout the source waters that is used to estimate the numbers of larvae potentially subject to entrainment. In Humboldt Bay, source water stations were located in each of the four regions of the bay: Arcata Bay, Main Channel Entrance Bay, and South Bay. The entrainment and source water stations were all sampled twice a survey (day and night) on a roughly monthly interval. The average taxa concentrations at the entrainment and source water stations during each survey were multiplied by the volumes of the intakes and source water bodies to calculate an estimate of proportional entrainment (*PE*) for each species and survey. The *PE* is the ratio of the estimated number entrained each day to the number in the source water. For each species analyzed, the estimates of *PE* for each survey are used to calculate the ETM estimate of proportional mortality (P_M), which is an estimate of the loss to the source water population of that species over the year due to entrainment.

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

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

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

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

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

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

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

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

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

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

1.0 Introduction

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

1.1 Project Description

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

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

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

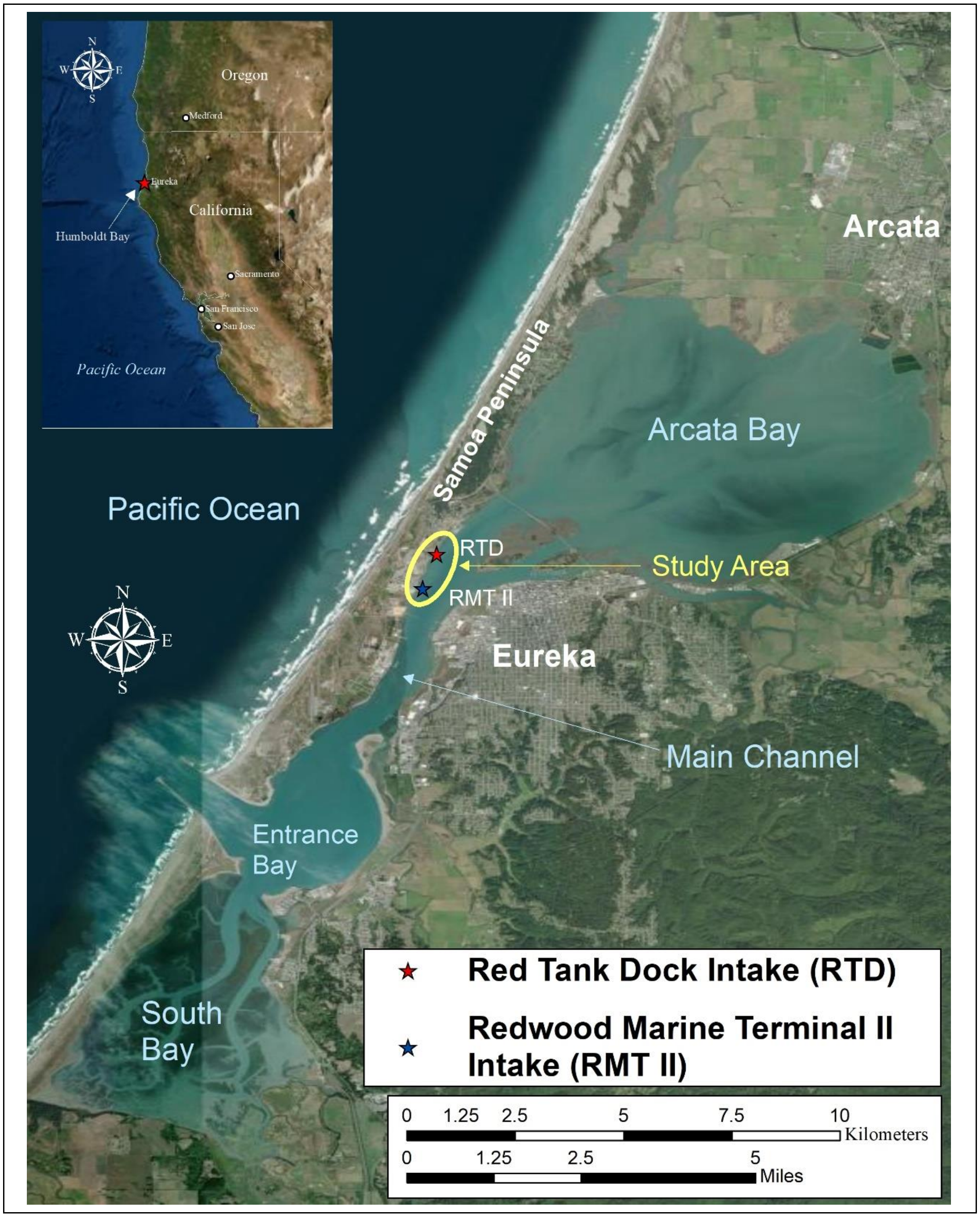


Figure 1-1. Map showing the locations of the two intakes on the eastern shore of the Samoa Peninsula along Humboldt Bay.

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

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

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

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

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

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

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

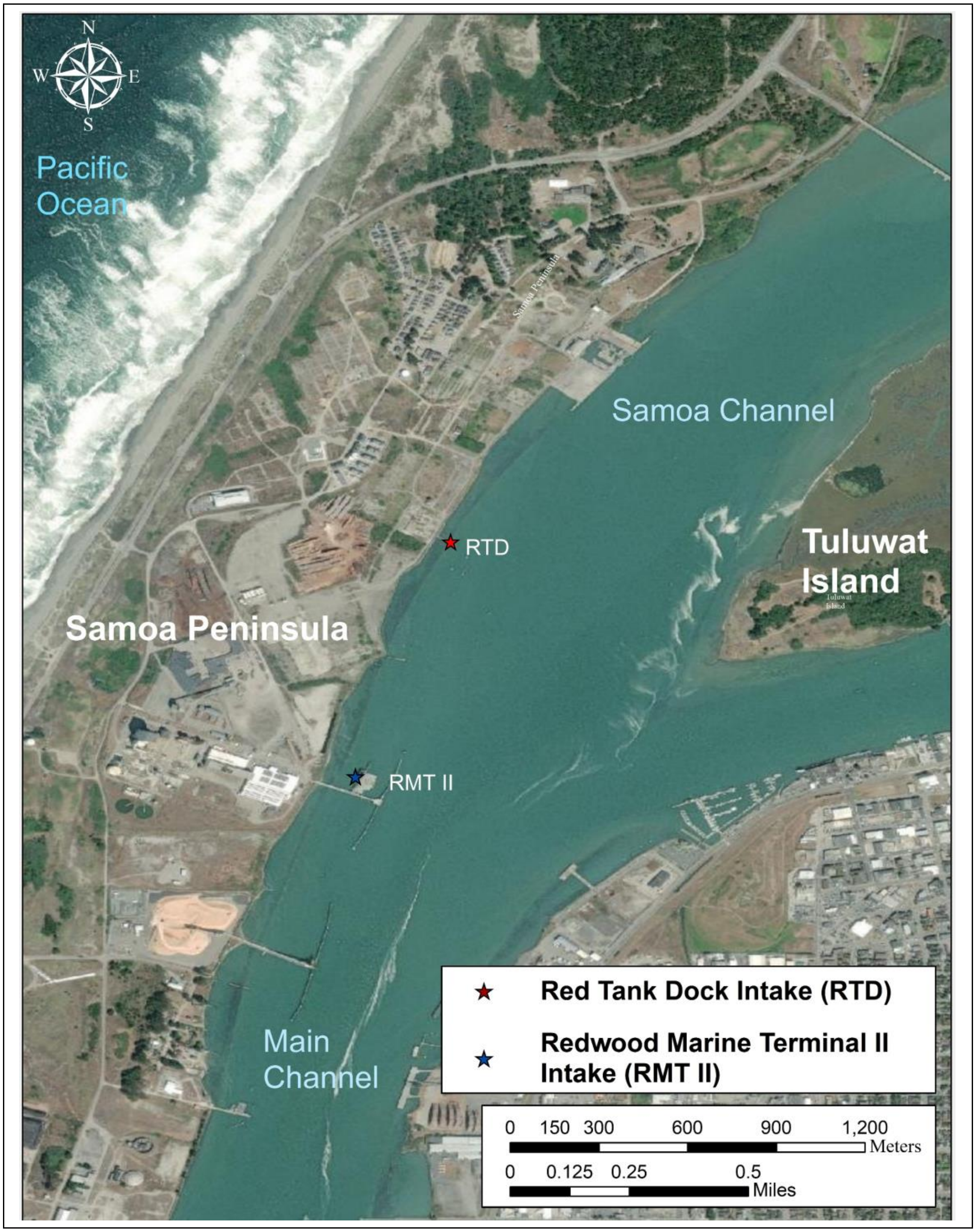


Figure 1-2. Detailed map showing locations of Redwood Marine Terminal II (RMT II) and the Red Tank Dock (RTD) intakes on the eastern shore of the Samoa Peninsula.

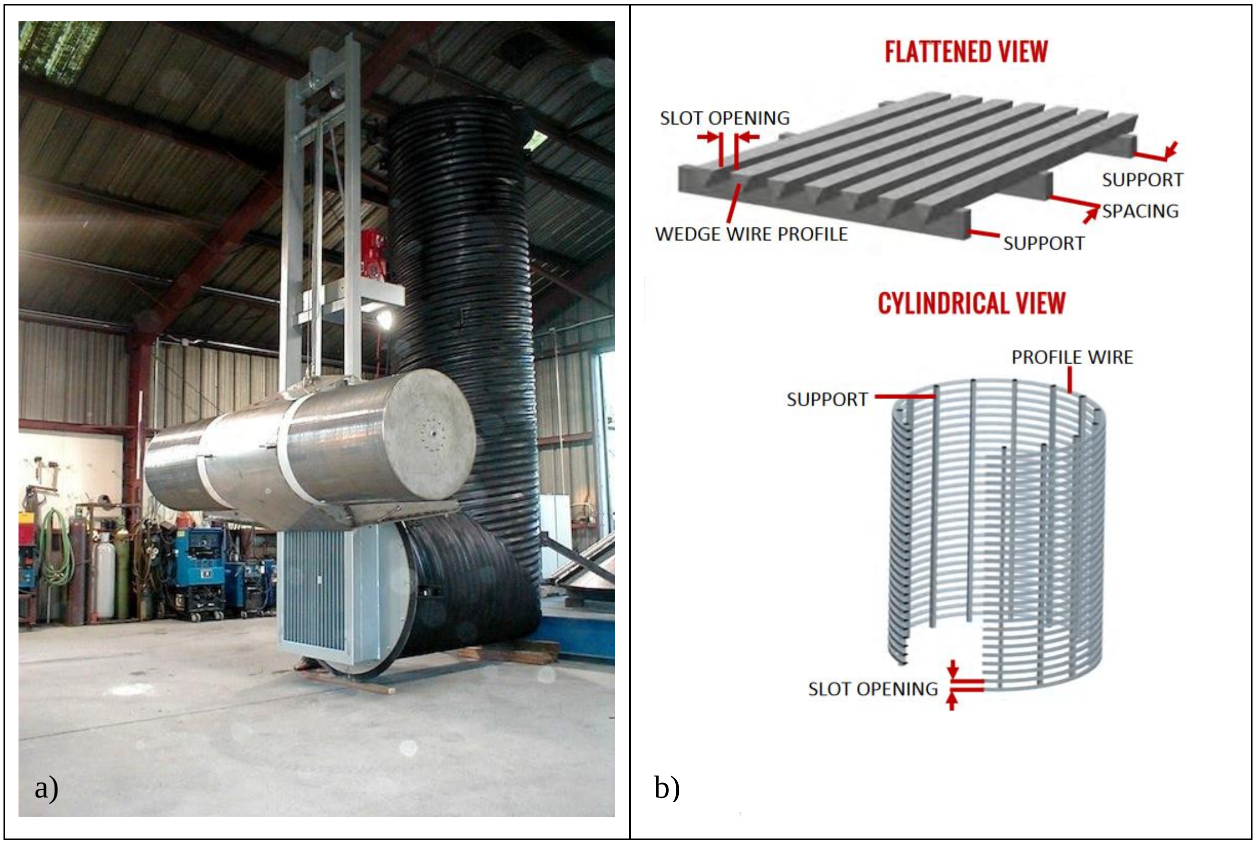


Figure 1-3. Wedgewire screen module and design showing **a)** wedgewire T-shaped module designed to be raised and lowered into place (Source: Intake Screens, Inc.), and **b)** design of wedgewire screen module (Source: Hendrick Manufacturing).

1.2 Policy and Regulatory Background

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

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

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

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

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

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

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

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

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

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

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

1.3 Approach

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

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

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

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

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

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

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

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

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

1.4 Report Organization

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

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

Appendices include the following:

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

2.0 Environmental Setting

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

2.1 Physical Setting of Humboldt Bay

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

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

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

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

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

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

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

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

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

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

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

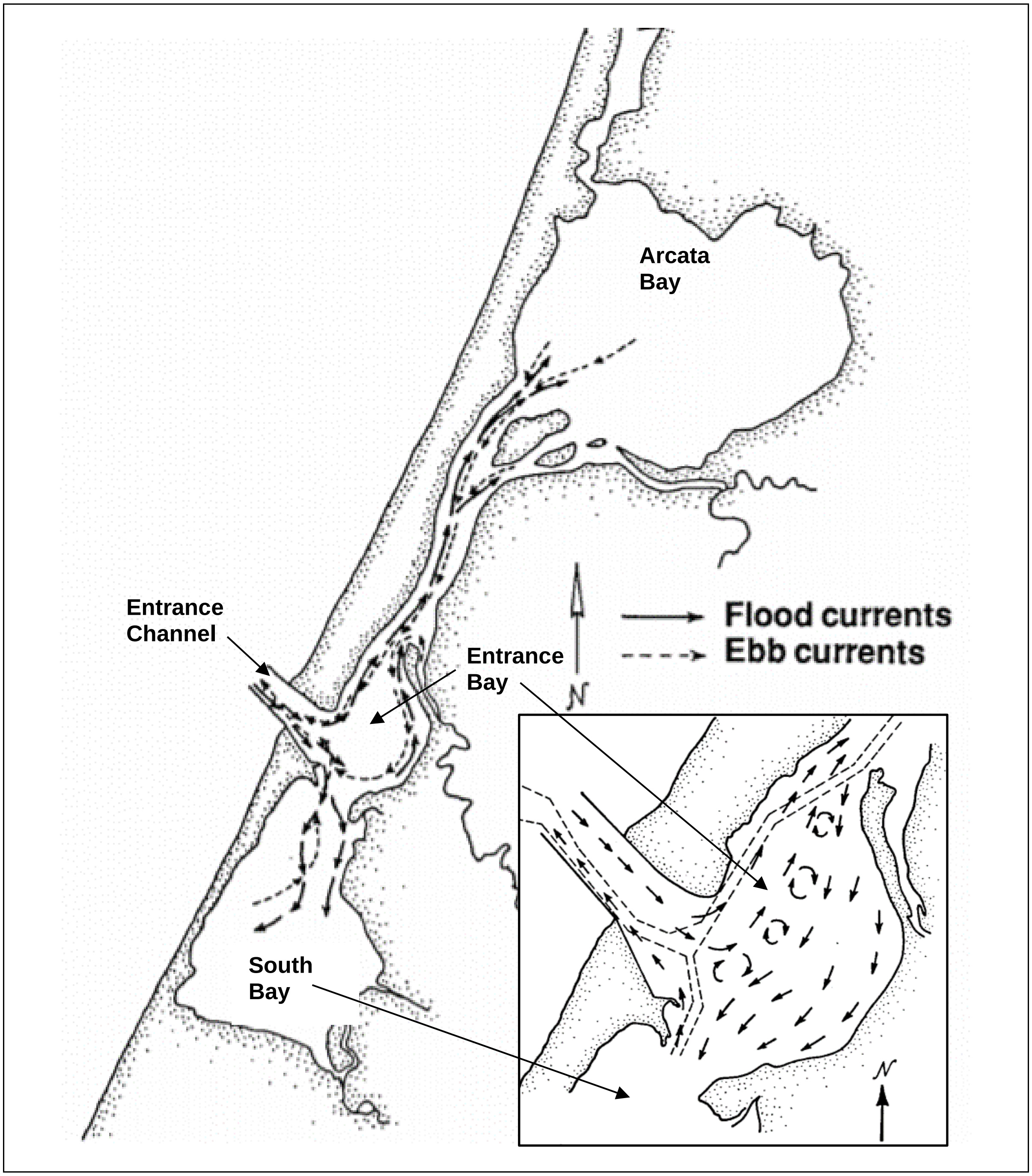


Figure 2-1. Ebb and flood tidal current patterns in Humboldt Bay with inset showing circulation into South Bay. Figures from Costa (1982).

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

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

2.2 Biological Resources of Humboldt Bay

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

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

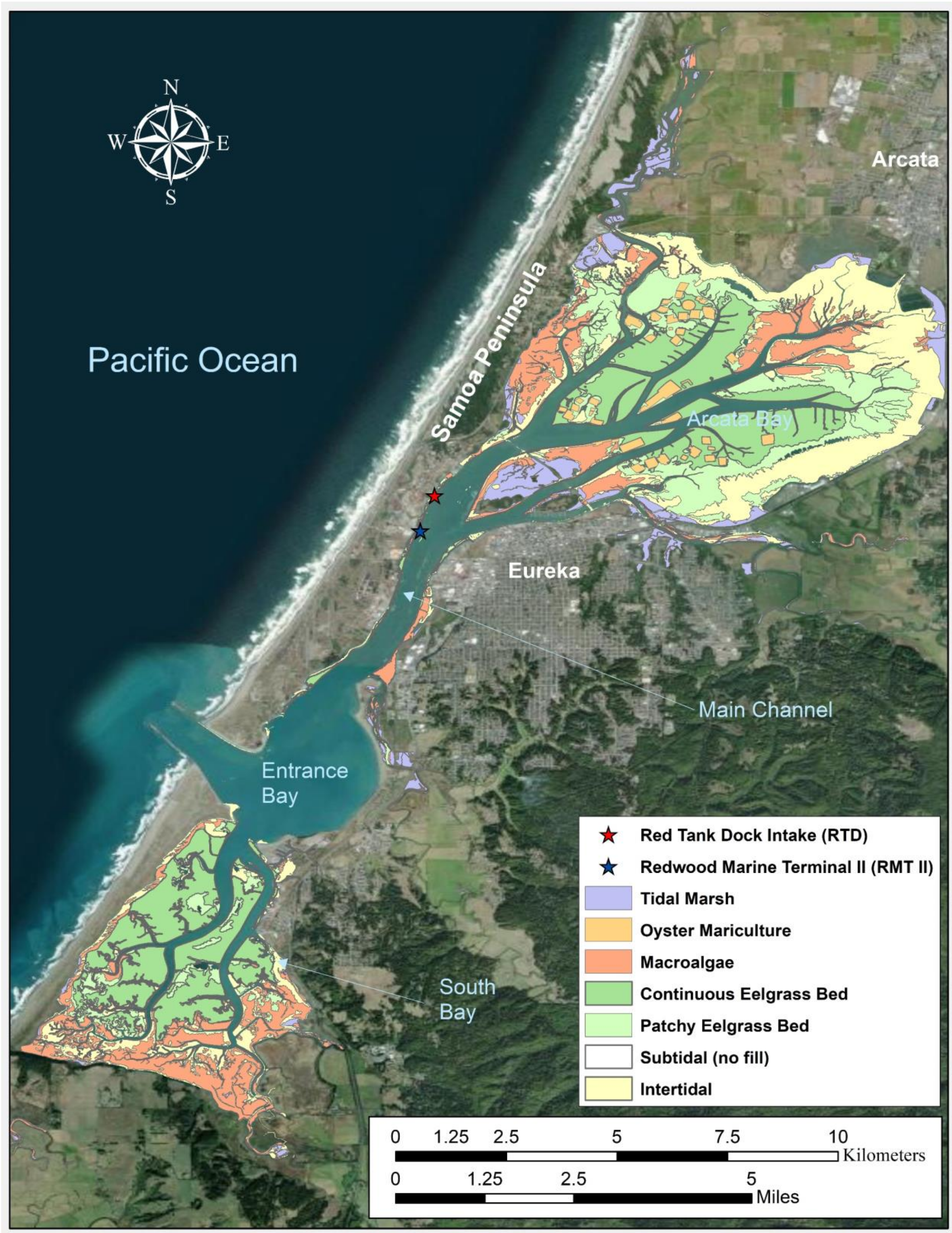


Figure 2-2. Map showing the classified benthic habitats in Humboldt Bay. Accessed 4/12/2023 at https://coast.noaa.gov/digitalcoast/data/.

2.2.1 Eelgrass Beds and Marshland Habitat

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

2.2.2 Fishes

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

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

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

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

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

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

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

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

2.2.3 **Special Status Fishes**

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

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

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

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

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

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

2.2.4 Dungeness Crab

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

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

2.2.5 Mariculture

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

2.2.6 Waterfowl

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

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

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

3.0 Methods

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

3.1 Study Design

3.1.1 Sampling Locations

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

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

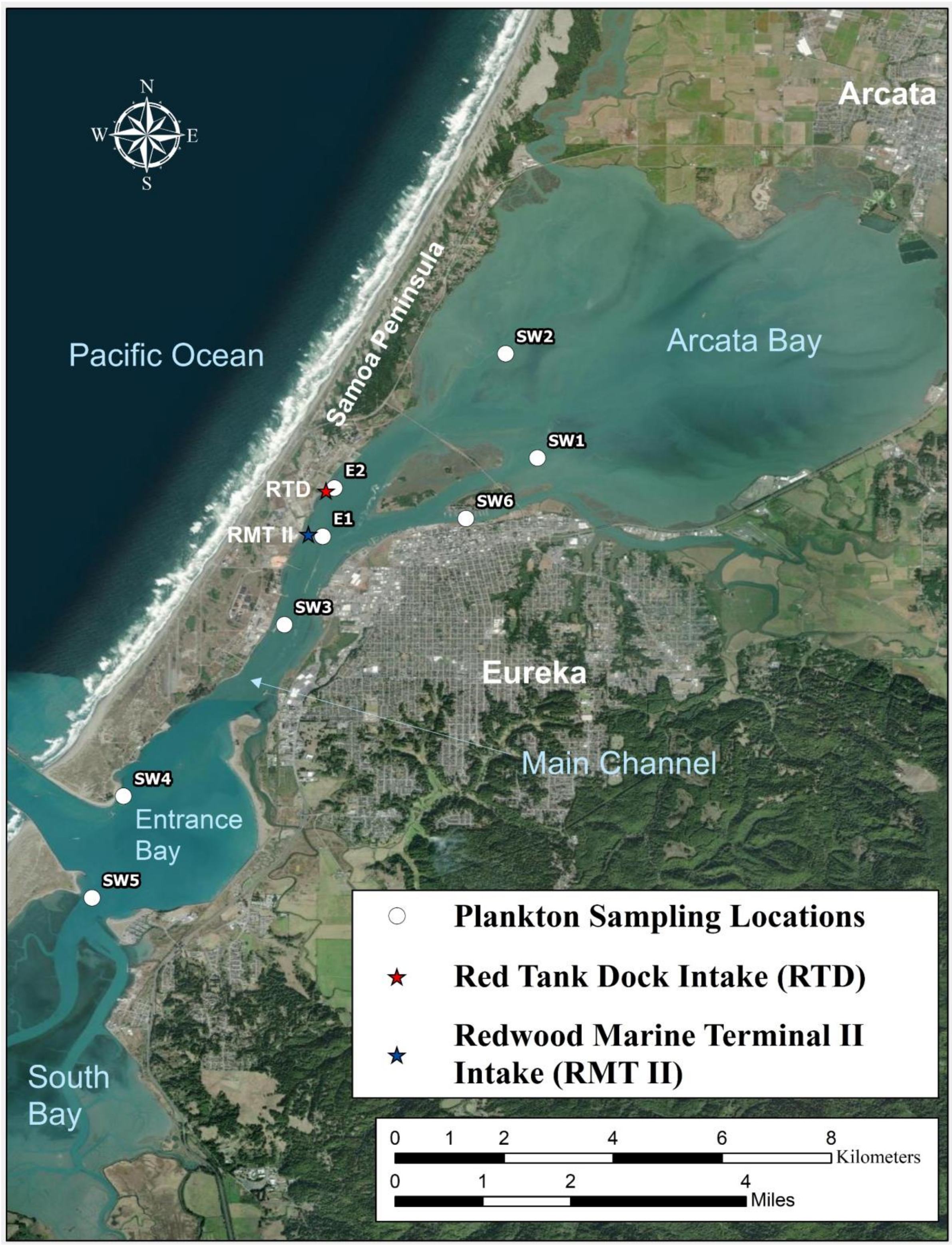


Figure 3-1. Map of the entrainment (E) and source water (SW) sampling stations.

3.1.2 Sampling Methods

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

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

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

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

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

3.1.3 Target Organisms

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

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

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

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

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

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

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

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

3.1.4 Sample Processing

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

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

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

DNA Analysis Methods

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

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

Larval Measurements

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

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

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

3.1.5 Quality Assurance/Quality Control Program

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

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

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

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

3.1.6 Initial Data Processing and Entrainment Estimates

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

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

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

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

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

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

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

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

3.1.7 Larval Age Estimation

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

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

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

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

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

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

3.1.8 Measurements for WWS Efficiency

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

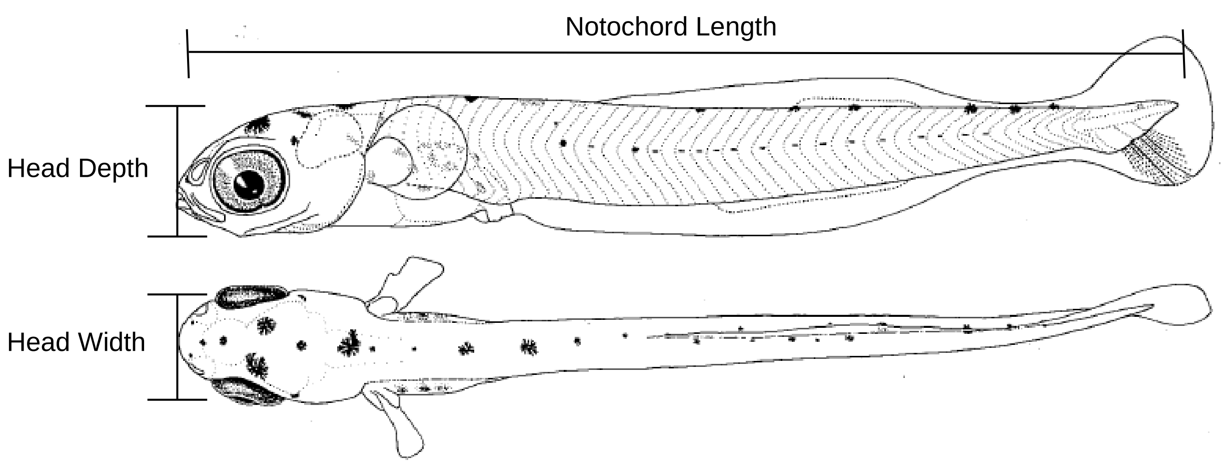


Figure 3-2. Illustration of the measurement locations for notochord length and head depth (height) and width of a preflexion stage larval fish. Larval fish is a jacksmelt from Moser (1996).

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

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

3.2 Analysis

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

3.2.1 Empirical Transport Model (ETM)

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

While absolute losses would be expected to vary considerably among years, the variation in the proportional losses to a fish population due to entrainment, represented by the *PE*, will likely be considerably less and will largely depend on the operation of the facility. This feature also allows regulators to directly track potential losses to source water populations of larvae and other plankton by just tracking the changes in operation of a facility.

For these reasons, the ETM has been the preferred approach for assessing entrainment impacts in California since it provides a relative measure of impact integrated over some time period (called proportional mortality [P_M] in the ETM terminology) that should vary much less over time than absolute levels of impact, such as an estimate of total entrained fishes.

The ETM is a demonstrably useful method for assessing impacts because the P_M provides the same type of information used in fisheries management. That is, the estimates of P_M are similar to estimates of the effects of fishing mortality on a population and, in this context, can be interpreted relative to other sources of mortality. Fisheries managers reduce the level of fishing mortality on a population by limiting the number of fishers targeting a population or closing areas of a population to fishing. These adjustments are calculated on a relative or proportional basis since estimates of natural and fishing mortality are calculated from survival proportions. Interpreted using these standard measures used by fisheries managers, an estimate of P_M that is very low relative to other natural sources of mortality and levels of natural variation, provides evidence that entrainment effects on that organism are not likely to be significant to the source water population subject to entrainment. Another important consideration that only applies to the assessment of impacts using the ETM estimate of P_M is that the mortality is occurring to the stock of larvae in the source water body that are subject to entrainment and not an adult population.

The ETM approach used in this study and in other intake assessments from California use a modified version of the ETM first proposed by the U.S. Fish and Wildlife Service to estimate mortality rates resulting from cooling water withdrawals by power plants along the Hudson River in New York (Boreman et al. 1978, 1981). The ETM provides an estimate of incremental mortality (a conditional estimate of entrainment mortality in absence of other mortality; Ricker 1975) based on estimates of the fractional loss to the source water population of larvae represented by entrainment. The conditional mortality is represented by estimates of proportional entrainment *(PE)* that are calculated for each survey and then expanded to predict regional effects on populations using the ETM. Variations of this model have been discussed in MacCall et al. (1983) and have been used to assess impacts at most of the studies of coastal power plants in California (MacCall et al. 1983, Steinbeck et al. 2007).

A definition of the source water population is critical to the ETM. The source water is the region or volume of water over which the *PE* is estimated, and the source water population is an estimate of the number of larvae in that region. In addition to the instantaneous source water volume, the estimated source water for each taxon varies depending on the number of days that the larvae are potentially exposed to mortality due to entrainment. The number of days the larvae are exposed to entrainment is calculated based on measurements of the length of the larvae collected in the impacted area. The lengths of the larvae are divided by estimates of daily growth rates to estimate the age in days of the larvae at different lengths. The data from the sampled source water are used in calculating the estimates of *PE*, which is then extrapolated to the entire source water body in the ETM as defined below.

The estimate of *PE* is the central feature of the ETM (Boreman et al. 1981, MacCall et al. 1983). *PE* estimates, which range from 0 to1, are calculated for each individual survey period i as the estimated numbers of larvae entrained into the intake per day as a proportion to the larval population estimated within the source water as follows:

$$PE_i = \frac{N_{E_i}}{N_{S_i}} = \frac{\bar{\rho}_{E_i} V_{E_i}}{\bar{\rho}_{S_i} V_{S_i}},$$

Equation 4

where N_{E_i} and N_{S_i} are the estimated numbers of larvae entrained and in the source water per day in survey period i, respectively; $\bar{\rho}_{E_i}$ and $\bar{\rho}_{S_i}$ are the average concentrations of larvae from the intake and source water sampling per day in survey period i, respectively; and V_{E_i} and V_{S_i} are the estimated volumes of the intake and sampled source water per day in survey period i, respectively.

Survival over one day is, therefore, $1 - PE_i$, and survival over the estimated number of days (q) that the larvae are susceptible to entrainment is $(1 - PE_i)^q$. In addition, the estimates of PE_i for each taxon of larvae from each survey are assumed to be representative of the cohort of larvae vulnerable to entrainment during the survey period.

Although it is typically easy to obtain a reasonably accurate estimate of the volume of the intake, estimating the extent and volume of the source water is more difficult. The source water volume may be fixed for studies inside enclosed embayments or may vary among survey periods for studies on the open coast, which are subject to changes in the speed and direction of ocean currents. The situation for Humboldt Bay, which is open to the ocean, falls in between those of the closed embayment and open coast.

One other important component of the ETM is an estimate of the number of days (q) that a taxon being analyzed is planktonic and exposed to entrainment. Typically, this period is estimated using length data from the larvae measured from the entrainment samples for each taxon. Estimates of the maximum length and hatch length are calculated and the period of exposure to entrainment estimated by dividing the difference between the lengths by an estimated larval growth rate usually obtained from scientific literature. The estimates of *PE* and period of exposure or site-specific planktonic larval duration (PLD) q, are combined in the ETM to provide an estimate of the proportional mortality (P_M) to a source water population due to entrainment. The basic formulation of P_M is:

$$P_M = 1 - \sum_{i=1}^{n} f_i (1 - PE_i)^q \qquad \text{Equation 5}$$

where f_i = the fraction of the source water population from the year present during survey i of n (usually monthly) based on the number of days in each survey period, and q = period in days that the larvae are exposed to entrainment mortality represented by the PE_i. As described above, the value of q is based on the age of larvae calculated using values estimated from the length measurements for each taxon.

3.2.1.1 ETM Calculations

This section describes how the components of the ETM are calculated using the data collected during the field sampling described in Section 3.1.2. The daily intake volumes used in both the Initial ETM Assessment and this study were based on the maximum flow rates for the intakes shown in **Table 1-1**. The daily maximum intake flows for the RMT II and RTD intakes (Station E1 and E2, respectively)) based on the maximum flow rates are 7.92 and 3.96 mgd (29,980 and 14,990 m^3), respectively.

One of the most critical steps in assessing environmental impacts of the proposed seawater intakes using the ETM is the estimation of the source water volume. Any measurement of species abundance in the vicinity of the intakes must be compared against the available population, which involves estimating the volume over which the population is dispersed. In the case of tidally dominated lagoons, such as Humboldt Bay, that volume is most often associated with the tidal prism, i.e., the volume of water that is exchanged with the open ocean over a tidal cycle.

In the ocean, the estimate of the volume of source water is influenced by the number of days that larvae are susceptible to entrainment because over that period, currents transport plankton to the point of entrainment. In bays and estuaries with little freshwater input, currents are mainly tidally driven. Water exchange can be significant and can result in moving larvae both away from and toward the point of entrainment.

Previous impact assessments at power plants located along open coastal sandy beach areas in southern California showed that the homogeneity of the habitat resulted in concentrations of larvae that were, on average, rather uniform throughout the sampled source water (e.g., MBC and Tenera 2005, Tenera and MBC 2008). The *PE* estimate used in the ETM is typically calculated as the ratio of the estimated numbers of larvae entrained to the population at risk in the sampled source water (Steinbeck et al. 2007). In the Initial ETM Assessment prepared by Tenera (2021) for this project, a simplifying assumption was made that the estimated *PE* could be calculated as the ratio of the volume of water entrained to the volume of the sampled source water. This simplification was used in the original formulation of the ETM to estimate impacts due to an intake along a river (Boreman et al. 1978, 1981). Although a river is a much simpler system to model because of the generally unidirectional flow of water, the volumetric assumption that larvae are uniformly distributed throughout the source water does not compromise the empirically derived calculation of the source water population extent. Instead, it allows for calculation of *PE* without the underlying biological data from the intake and source water volumes. The potential for using this volumetric modeling approach for intake assessment was shown to be applicable at certain locations by Steinbeck et al. (2016). This approach is especially useful for initial project planning and permitting, which was the purpose of the Initial ETM Assessment (Tenera 2021).

The Initial ETM Assessment (Tenera 2021) provided ETM results using three source water estimates: a highly conservative estimate that used the volume of Humboldt Bay as a closed system (Model M1 in **Table 3-1**), a much less conservative model that incorporated the volume of the tidal prism for the entire bay that assumed total mixing during each tidal cycle (Model M2 in **Table 3-1**), and a model that also included the tidal prism for the entire bay and accounted for differing exchange rates in each section of the bay (Model M3 in **Table 3-1**). Model M1 represented the lowest rate of mixing, Model M2 represented the highest rate of mixing, and Model M3 was between the other two models. Mixing is important to the ETM because it increases the volume of the source water body and subsequently, increases the size of the source water population from which entrainment occurs, resulting in a lower estimate of P_M for a larger rate of mixing.

Table 3-1. Initial ETM Assessment Study estimates of P_M for three source water models for Humboldt Bay. The values in this table represent the proportion (percentage) of the source water population of larvae at risk due to entrainment by the two intakes located off the Samoa Peninsula. Reproduced from Table 4-1 in Initial ETM Assessment (Tenera 2021). Model M3 is bolded as it is the selected model for use in this study.

	Pacific Herring	**Arrow Goby**	**Bay Goby**	**Northern Anchovy**	**Maximum Turnover**
Larval Durations (d) **Models**	6.8	17.4	4.3	24.3	30
M1 – Closed	0.00208 (0.208%)	0.00532 (0.532%)	0.00132 (0.132%)	0.00743 (0.743%)	0.00916 (0.916%)
M2 – Tidal Prism	0.00023 (0.023%)	0.00025 (0.025%)	0.00022 (0.022%)	0.00025 (0.025%)	0.00026 (0.026%)
M3 – Exchange Ratios	0.00075 (0.075%)	0.00096 (0.096%)	0.00062 (0.062%)	0.00101 (0.101%)	0.00104 (0.104%)

These models, their assumptions, and supporting results from the historical literature are presented in the Initial ETM Assessment. The results using this range of source water estimates were provided in that report to allow environmental managers and regulators to compare the range of effects of the intakes. This exercise was useful and provided that evidence could also be presented to rule out the truly worst-case, most conservative model which could support isolated populations near the proposed seawater intake that do not exchange regularly with the broader Humboldt Bay and open ocean waters and therefore represents a much smaller source water volume and population. This most conservative model would result in much higher, and unrealistic, estimates of population impacts when considering that Barnhart et al. 1992 estimated that the tidal prism of Humboldt Bay can be up to 54% of the MHHW volume. Therefore, one of the goals of this study was to identify the model that provided the most appropriate representation of the dynamics of Humboldt Bay. This study used the data from Swanson (2105) for the four sub-bay regions and the flushing rates for each of the regions that he calculated based on the model results from Anderson (2015).

Figure 3-3. Map of Humboldt Bay showing regions used in calculating volumes. From Swanson (2015; Figure 18).

The use of volumetric ratio models for the Initial ETM Assessment was possible due to the extensive hydrographic modeling data for Humboldt Bay presented in Swanson (2015). These data were, in turn, based on previous studies by Costa (1982), Barnhart et al. (1992), and unpublished data from a study by Andersen (2015). These data included estimated tidal flushing rates, areas, and volumes for the four regions of the Bay. These data were used in the Initial ETM Assessment along with a range of assumptions regarding tidal flushing rates and turnover of waters in the Bay to provide a corresponding range of ETM estimates of P_M. The same data on the source water characteristics of Humboldt Bay used in the previous study are also used in this study.

The three models presented in the Initial ETM Assessment (Tenera 2021) utilized different approaches to account for tidal exchange in Humboldt Bay (**Table 3-1**). Previous studies of fish larvae in Humboldt Bay (e.g., Eldridge and Bryan 1972) showed differing abundances and composition of larvae in each region of the Bay. Therefore, the model used in the Initial ETM Assessment that incorporated estimates from each of the four regions of Humboldt Bay shown in **Figure 3-3**: Arcata Bay, Main Channel, Entrance Bay, and South Bay was expected to be the most appropriate model for this study. The approach to verifying this model is provided below in Section 3.2.1.2.

The intakes are proposed to be located near the junction of the Main Channel and the Samoa Channel off the Samoa Peninsula, across from the city of Eureka (**Figure 1-2**). Swanson (2015) describes the physical oceanography of the various regions of Humboldt Bay and states that at MLLW the North Bay Channel and the Main Channel can contain half the tidal prism from Arcata Bay, and at MHHW can contain twice the tidal prism from Entrance Bay (citing unpublished data from Andersen 2015). Swanson presents areas and volumes of the components of Humboldt Bay (Swanson 2015 citing unpublished data from Andersen 2015) as well as discussing estimates of flushing times for each region. The regions delineated are similar to previous studies with some simplification for modeling. The areas and volumes for the four subregions are provided in **Table 3-2**.

One of the simplest methods for calculating the retention or turnover time is dividing the estuary volume by the tidal prism (V_{TP}, Shelden and Alber 2006)

$$\varepsilon = \frac{V_B}{V_{TP}},$$

where ε is the retention time, V_B is the estuary volume, and V_{TP} is the average tidal range (MHW-MLW volumes). However, this simple calculation does not reflect different sub-regional retention rates or their populations. Swanson (2015) presents flushing rates for the four sub-bay regions in Humboldt Bay. Using Swanson's data for the four sub-bay regions (**Table 3-2**), the overall MHHW volume weighted flushing rate was 0.24 per day, resulting in a retention time of 4.16 days (**Table 3-3**). These values were used in the calculation of the ETM model results for Model M3.

Table 3-2. Areas and volumes for four Humboldt Bay sub-bay regions at five tidal datums. From Swanson (2015 using data from Andersen 2015).

	Arcata Bay		Main Channel		Entrance Bay		South Bay	
Tidal Datum	Surface Area (mi^2 [km^2])	Volume (ft^3 x 10^6 [m^3 x 10^6])	Surface Area (mi^2 [km^2])	Volume (ft^3 x 10^6 [m^3 x 10^6])	Surface Area (mi^2 [km^2])	Volume (ft^3 x 10^6 [m^3 x 10^6])	Surface Area (mi^2 [km^2])	Volume (ft^3 x 10^6 [m^3 x 10^6])
MLLW	4.79 (12.41)	578 (16.36)	1.84 (4.77)	1,062 (30.08)	2.96 (7.67)	1,425 (40.36)	2.25 (5.83)	385 (10.91)
MLW	6.65 (17.22)	766 (21.70)	1.88 (4.87)	1,134 (32.11)	2.97 (7.69)	1,517 (42.95)	4.34 (11.24)	503 (14.24)
MSL	12.06 (31.23)	1,361 (38.53)	2.10 (5.44)	1,269 (35.92)	3.10 (8.03)	1,736 (49.15)	6.38 (16.52)	866 (24.52)
MHW	14.28 (37.00)	2,364 (66.94)	2.22 (5.75)	1,413 (40.01)	3.11 (8.05)	1,927 (54.56)	6.91 (17.90)	1,333 (37.74)
MHHW	14.42 (37.35)	2,600 (73.61)	2.29 (5.93)	1,456 (41.24)	3.12 (8.08)	1,991 (56.37)	6.91 (17.90)	1,427 (40.42)

The availability of flushing rates for the four sub-bay regions from the hydrodynamic model used in Swanson (2015) provided justification for the development of Model M3 (**Table 3-1**) that uses flushing rates that account for the variation among source water areas as follows:

$$P_M = 1 - \sum_{i=1}^{12} f_i \left(1 - \left[\frac{N_{E_i}}{N_{B_i} + \left[(q \cdot 1.93) \cdot \left(\left(N_{SB_i} \cdot 0.04\right) + \left(N_{EB_i} \cdot 0.31\right) + \left(N_{MCh_i} \cdot 0.14\right) + \left(N_{AB_i} \cdot 0.02\right)\right)\right]}\right]\right)^q \quad \text{Equation 6}$$

where for each survey i, N_E is calculated as shown in Equation 4, N_B is the estimated number in Humboldt Bay at MSL, N_{SB} the estimated number of larvae in the South Bay, N_{EB} the estimated number of larvae in the Entrance Bay, N_{MCh} the estimated number of larvae in the Main Channel, and N_{AB} the estimated number of larvae in Arcata Bay all at MSL. The estimate for each subregion is multiplied by its corresponding estimated flushing rate from Swanson (2015) (**Table 3-3**). This ETM model, identified as Model M3 in **Table 3-1**, accounts for the variation in flushing rates between areas.

In the model in Equation 6, the estimated numbers for each subregion is calculated based on the average concentrations of larvae from the stations in each region in **Figure 3-1** as follows: N_{SB} is calculated using the data from Station SW5 in the South Bay, N_{EB} is calculated using the data from Station SW4 in the Entrance Bay, N_{MCh} is calculated using the data from stations SW3, E1, E2, and E6 in the Main Channel, and N_{AB} is calculated using the data from stations SW1 and SW2 in Arcata Bay. The numbers from all four regions of the bay are combined to provide the estimate of N_B for Humboldt Bay.

Table 3-3. Flushing rates for the four Humboldt Bay sub-bay regions from Swanson 2015 (using data from Andersen 2015) and calculated volume weighted flushing rate.

Sub-Bay Region	Flushing rate τ per tidal cycle[1]	MHHW Volume ($ft^3 \times 10^6$ [$m^3 \times 10^6$])	Volume Weighted τ per tidal cycle	Volume Weighted τ per day
Arcata Bay	0.02	2,600 (73.61)		
Main Channel	0.14	1,456 (41.24)		
Entrance Bay	0.31	1,991 (56.37)		
South Bay	0.04	1,427 (40.42)		
Sum		7,474 (211.64)	0.12	0.24

[1] Swanson calculated the flushing rate for the Main Channel as the MHHW volume-weighted average of the Entrance and Arcata Bay "since it connects the two".

3.2.1.2 Verification of Source Water Models

Identifying the most appropriate source water model for this study involved consultation with oceanographers and local experts on the hydrographic processes in the Bay. The model used to estimate the source water population subject to entrainment was verified using physical and biological data collected during the sampling. The locations of the two intakes for the project are along the channel formed by the north spit about 3.7 mi (6 km) from the Entrance Bay. The approach using both physical and biological data was used to evaluate indicators of the mixing length along the channel and its effect on biological populations. Acoustic Doppler Current Meter (ADCP) observations of Brown and Caldwell (2014) and circulation modeling results summarized by Claasen (2003) show that the tidal currents in the main channel of Humboldt Bay have amplitudes in the range of 0.5 m/sec to 1.0 m/sec. This means that particles within that flow would be displaced between 7 km and 14 km every tidal cycle, which is equal to or greater than the length of the main channel between the Harbor Entrance and the two intakes.

Changes in salinity and temperature among areas are commonly used to estimate the rates of mixing within estuaries (Sheldon and Alber 2006). Therefore, an instrument that measured conductivity (salinity) and seawater temperatures through the water column was deployed during the biological sampling at each station, except during the first survey in January due to instrument failure (**Figure 3-1**). A temperature recorder was also trailed through the water during each sampling cycle to record seawater temperatures throughout the bay. Humboldt Bay is not a true estuary and does not have a continuous source of freshwater input that would produce the types of gradients in temperature and salinity that would provide reliable data to determine mixing. Therefore, in addition to the analysis of temperature and salinity, differences among areas within the bay were calculated using the biological data collected during the sampling. This was done by calculating the Bray-Curtis similarity among all station pairs within each survey and cycle. The Bray-Curtis index measures the similarity between station pairs based on the composition of the taxa in the samples (Clarke and Warwick 2001) and is calculated as:

$$100 * \frac{2C_{ij}}{S_i+S_j},$$

where C_{ij} is the sum of the lowest count from each species common to both samples and S_i+S_j is the sum of the total fish larvae in both samples. Only the data on fish larvae were used in the analysis and did not include the group of unidentified fish larvae. The calculations were done using the PRIMER analysis package and included 189 samples and 60 different taxa on fish larvae. Predicted tide data for each minute from the NOAA tides and currents website (https://tidesandcurrents.noaa.gov/tide_predictions.html) for the North Sand Spit tide station in Humboldt Bay (Site 9418767) were downloaded and matched with the sampling times for all 189 samples. Approximate distances among the sampling locations were calculated from using ESRI ArcMap 10.8 based on the station locations shown in **Figure 3-1**. The relationships between distance and Bray-Curtis similarity were analyzed using regression. The relationships between stations were of special interest for the stations located along the North Sand Spit from the Harbor mouth (SW4), up past Station SW3 and the entrainment stations (E1 and E2), and into Arcata Bay and the location of Station SW2. These stations would be especially subject to strong tidal currents due to the narrowing of the channel along this stretch of the bay, especially in the areas where the intake stations are located across from where Tuluwat Island extends into the Samoa Channel (**Figure 1-2**).

3.2.1.3 Humboldt Bay Source Water Body Calculations

Using the data from Swanson (2015) for Arcata Bay, Main Channel, Entrance Bay, and South Bay in **Table 3-2**, the volume of V_B at MSL was 5,231 Mft^3 (148.12 Mm^3). At V_{TP} the volume was 3,117 Mft^3 (88.25 Mm^3). The retention time was 8.04 tidal cycles or 4.12 days. These values were used to populate parameters in Equation 6. Larval durations were calculated using the data on the length of the larvae collected during this study. The model results from the Initial ETM Assessment based on the maximum estimate of approximately 30 days for complete turnover of water in the bay based on information in Swanson (2015) could be used for larval stages of shellfish such as crabs that go through multiple larval stages before settling out of the plankton as juveniles.

3.2.1.4 ETM Assumptions

Several assumptions are associated with the estimation of P_M in this ETM:

1. The samples from each survey period *i*, represent a new and independent cohort of larvae.
2. The estimates of larval abundance for each approximately monthly survey period *i* represent a proportion of total annual larval production during that the i^{th} survey period.
3. The conditional probability of entrainment, PE_i, is constant within each survey period *i*.
4. The conditional probability of entrainment, PE_i, is constant within each of the size classes of larvae present during each survey period *i*.
5. The concentrations of larvae in the sampled source water are representative of the concentrations in the extrapolated source water.
6. Lengths and applied growth rates of larvae accurately estimate the period of time that the larvae are vulnerable to entrainment.

3.2.2 Calculation of Area of Production Foregone (APF) Estimates

Estimates of APF corresponding to each of the taxa analyzed by the ETM is calculated using the estimate of the area of Humboldt Bay at MSL (23.6 mi^2 [61.1 km^2]) in **Table 2-2** as follows:

$$APF = \widehat{P_{M_\iota}} A_{HB},$$

where $\widehat{P_{M_\iota}}$ is the ETM estimate of P_M for the i^{th} taxa and A_{HB} is the surface area of Humboldt Bay at MSL. Using the estimate of the entire area of Humboldt Bay in the APF calculations is conservative, especially for taxa that use specific habitat for spawning, since the entire area of the bay is not used as spawning habitat by most fishes.

4.0 Results

This section presents the results from the sampling completed January through December 2022. The sampling results for the major taxonomic groups are followed by the analyses used to verify the source water model that uses all of the data on larval fishes. Results for the most abundant individual taxa collected during the study as well as results for LFS larvae are presented. The results for the individual taxa include results on the measurements of the larvae and other data used to calculate estimates of *PE* for each survey and in the calculation of the ETM estimates of P_M for each of the two intakes in Humboldt Bay.

The data from each sample collected during the study are provided in Appendix A. Details on conditions during each sample including date, time, sample volume, sample depth, tide conditions, and temperature and salinity data are provided in Appendix B. Plots of temperature and salinity through the water column at each station during sampling are presented in Appendix C.

4.1 Sampling Overview

A total of 189 samples were collected during the sampling from January–December 2022 (**Table 4-1**). Surveys were completed approximately monthly, beginning on January 11, 2022 and ending on December 6, 2022. At each monthly survey, eight stations were sampled during the day and night, totaling 16 samples per survey. However, during the night-time cycle of the first survey, three of the source water stations were not sampled due to failure of the winch used to retrieve the plankton net. Since the numbers of days between the surveys were not the same, a start and end date was designated to provide the number of days within each survey period to provide a total of 365 days for the entire study. The surveys periods were used in calculating the annual entrainment estimates.

The sampling resulted in the collection of 60 different taxa of larval fishes from 28 different families. The taxa with the highest average concentrations were Arrow Goby and Bay Goby which are both in the Family Gobiidae (**Table 4-2**). These two taxa were abundant at all of the sampling locations but had the highest average concentrations at entrainment Station E1 where the intake for the existing RMT II intake is located (**Figure 3-1**). The other taxa with high average concentrations included Whitebait Smelt, Pacific Herring, Surf Smelt, and Pacific Tomcod. These taxa varied in abundance across all eight stations. The highest average concentrations of fish larvae occurred at entrainment Station E1 and source water Station SW2. This was likely due to the high concentrations of Arrow Goby larvae that are produced from the large expanses of mudflat habitat in Arcata Bay (**Figure 2-2**). The average concentrations at stations E2 and SW6 in Arcata Bay were also high (**Table 4-2**). The concentrations for Arrow Goby and Bay Goby at Station SW1 were lower, which may be due to the lower salinities measured at that station during the sampling (Appendix B), possibly due to freshwater outflow from tributaries entering Humboldt Bay from Eureka Slough, which is proximate to that station. The largest number of taxa were collected at source water Station SW5, which is located in South Bay but is also close to the Main Entrance (**Figure 3-1**). Station SW5 is also located in primarily mudflat habitat, which is typically not an area of high species diversity, but the high number of taxa may also be because the station is close to other habitats such as the harbor breakwaters and the open ocean. The lowest numbers of taxa occurred at source water stations SW1 and SW2 located in Arcata Bay, which are also situated in and surrounded by mudflat habitat. However, unlike SW5, stations SW1 and SW2 are not adjacent to other habitats and are the stations furthest from the open ocean, so may have low taxa diversity relative to other stations because of low adjacent habitat diversity. Overall, the taxa collected represent a mix of open ocean and bay species, with the relative abundances at the stations generally reflective of the taxa associated with the habitats in proximity to those stations.

Table 4-1. The table shows the dates of each survey, dates used in calculating surveys periods used in entrainment estimates, and numbers of samples collected each survey.

Survey Date	Number of Samples	Start Date	End Date	Interval (d)	Notes
1/11/2022	13	12/23/2021	1/26/2022	34	SW stations 4, 5, and 6 not sampled in cycle 2
2/10/2022	16	1/26/2022	2/27/2022	32	All samples collected
3/17/2022	16	2/27/2022	4/5/2022	37	All samples collected
4/26/2022	16	4/5/2022	5/10/2022	35	All samples collected
5/26/2022	16	5/10/2022	6/11/2022	32	All samples collected
6/28/2022	16	6/11/2022	7/13/2022	32	All samples collected
7/29/2022	16	7/13/2022	8/8/2022	26	All samples collected
8/18/2022	16	8/8/2022	9/4/2022	27	All samples collected
9/22/2022	16	9/4/2022	10/1/2022	27	All samples collected
10/11/2022	16	10/1/2022	10/24/2022	23	All samples collected
11/7/2022	16	10/24/2022	11/21/2022	28	All samples collected
12/6/2022	16	11/21/2022	12/23/2022	32	All samples collected
Total =	**189**				

The highest average concentrations of all fish larvae combined at the two entrainment stations occurred during the months of June through August with the highest concentrations occurring during the late June survey at Station E1, with an average concentration of 11,311 per 1,000 m^3 (average of samples 4 and 12, Survey 6 in Appendix A and **Figure 4-1**). Although one explanation for the large concentration during that survey could be that a large number of larvae transported out of Arcata Bay on an ebb tide were present during the sampling, the data in Appendix B show a flood tide during the sample collection. Therefore, it is likely that the high concentration reflects the extremely patchy nature of plankton abundance. The lowest average concentrations occurred during the fall and winter month surveys with the lowest average concentration occurring during the November survey at Station E1 with an average concentration of approximately 0.05 larvae per 1,000 m^3. In general, nighttime concentrations were higher than daytime concentrations. The months when this pattern was reversed generally occurred during the same months at both stations.

Table 4-2. Average larval concentration (# per 1,000 m3) and total sample counts of larvae collected from all stations (entrainment and source water) sampled in Humboldt Bay from January – December 2022.

		Mean Concentrations (# per 1,000 m^3) and Sample Counts in Parentheses							
Taxon	**Common Name**	**E1**	**E2**	**SW1**	**SW2**	**SW3**	**SW4**	**SW5**	**SW6**
Fish Larvae									
Clevelandia ios	Arrow Goby	1,025.14 (609)	340.82 (356)	190.19 (364)	905.62 (899)	102.43 (127)	4.98 (5)	4.89 (9)	449.11 (710)
Lepidogobius lepidus	Bay Goby	98.32 (208)	87.92 (187)	40.62 (49)	46.07 (100)	62.17 (153)	43.86 (75)	91.12 (222)	48.85 (107)
Allosmerus elongatus	Whitebait Smelt	70.83 (110)	60.50 (67)	9.90 (11)	15.04 (18)	52.87 (107)	203.11 (119)	19.88 (36)	14.26 (31)
Clupea pallasii	Pacific Herring	15.47 (37)	12.17 (30)	37.97 (105)	17.90 (47)	16.89 (63)	54.19 (139)	82.31 (197)	6.82 (16)
Hypomesus pretiosus	Surf Smelt	12.55 (9)	11.26 (11)	4.95 (8)	3.82 (5)	3.92 (8)	18.78 (13)	8.22 (7)	8.06 (17)
Microgadus proximus	Pacific Tomcod	20.72 (46)	5.12 (13)	2.23 (4)	1.05 (2)	23.91 (57)	11.95 (22)	4.19 (9)	1.32 (3)
Citharichthys sordidus	Pacific Sanddab	5.80 (13)	1.80 (4)	1.95 (1)	0.88 (2)	16.16 (47)	19.71 (22)	20.74 (49)	0.00 (0)
Leptocottus armatus	Pacific Staghorn Sculpin	8.29 (21)	7.44 (21)	6.61 (14)	6.83 (18)	8.28 (22)	8.52 (16)	9.27 (19)	7.46 (16)
Spirinchus starksi	Night Smelt	13.51 (33)	2.54 (6)	9.84 (6)	0.52 (1)	8.31 (23)	17.85 (24)	6.28 (16)	1.41 (3)
Hippoglossoides elassodon	Flathead Sole	2.40 (6)	0.44 (1)	0.00 (0)	0.44 (1)	3.41 (10)	10.09 (11)	10.38 (18)	0.00 (0)
Ammodytes hexapterus	Pacific Sand Lance	4.53 (10)	2.62 (7)	1.48 (4)	2.39 (6)	4.06 (12)	5.00 (10)	4.98 (10)	0.38 (1)
Artedius spp.	sculpins	2.53 (6)	2.90 (3)	1.05 (2)	1.65 (1)	5.55 (8)	6.64 (7)	1.89 (4)	0.84 (2)
Liparis spp.	snailfishes	5.38 (6)	7.24 (10)	2.00 (4)	1.46 (3)	1.78 (5)	1.67 (4)	1.32 (3)	0.73 (2)
larval/post-larval fish	unidentified larval fishes	0.78 (2)	0.79 (2)	1.25 (3)	6.86 (13)	1.95 (5)	4.18 (10)	1.86 (4)	1.24 (3)
Pleuronectoidei	flatfishes	0.00 (0)	0.00 (0)	1.95 (1)	0.00 (0)	2.76 (7)	1.45 (2)	11.49 (21)	0.37 (1)
Engraulis mordax	Northern Anchovy	2.22 (5)	0.82 (2)	3.62 (5)	3.09 (3)	3.68 (8)	0.86 (2)	2.40 (5)	0.81 (2)
Oligocottus/Clinocottus spp.	Sculpins	2.67 (6)	4.95 (12)	0.39 (1)	2.55 (6)	1.86 (5)	1.64 (3)	2.09 (5)	1.32 (3)
Cottus asper	Prickly Sculpin	5.08 (5)	2.11 (5)	0.92 (2)	0.00 (0)	0.68 (2)	2.46 (5)	1.35 (3)	0.83 (2)
Gillichthys mirabilis	Longjaw Mudsucker	0.36 (1)	1.19 (2)	1.23 (3)	5.31 (10)	0.90 (2)	0.33 (1)	0.00 (0)	3.26 (5)
Rhinogobiops nicholsii	Blackeye Goby	0.75 (2)	0.83 (2)	2.31 (2)	2.94 (2)	1.63 (4)	0.42 (1)	0.00 (0)	1.21 (3)
Sebastes spp. V_	KGB rockfish complex larvae	4.18 (3)	2.60 (7)	0.56 (1)	0.44 (1)	0.62 (2)	0.00 (0)	0.00 (0)	1.21 (3)
Spirinchus thaleichthys	Longfin Smelt	2.18 (6)	0.27 (1)	0.51 (1)	0.44 (1)	0.51 (1)	0.00 (0)	1.01 (1)	0.00 (0)

table continued

Table 4-2 (cont.). Average larval concentration (# per 1,000 m3) and total sample counts of larvae collected from all stations (entrainment and source water) sampled in Humboldt Bay from January – December 2022.

		Mean Concentrations (#per 1,000 m^3) and Sample Counts in Parentheses							
Taxon	**Common Name**	**E1**	**E2**	**SW1**	**SW2**	**SW3**	**SW4**	**SW5**	**SW6**
Sebastes spp. V	Blue Rockfish complex larvae	0.83 (2)	0.00 (0)	0.40 (1)	0.83 (2)	0.85 (2)	0.92 (2)	0.90 (2)	0.00 (0)
Atherinops affinis	Topsmelt	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	4.01 (10)	0.00 (0)	0.37 (1)
Parophrys vetulus	English Sole	0.85 (2)	0.00 (0)	0.36 (1)	0.00 (0)	0.32 (1)	0.56 (1)	0.85 (2)	0.48 (1)
Tarletonbeania crenularis	Blue Lanternfish	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.42 (1)	1.26 (3)	1.39 (3)	0.00 (0)
Bathymasteridae	ronquils	0.41 (1)	0.44 (1)	0.00 (0)	1.70 (2)	0.43 (1)	0.00 (0)	0.00 (0)	0.00 (0)
Isopsetta isolepis	Butter Sole	0.82 (2)	0.42 (1)	0.00 (0)	1.05 (2)	0.00 (0)	0.56 (1)	0.00 (0)	0.00 (0)
Genyonemus lineatus	White Croaker	0.00 (0)	0.40 (1)	0.48 (1)	0.00 (0)	0.00 (0)	0.83 (2)	0.96 (2)	0.00 (0)
Stenobrachius leucopsarus	Northern Lampfish	0.82 (2)	0.36 (1)	0.00 (0)	0.00 (0)	0.85 (2)	0.00 (0)	0.00 (0)	0.00 (0)
Oligocottus snyderi	Fluffy Sculpin	0.45 (1)	0.00 (0)	0.00 (0)	0.00 (0)	0.76 (2)	0.00 (0)	0.77 (2)	0.00 (0)
Ruscarius meanyi	Puget Sound Sculpin	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.26 (1)	0.00 (0)	1.67 (1)	0.00 (0)
Atherinopsis californiensis	Jacksmelt	0.00 (0)	1.85 (1)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Lipolagus ochotensis	Popeye Blacksmelt	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.40 (1)	1.43 (3)	0.00 (0)
Acanthogobius flavimanus	Yellowfin Goby	0.00 (0)	0.00 (0)	0.00 (0)	1.29 (1)	0.00 (0)	0.00 (0)	0.00 (0)	0.39 (1)
Porichthys notatus	Plainfin Midshipman	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	1.60 (2)
Pholidae	gunnels	0.52 (1)	0.00 (0)	0.00 (0)	0.00 (0)	0.41 (1)	0.00 (0)	0.44 (1)	0.00 (0)
Stichaeidae	pricklebacks	0.41 (1)	0.36 (1)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.52 (1)	0.00 (0)
Platichthys stellatus	Starry Flounder	0.00 (0)	0.00 (0)	0.00 (0)	1.29 (1)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Citharichthys stigmaeus	Speckled Sanddab	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.32 (1)	0.00 (0)	0.81 (2)	0.00 (0)
Cebidichthys violaceus	Monkeyface Prickleback	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.52 (1)	0.48 (1)
Syngnathidae	pipefishes	0.65 (1)	0.00 (0)	0.35 (1)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Chitonotus pugetensis	Roughback Sculpin	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.94 (1)	0.00 (0)	0.00 (0)
Icichthys lockingtoni	Medusa Fish	0.44 (1)	0.47 (1)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Scorpaenichthys marmoratus	Cabezon	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.42 (1)	0.00 (0)	0.48 (1)	0.00 (0)
Ruscarius creaseri	Roughcheek Sculpin	0.41 (1)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.48 (1)	0.00 (0)

table continued

Table 4-2 (cont.). Average larval concentration (# per 1,000 m3) and total sample counts of larvae collected from all stations (entrainment and source water) sampled in Humboldt Bay from January – December 2022.

		Mean Concentrations (#per 1,000 m^3) and Sample Counts in Parentheses							
Taxon	**Common Name**	**E1**	**E2**	**SW1**	**SW2**	**SW3**	**SW4**	**SW5**	**SW6**
Trachipterus altivelis	King-of-the-Salmon	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.39 (1)	0.00 (0)	0.49 (1)
Actinopterygii	ray-finned fishes	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.48 (1)	0.38 (1)
Lyopsetta exilis	Slender Sole	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.42 (1)	0.39 (1)	0.00 (0)	0.00 (0)
Cottidae	sculpins	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.81 (2)	0.00 (0)	0.00 (0)	0.00 (0)
Nannobrachium regalis	Pinpoint Lanternfish	0.00 (0)	0.39 (1)	0.00 (0)	0.00 (0)	0.00 (0)	0.39 (1)	0.00 (0)	0.00 (0)
Artedius harringtoni	Scalyhead Sculpin	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.56 (1)	0.00 (0)	0.00 (0)
Pleuronectidae	Righteye Flounders	0.49 (1)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Radulinus spp.	sculpins	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.48 (1)
Stellerina xyosterna	Pricklebreast Poacher	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.48 (1)
Hexagrammos decagrammus	Kelp Greenling	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.48 (1)	0.00 (0)
Psettichthys melanostictus	Sand Sole	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.48 (1)	0.00 (0)
Clinocottus embryum	Calico Sculpin	0.41 (1)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Bathylagidae	blacksmelts	0.00 (0)	0.00 (0)	0.00 (0)	0.40 (1)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Osmeridae	smelts	0.35 (1)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Nannobrachium spp.	lanternfishes	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.33 (1)	0.00 (0)
Larval Fish Totals		**1,311.55 (1,162)**	**561.05 (757)**	**323.12 (595)**	**1,031.84 (1,148)**	**330.60 (694)**	**428.89 (516)**	**298.66 (664)**	**554.64 (940)**
# Larval Fish Taxa		**34**	**28**	**24**	**25**	**33**	**31**	**35**	**27**
Fish Eggs									
non-engraulidae eggs	non-engraulidae eggs	1,496.54 (2,009)	1,028.55 (2,085)	568.86 (1,011)	451.60 (791)	1,557.32 (1,665)	1,275.90 (1,664)	1,375.05 (1,485)	901.27 (1,945)
Engraulidae (eggs)	anchovy eggs	13.90 (25)	20.67 (18)	4.43 (12)	11.61 (10)	13.80 (25)	28.21 (66)	29.23 (42)	7.00 (11)
Fish Egg Totals		1,510.44 (2,034)	1,049.22 (2,103)	573.29 (1,023)	463.21 (801)	1,571.12 (1,690)	1,304.12 (1,730)	1,404.28 (1,527)	908.27 (1,956)
Larval Crabs									
Metacarcinus magister	Dungeness crab megalops	38.02 (93)	5.24 (12)	7.81 (4)	1.84 (4)	60.56 (179)	3.77 (5)	2.24 (6)	0.00 (0)

table continued

Table 4-2 (cont.). Average larval concentration (# per 1,000 m3) and total sample counts of larvae collected from all stations (entrainment and source water) sampled in Humboldt Bay from January – December 2022.

		Mean Concentrations (#per 1,000 m³) and Sample Counts in Parentheses							
Taxon	**Common Name**	**E1**	**E2**	**SW1**	**SW2**	**SW3**	**SW4**	**SW5**	**SW6**
Cancer productus / Romaleon spp.	rock crab megalops	5.42 (6)	2.57 (6)	0.40 (1)	0.00 (0)	1.89 (5)	7.51 (9)	2.19 (6)	0.86 (2)
Romaleon antennarius / Metacarcinus gracilis	cancer crabs	1.64 (4)	0.00 (0)	0.45 (1)	0.00 (0)	0.00 (0)	0.00 (0)	1.23 (3)	0.00 (0)
Cancridae	cancer crabs megalops	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.51 (1)	0.00 (0)	0.00 (0)
Crab Larvae Totals		45.08 (103)	7.81 (18)	8.66 (6)	1.84 (4)	62.46 (184)	11.79 (15)	5.66 (15)	0.86 (2)

The highest average concentrations of all fish larvae combined at the six source water stations occurred during the months of May through August with the highest concentrations occurring during the May survey at Station SW2 and the August survey at stations SW2 and SW6 (see sample data in Appendix A and **Figure 4-2**). Although concentrations were generally lower during the fall and winter month surveys, the lowest average concentration occurred during the September survey at stations SW3 and SW5. Similar to the pattern at the entrainment stations, nighttime concentrations were generally higher than daytime concentrations for most surveys. The months when this pattern was reversed varied among the stations which probably reflects differences in species composition among the stations.

There was a total of 37 separate taxa of larval fishes, not including unidentified larvae, collected at the two entrainment stations (E1 and E2) with a total estimated annual entrainment by the two intakes of approximately 17.8 million larvae (**Table 4-3**). Although the daily intake volume at the RTD Intake (Station E2) accounts for one-third of the total flow, the total entrainment of fish larvae at Station E2 only accounted for approximately 17% of the total annual estimated entrainment due to differences in the composition and abundances of the larvae at the two locations. The taxon with the highest estimated entrainment was Arrow Goby which comprised over 75% of the total estimated entrainment at the two intakes, largely due to the high concentrations for the June survey samples (Appendix A). Bay Goby and Whitebait Smelt had the second and third highest estimated entrainment. Including Arrow Goby only seven taxa contributed greater than one percent to the total entrainment and collectively comprised over 95% of the total entrainment.

The fish eggs collected during the study were categorized as either engraulid or non-engraulid eggs. The categorization is based on the shape of the eggs. Eggs from species in the Family Engraulidae, such as Northern Anchovy are barrel-shaped, whereas most other fish eggs are circular. At the entrainment stations, the highest average concentrations of fish eggs occurred during the months of June through September with the highest concentrations occurring during the late August survey at Station E1 with a concentration of 7,184 fish eggs per 1,000 m^3 (**Figure 4-3**). The concentrations were also highest during the August survey at Station E2. The abundance patterns for the concentrations of fish eggs were very similar at the two entrainment stations. The lowest average concentrations occurred from December through May. There was no obvious pattern of abundance related to night and day conditions. This may be because most fish eggs are slightly buoyant due to the presence of oil globules in the yolk. Therefore, unlike fish larvae which may migrate vertically through the water column through the day, eggs for many species of fish tend to stay near the surface and would be less susceptible to entrainment at the submerged intakes.

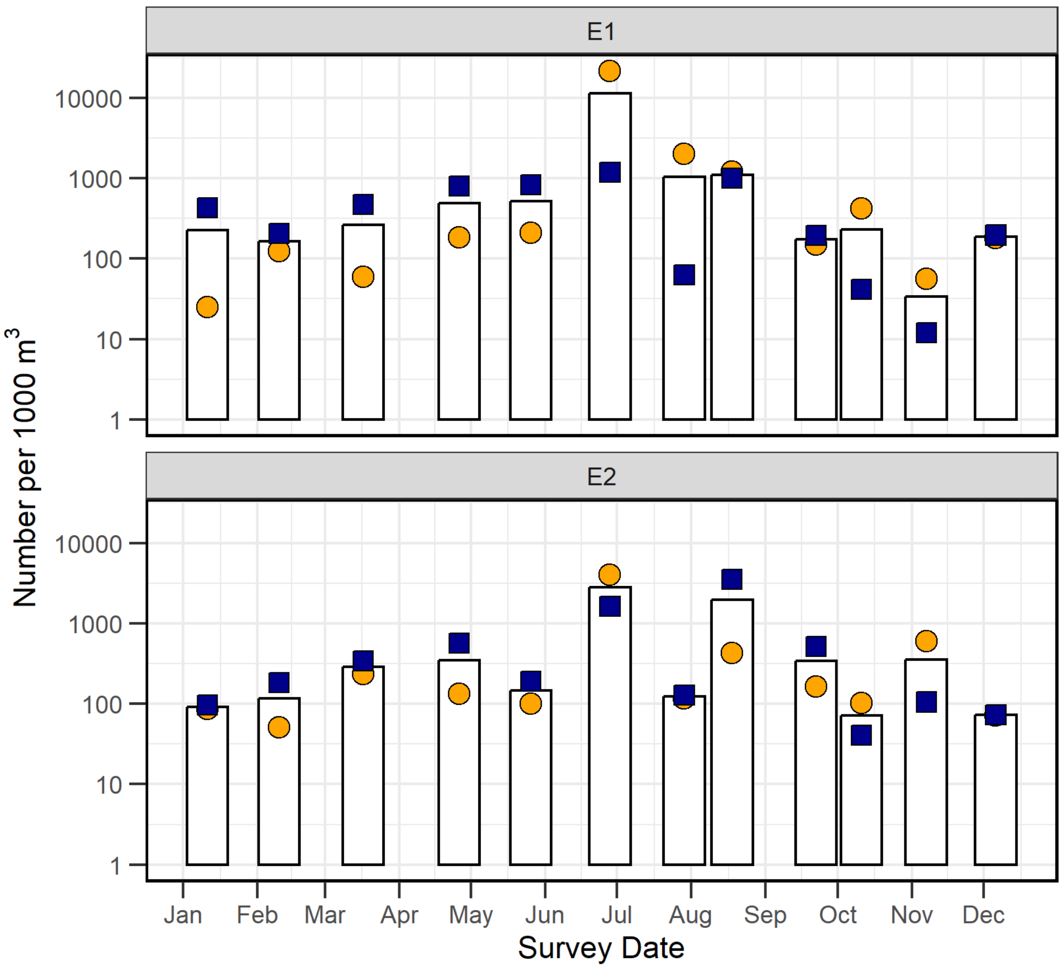


Figure 4-1. Total average concentrations of all fish larvae (height of bar) collected during monthly surveys at entrainment stations E1 and E2 from January 2022–December 2022. Concentrations from daytime (orange circles) and nighttime (blue squares) are also shown. Dates of the surveys correspond to the centers of the bars.

The highest average concentrations of fish eggs at the six source water stations occurred during the months of June through September, with the highest concentrations occurring during the August survey at stations SW2, SW3,and SW5 (**Figure 4-4**). The abundance patterns for the concentrations of fish eggs were very similar at the two Arcata Bay stations (SW1 and SW2), and at stations SW3, SW4, and SW5. These patterns probably reflect the difference in species composition for the stations in those two areas. At both sets of stations, the abundances were generally lowest during the winter month from December through February. Similar to the results for the entrainment stations (**Figure 4-3**), there was no clear pattern of concentrations varying between night and day samples.

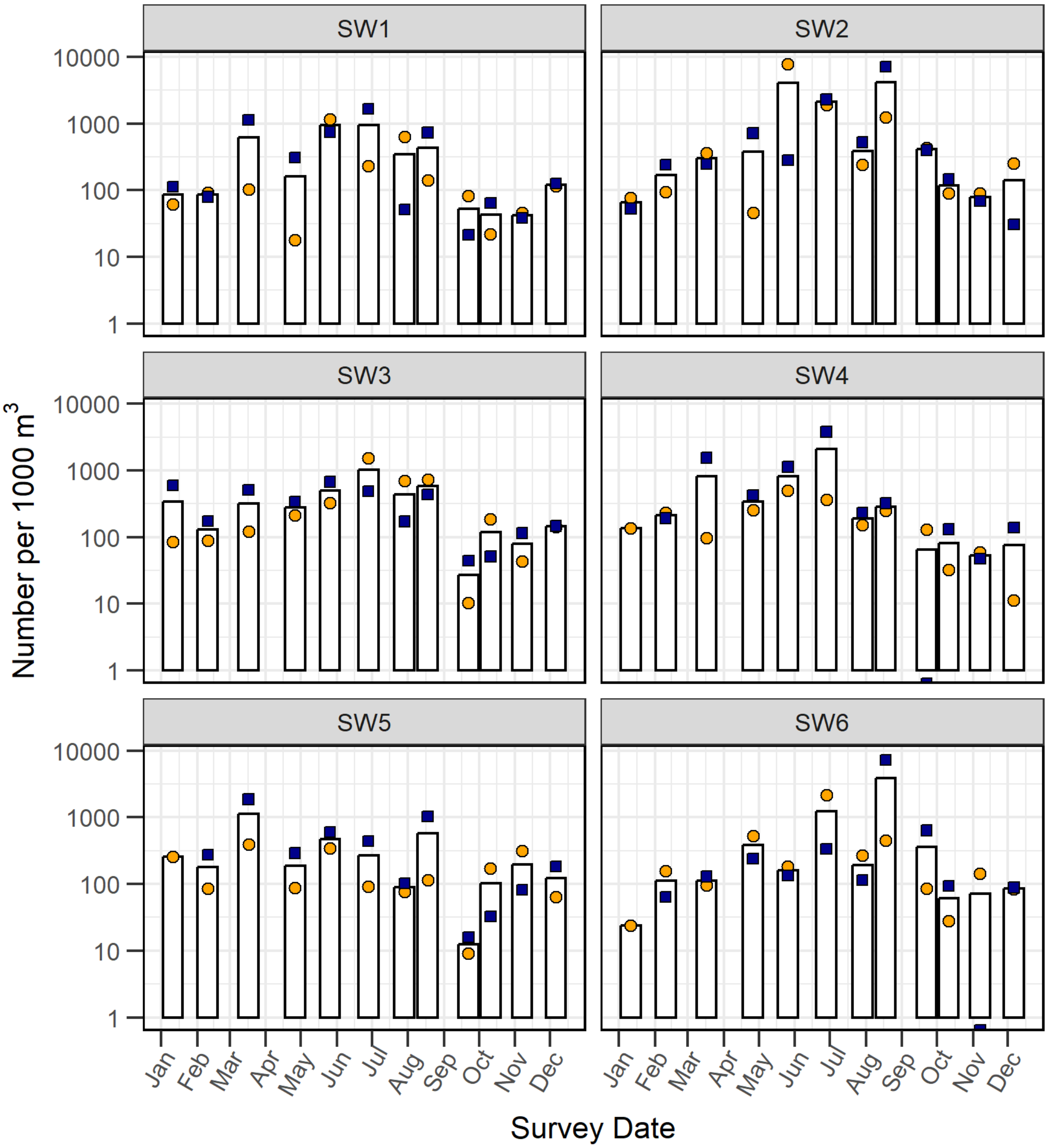


Figure 4-2. Total average concentrations of all fish larvae (height of bar) collected during monthly surveys at source water stations SW1–SW6 from January 2022–December 2022. Concentrations from daytime (orange circles) and nighttime (blue squares) are also shown. Dates of the surveys correspond to the centers of the bars.

Based on the concentration of fish eggs recorded at the entrainment stations and the anticipated volume of water entrained by the proposed project, the total estimated annual entrainment of fish eggs for the proposed project is 20,441 million (**Table 4-3**). Only approximately 0.5 million of these were anchovy eggs. A large proportion of these eggs are buoyant and would not be subject to entrainment due to the submerged intakes.

Table 4-3. Total annual estimated entrainment (standard errors in parentheses) for all larvae from intake stations E1 and E2 and both stations combined calculated from sampling in Humboldt Bay from January – December 2022 based on daily intake volumes for the RMT II (Station E1) and RTD (Station E2) intakes of 7.92x10^6 gal (29,980 m^3) and 3.96x10^6 gal (14,990 m^3), respectively.

Taxon	Common Name	Station E1 (1,000s)	Station E2 (1,000s)	Total (1,000s)	Percent of Total	Cumulative Percent
Larval Fishes						
Clevelandia ios	Arrow Goby	11,552 (10,271)	1,827 (1,040)	13,379 (10,323)	75.13%	75.13%
Lepidogobius lepidus	Bay Goby	969 (339)	444 (143)	1,413 (368)	7.93%	83.06%
Allosmerus elongatus	Whitebait Smelt	828 (447)	355 (222)	1,183 (499)	6.64%	89.70%
Microgadus proximus	Pacific Tomcod	253 (112)	32 (9)	285 (112)	1.60%	91.31%
Clupea pallasii	Pacific Herring	201 (158)	78 (20)	279 (159)	1.56%	92.87%
Hypomesus pretiosus	Surf Smelt	142 (115)	62 (49)	205 (125)	1.15%	94.02%
Spirinchus starksi	Night Smelt	162 (115)	16 (12)	178 (115)	1.00%	95.02%
Leptocottus armatus	Pacific Staghorn Sculpin	100 (39)	44 (5)	143 (39)	0.80%	95.82%
Liparis spp.	snailfishes	65 (39)	43 (26)	108 (47)	0.61%	96.43%
Citharichthys sordidus	Pacific Sanddab	66 (16)	10 (8)	76 (18)	0.43%	96.85%
Cottus asper	Prickly Sculpin	60 (45)	13 (11)	74 (46)	0.41%	97.27%
Ammodytes hexapterus	Pacific Sand Lance	52 (17)	15 (4)	68 (17)	0.38%	97.65%
Sebastes spp. V_	KGB rockfish complex	49 (38)	17 (5)	66 (39)	0.37%	98.02%
Oligocottus / Clinocottus spp.	sculpins	33 (1)	32 (9)	64 (9)	0.36%	98.38%
Artedius spp.	sculpins	31 (15)	17 (12)	48 (20)	0.27%	98.65%
Hippoglossoides elassodon	Flathead Sole	27 (24)	3 (3)	29 (24)	0.16%	98.81%
Spirinchus thaleichthys	Longfin Smelt	26 (22)	2 (2)	28 (22)	0.16%	98.97%
Engraulis mordax	Northern Anchovy	24 (17)	4 (0)	28 (17)	0.16%	99.12%
Stenobrachius leucopsarus	Northern Lampfish	11 (0)	2 (2)	13 (2)	0.08%	99.20%
Isopsetta isolepis	Butter Sole	10 (10)	3 (3)	13 (11)	0.07%	99.27%
larval/post-larval fish	unidentified larvae	8 (6)	5 (3)	13 (7)	0.07%	99.34%
Rhinogobiops nicholsii	Blackeye Goby	8 (6)	4 (3)	12 (7)	0.07%	99.41%
Sebastes spp. V	Blue Rockfish complex	11 (11)	0 (0)	11 (11)	0.06%	99.47%
Atherinopsis californiensis	Jacksmelt	0 (0)	11 (11)	11 (11)	0.06%	99.53%
Parophrys vetulus	English Sole	10 (10)	0 (0)	10 (10)	0.06%	99.59%
Gillichthys mirabilis	Longjaw Mudsucker	3 (3)	5 (4)	9 (5)	0.05%	99.64%
Bathymasteridae	ronquils	6 (6)	3 (3)	8 (6)	0.05%	99.69%
Stichaeidae	pricklebacks	5 (5)	2 (2)	8 (6)	0.04%	99.73%
Syngnathidae	pipefishes	6 (6)	0 (0)	6 (6)	0.04%	99.76%

table continued

Table 4-3 (cont.). Total annual estimated entrainment (standard errors in parentheses) for all larvae from intake stations E1 and E2 and both stations combined calculated from sampling in Humboldt Bay from January – December 2022 based on daily intake volumes for the RMT II (Station E1) and RTD (Station E2) intakes of 7.92x10^6 gal (29,980 m^3) and 3.96x10^6 gal (14,990 m^3), respectively.

Taxon	Common Name	Station E1 (1,000s)	Station E2 (1,000s)	Total (1,000s)	Percent of Total	Cumulative Percent
Icichthys lockingtoni	Medusa Fish	4 (4)	2 (2)	6 (5)	0.04%	99.80%
Pholidae	gunnels	6 (6)	0 (0)	6 (6)	0.03%	99.83%
Oligocottus snyderi	Fluffy Sculpin	6 (6)	0 (0)	6 (6)	0.03%	99.86%
Pleuronectidae	righteye flounders	6 (6)	0 (0)	6 (6)	0.03%	99.90%
Clinocottus embryum	Calico Sculpin	5 (5)	0 (0)	5 (5)	0.03%	99.93%
Ruscarius creaseri	Roughcheek Sculpin	5 (5)	0 (0)	5 (5)	0.03%	99.95%
Osmeridae	smelts	4 (4)	0 (0)	4 (4)	0.02%	99.98%
Genyonemus lineatus	White Croaker	0 (0)	2 (2)	2 (2)	0.01%	99.99%
Nannobrachium regalis	Pinpoint Lanternfish	0 (0)	2 (2)	2 (2)	0.01%	100.00%
Totals		14,754 (10,290)	3,055 (1,075)	17,809 (10,346)		
Fish Eggs						
non-engraulidae eggs	non-engraulidae eggs	15,090 (1,540)	5,095 (1,025)	20,185 (1,850)	98.75%	98.75%
Engraulidae (eggs)	anchovy eggs	141 (67)	115 (97)	256 (118)	1.25%	100.00%
Totals		15,231 (1,607)	5,210 (1,122)	20,441 (1,967)		

The crab megalops larvae collected during the sampling were categorized into four taxa groups: *Metacarcinus magister*, *Cancer productus*/*Romaleon* spp., *Romaleon antennarius*/*Metacarcinus gracilis*, and unidentified Cancridae. The megalops larval stage is the final stage in the larval development of all species of crabs including the Family Cancridae which includes Dungeness crab and several species of rock crabs that are important targets of recreational and commercial fisheries. The crab megalops collected during the study were all larger than 0.16 in. (4 mm) and would not be subject to entrainment. The most abundant taxa of crab megalops larvae collected during the sampling was Dungeness crab (**Table 4-2**).

The highest average concentrations of all crab megalops larvae combined at the two entrainment stations occurred during the months of March–June and in November with the highest concentrations occurring during the May survey at both stations (**Figure 4-5**). Megalops larvae were generally only collected during the night surveys except for the May survey at Station E1 and the November survey at Station E2.

The highest average concentrations of all crab megalops larvae combined at the source water stations occurred during the month of May with the highest concentrations occurring during the May survey at Station SW3 (**Figure 4-6**). Megalops larvae were generally only collected during the night surveys at the stations in Arcata Bay (SW1, SW2, and SW6), while crab larvae were collected in both day and samples at the other stations.

There are no entrainment totals for crab megalops larvae shown in **Table 4-3** since these larvae are too large to be entrained by the intakes due to the small slot openings.

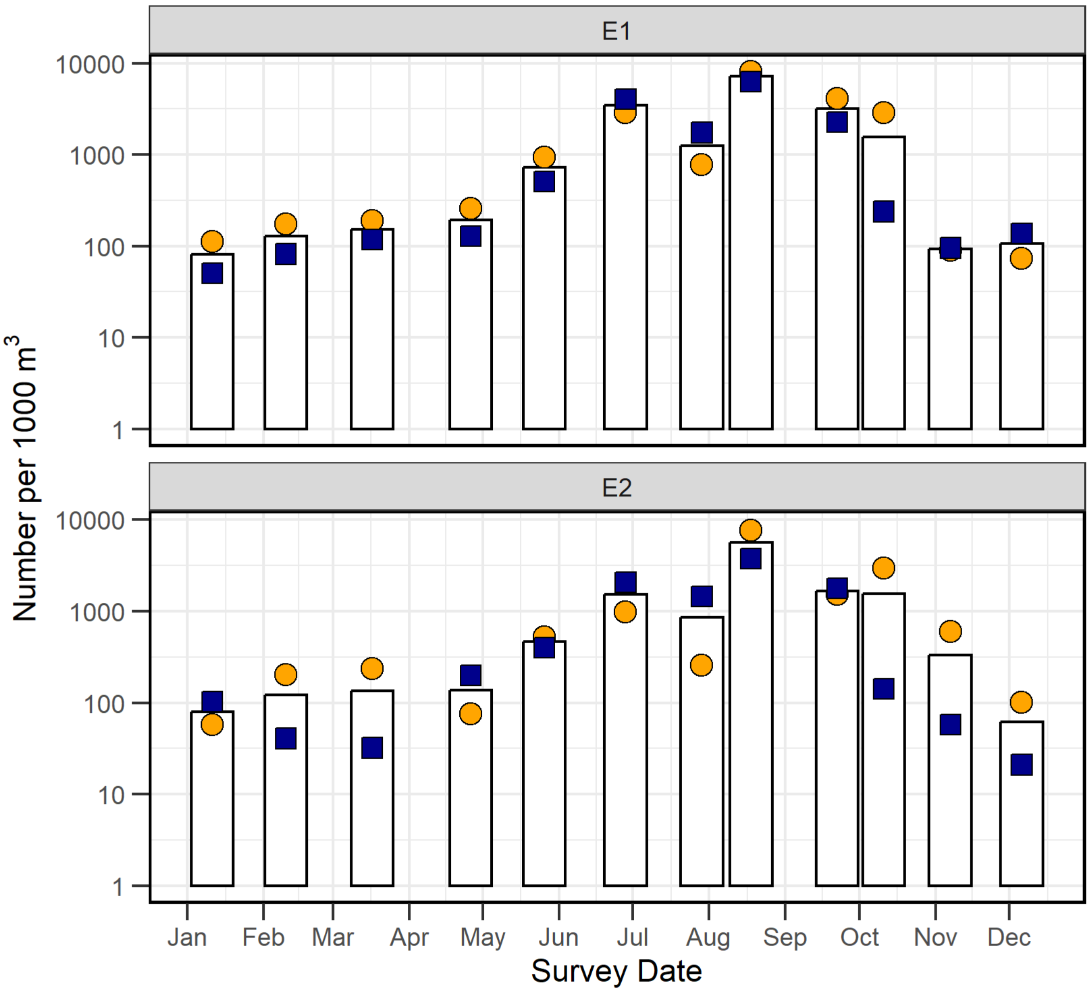


Figure 4-3. Total average concentrations of all fish eggs (height of bar) collected during monthly surveys at entrainment stations E1 and E2 from January 2022–December 2022. Concentrations from daytime (orange circles) and nighttime (blue squares) are also shown. Dates of the surveys correspond to the centers of the bars.

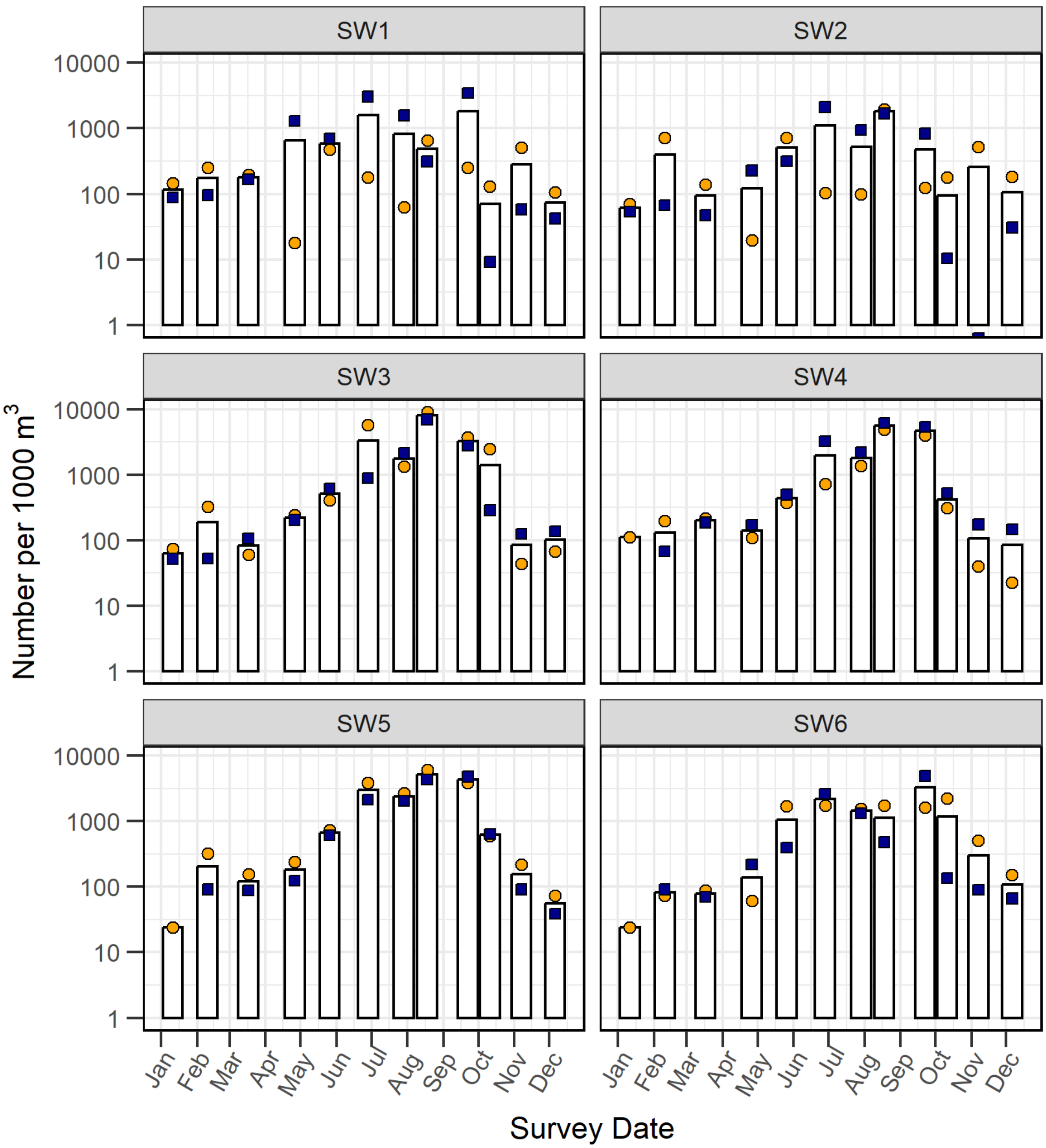


Figure 4-4. Total average concentrations of all fish eggs (height of bar) collected during monthly surveys at source water stations SW1–SW6 from January 2022–December 2022. Concentrations from daytime (orange circles) and nighttime (blue squares) are also shown. Dates of the surveys correspond to the centers of the bars.

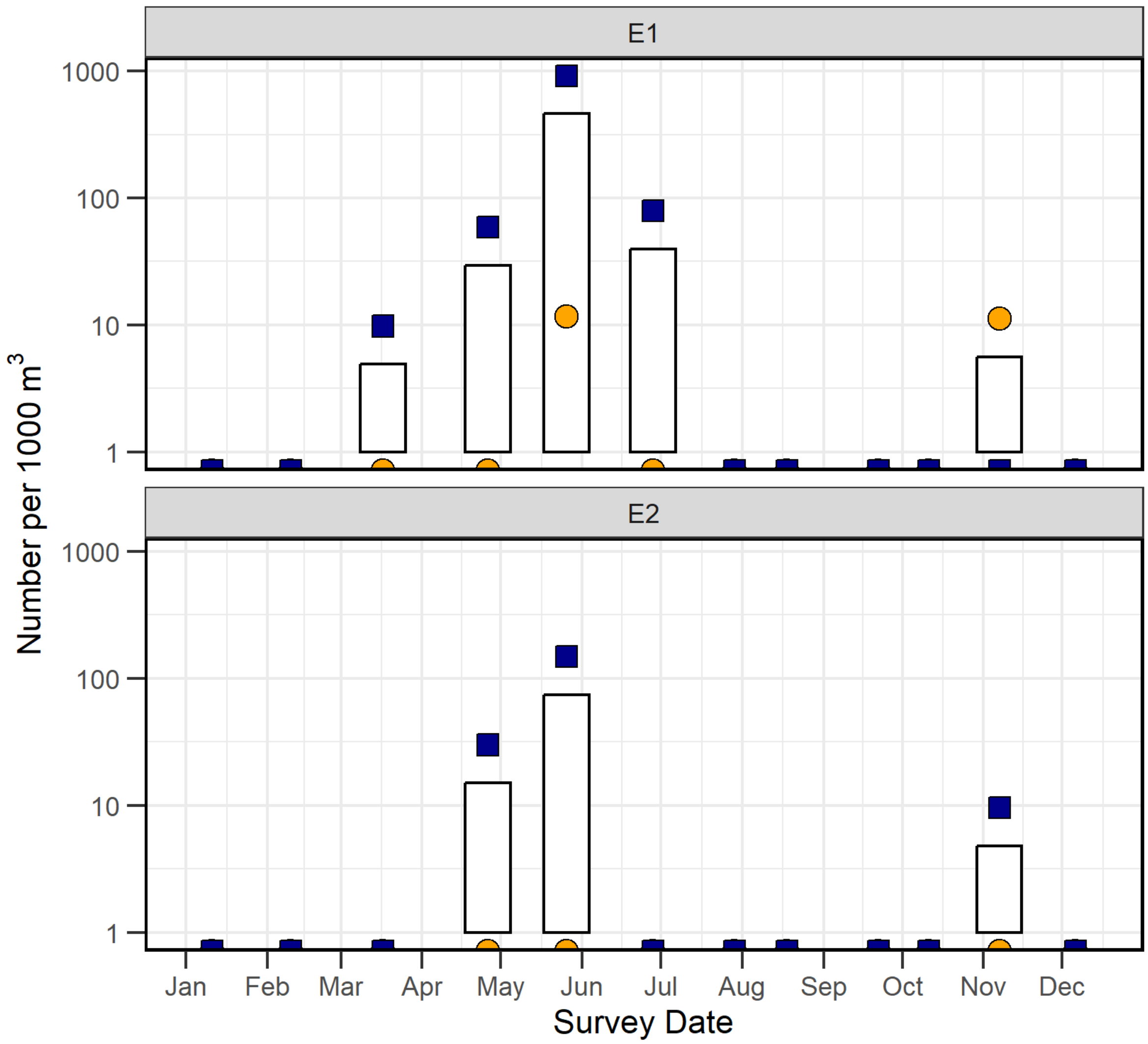


Figure 4-5. Total average concentrations of all crab megalops larvae (height of bar) collected during monthly surveys at entrainment stations E1 and E2 from January 2022–December 2022. Concentrations from daytime (orange circles) and nighttime (blue squares) are also shown. Dates of the surveys correspond to the centers of the bars.

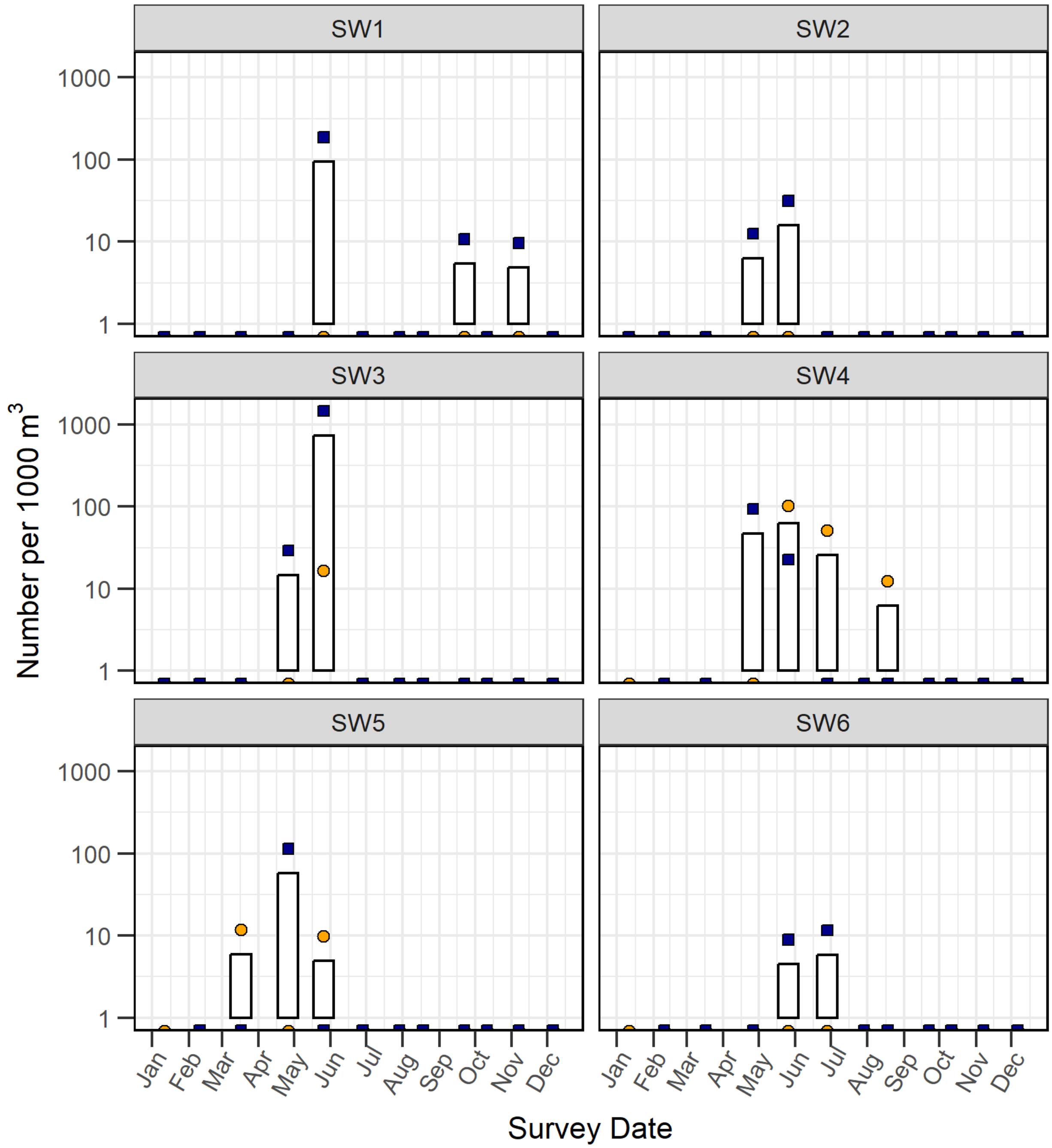


Figure 4-6. Total average concentrations of all crab megalops larvae (height of bar) collected during monthly surveys at entrainment stations E1 and E2 from January 2022–December 2022. Concentrations from daytime (orange circles) and nighttime (blue squares) are also shown. Dates of the surveys correspond to the centers of the bars.

4.2 Taxa Profiles

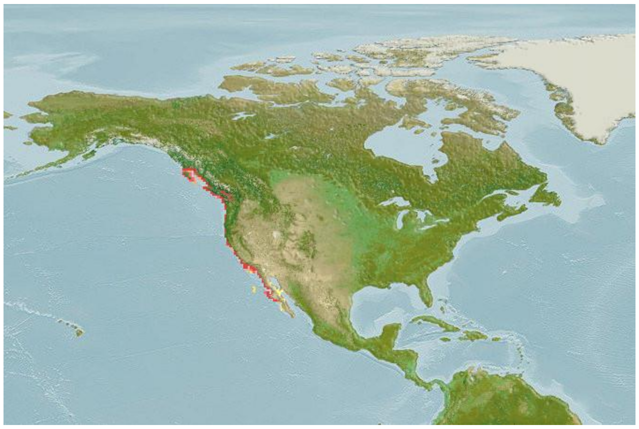
Seven taxa of fishes were selected for evaluation of entrainment effects based on their abundance in the sampling for the study. These seven taxa comprised almost 95% of the total abundance of larval fishes at the two entrainment stations (**Table 4-3**). Four of the seven taxa (Surf Smelt, Pacific Staghorn Sculpin, Arrow Goby, and Pacific Herring) were included in the top ten most abundant taxa in a study of adult fishes in Humboldt Bay (Gleason et al. 2007). Two of the other taxa, Bay Goby and Arrow Goby, along with Pacific Herring and Pacific Staghorn Sculpin were four of the five most abundant taxa of fish larvae collected by Eldridge and Bryan (1972). Although Night Smelt were in slightly higher abundance than Pacific Staghorn Sculpin at the entrainment stations, the Night Smelt were only collected during two surveys at the entrainment stations resulting in only two estimates of *PE* for the ETM calculations. As a result, Pacific Staghorn Sculpin were selected to be included in the ETM analyses since this taxon also represented a different habitat type than that occupied by Night Smelt which is probably similar to Whitebait Smelt in its habitat preferences.

The seven taxa selected for ETM analysis are:

- Arrow Goby *(Clevelandia ios)*
- Bay Goby (*Lepidogobius lepidus*)
- Whitebait Smelt (*Allosmerus elongatus*)
- Pacific Herring (*Clupea pallasi*)
- Pacific Tomcod *(Microgadus proximus)*
- Surf Smelt *(Hypomesus pretiosus)*
- Pacific Staghorn Sculpin *(Leptocottus armatus)*

Information is also provided on Longfin Smelt (LFS), a species listed in 2009 by the State of California as threatened under the California Endangered Species Act. The natural history and life history parameters of these taxa are described in the following sections as background for interpreting the results of the entrainment modeling which relies on life history information for each taxon. Other fishes and invertebrates with larvae that could be subject to entrainment at the two intakes are discussed, but model results using estimated larval durations are only presented in Section 5.0 for these seven taxa.

4.2.1 **Arrow Goby** *Clevelandia ios*



Native distribution of the Arrow Goby. Range of colors indicate degree of suitability of habitat which can be interpreted as probabilities of occurrence. Red indicates highest probability of occurrence, yellow indicates lowest. *(Kaschner et. al. 2019)*

(Greg Goldsmith, USFW)

Range: Vancouver Island, British Columbia to southern Baja California

Life History: Size up to 2.24 in. (57 mm); age at maturity from 1– 2 yr; Life span ≥3 yr; spawns year-round in bays and estuaries; demersal adhesive eggs with fecundity from 300–1,100 eggs per spawning event with multiple spawning (2–5 per yr).

Habitat: Mud and sand substrates of bays and estuaries; commensally in burrows of shrimps and other invertebrates.

Fishery: None

The family Gobiidae is composed of small, demersal fishes that are found worldwide in shallow tropical and subtropical environments (Moser 1996). The family contains around 1,875 species in 212 genera (Nelson 1994). Twenty-one goby species from 16 genera occur from the northern California border to south of Baja California (Moser 1996). Arrow Goby is one of several species of gobies that are abundant in mudflat habitat in coastal embayments and estuaries in California. The Arrow Goby was the ninth most abundant species collected during a study in 2000–2001 on the fishes of Humboldt Bay (Gleason et al. 2007). It was the fourth most abundant taxon of larval fish collected during a study of ichthyoplankton during 1969 in Humboldt Bay by Eldridge and Bryan (1972).

Goby larvae look distinctly different from other families of larval fishes in California. The larvae, however, are similar to each other at all stages of their development, making them difficult to identify to species. In very early developmental stages, the Arrow Goby shares morphologic and meristic similarities with other species including the Bay Goby (*Lepidogobius lepidus*). Moser (1996) indicates that Arrow Goby, Cheekspot Goby (*Ilypnus gilberti*), and the Shadow Goby (*Quietula y-cauda*) cannot be differentiated during any larval stage. Brothers (1975) reported difficulty in separating developed Arrow and Cheekspot goby larvae that were less than 2.6 in. (65 mm) long. However, of these three species, only Arrow Goby occurs in Humboldt Bay.

Members of the family Gobiidae share many life history characteristics. Adult gobies are oviparous and produce demersal eggs that are elliptical in shape, typically adhesive, and attached to a nest substratum at one end (Wang 1986, Matarese et al. 1989, Moser 1996). Most species, including the Arrow Goby, inhabit burrows in mud flats and other shallow regions of bays and estuaries (Miller and Lea 1972). The fecundity of the Arrow Goby ranges from 750 to 1,000 eggs (Wang 1986), and spawning may occur multiple times per year (Brothers 1975). No data on the seasonality of the larvae was reported in the only available study on fish larvae from Humboldt Bay (Eldridge and Bryan 1972). Goby larvae hatch at a length of 0.08–0.12 in. (2–3 mm) (Moser 1996) and enter the plankton following hatching and remain in this pelagic phase until they transform and become benthic-oriented juveniles.

The duration of the planktonic phase varies greatly within the family and is not well described for most species. The period of entrainment risk used in the ETM model was estimated using a larval Arrow Goby growth rate of 0.008 in. (0.198 mm) per day calculated from data in Brothers (1975).

Sampling Results

The Arrow Goby was the most abundant taxa of fish larvae collected during the sampling from January–December 2022 (**Table 4-2** and **Table 4-3**). A total of approximately 13.4 million Arrow Goby were estimated to be entrained during the year, comprising over 75% of the total estimated entrainment of larval fishes. They were the most abundant taxa at all of the stations except for stations SW4 and SW5 (**Table 4-2**). They were also in much higher abundance at Station E1 than E2, which resulted in correspondingly higher entrainment at Station E1 for this taxon (**Table 4-3** and **Figure 4-7**). Arrow Goby larvae were collected from all the surveys from at least one of the entrainment stations except for the surveys in January and February. The peak abundance for this taxon occurred during the June survey at both entrainment stations. The average concentration for Station E1 during the late June survey was 10,673 per 1,000 m^3 (sample 4, Survey 6 in Appendix A). As suggested above, this could have been due to a large number of Arrow Goby produced in Arcata Bay passing through the sampling area on an ebb tide, but the data in Appendix B show a flood tide during the sample collection, and it is likely that the high concentration for that sample is a reflection of the extremely patchy nature of plankton abundance. The highly variable nature of ichthyoplankton abundance is reflected in the concentrations of Arrow Goby larvae in the two samples collected during Survey 6. The concentration was 21,346/1000 m^3 in the day sample and zero in the night sample.

Arrow Goby were collected in highest abundance at the source water stations in Arcata Bay (SW1, SW2, and SW6) which are dominated by mud flat habitat, the preferred habitat for this species (**Figure 4-8**). They were collected in only three surveys at source water Station SW4 which is located just upcoast from the Harbor Entrance along the North Sand Spit, which most likely has sandier habitat than the areas in Arcata Bay.

The length frequency of the 204 Arrow Goby larvae measured from the study that were less than 0.98 in. (24.89 mm) shows that the largest numbers of larvae were very close in notochord length (NL) to the estimated hatch length (**Figure 4-9**). The average NL was 0.15 in. (3.89 mm) and the smallest and longest larvae measured were 0.09 and 0.84 in. (2.35 and 21.35 mm) NL, respectively. These measurements are used to calculate bootstrap estimates of the minimum and maximum lengths used in calculating the period of larval exposure to entrainment for the ETM.

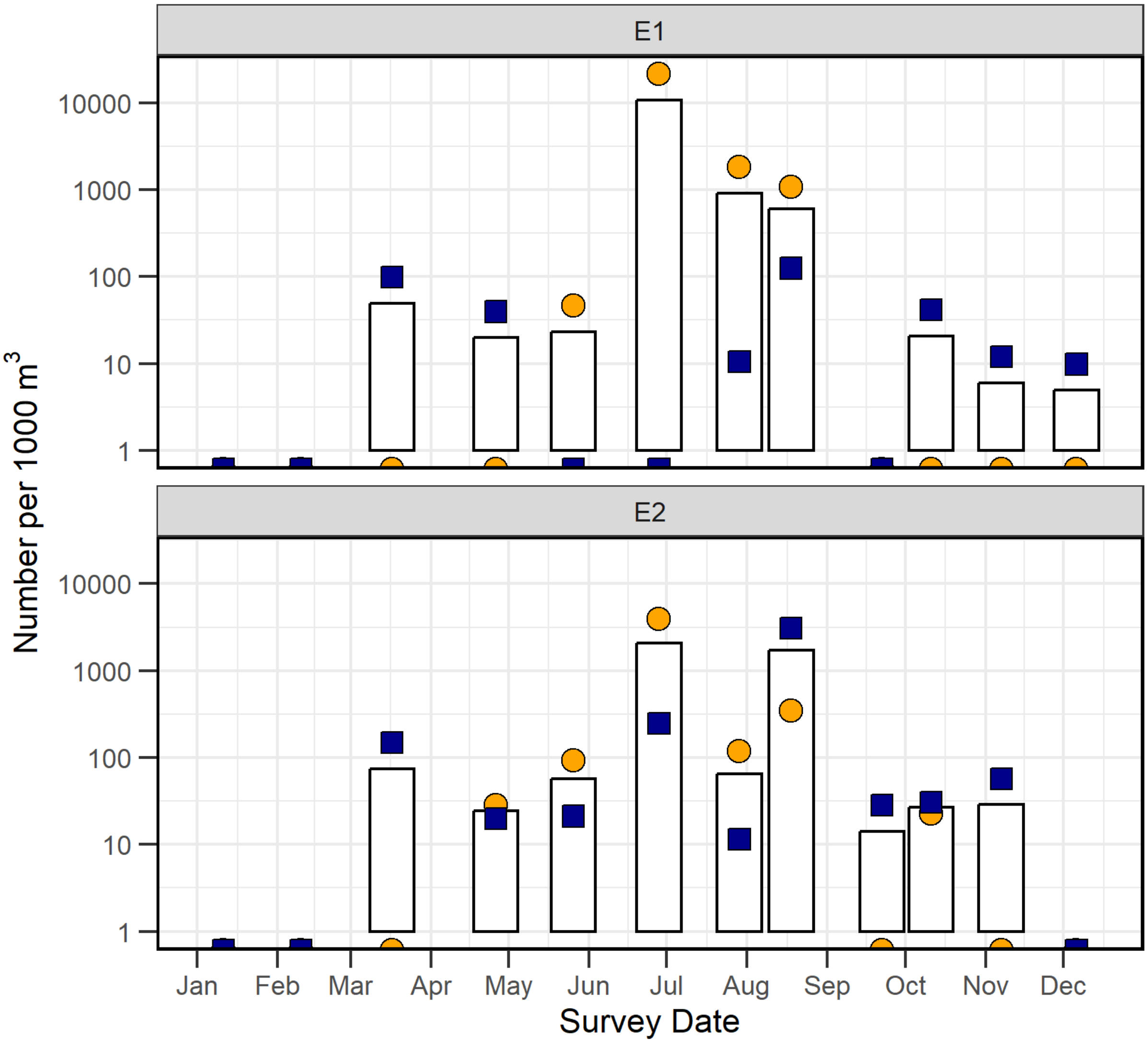


Figure 4-7. Total average concentrations of Arrow Goby larvae (height of bar) collected during monthly surveys at entrainment stations E1 and E2 from January 2022–December 2022. Concentrations from daytime (orange circles) and nighttime (blue squares) are also shown. Dates of the surveys correspond to the centers of the bars. Note use of log-scale due to magnitude of some of the abundances.

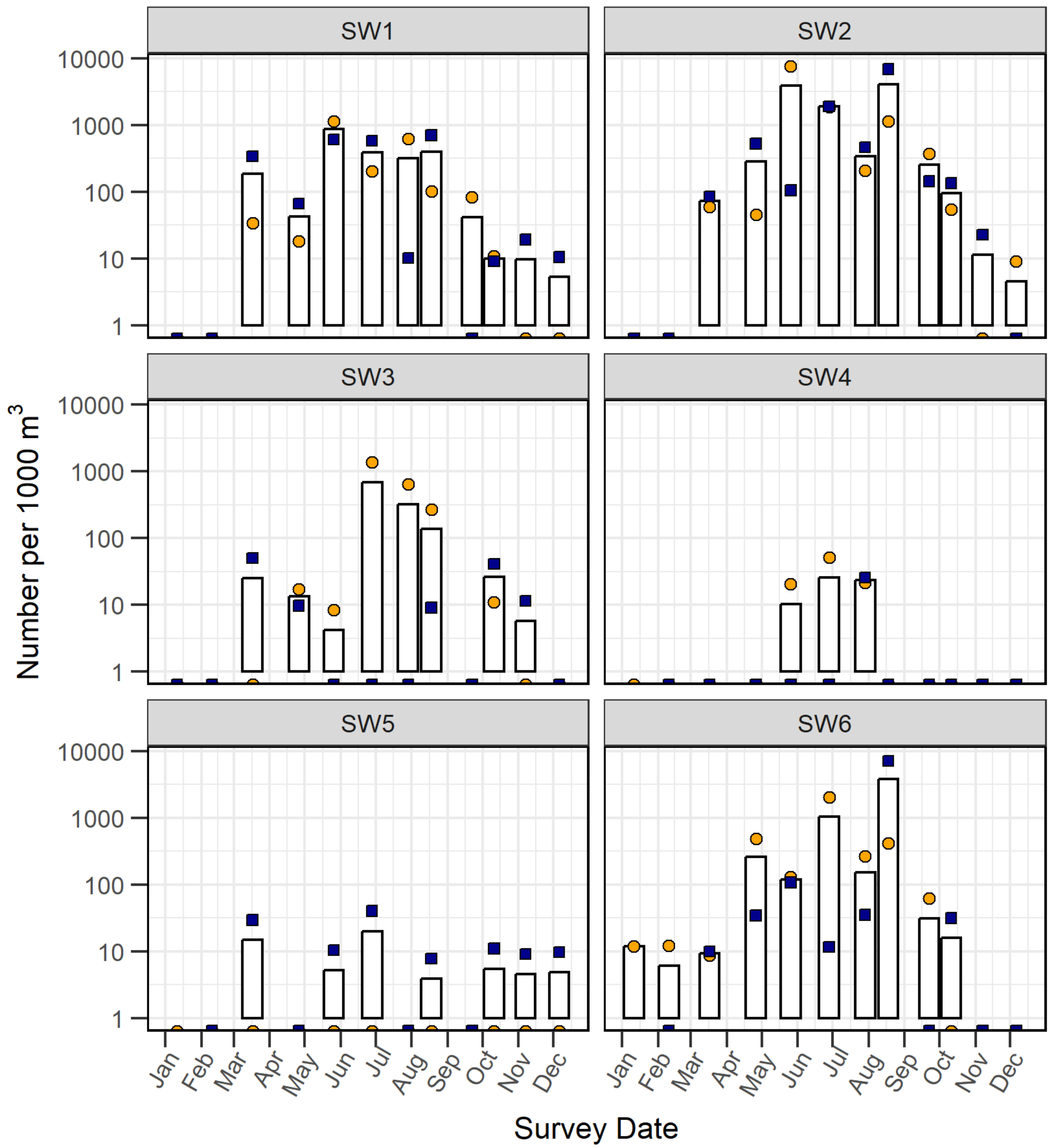


Figure 4-8. Total average concentrations of Arrow Goby larvae (height of bar) collected during monthly surveys at source water stations SW1–SW6 from January 2022–December 2022. Concentrations from daytime (orange circles) and nighttime (blue squares) are also shown. Dates of the surveys correspond to the centers of the bars. Note use of log-scale due to magnitude of some of the abundances.

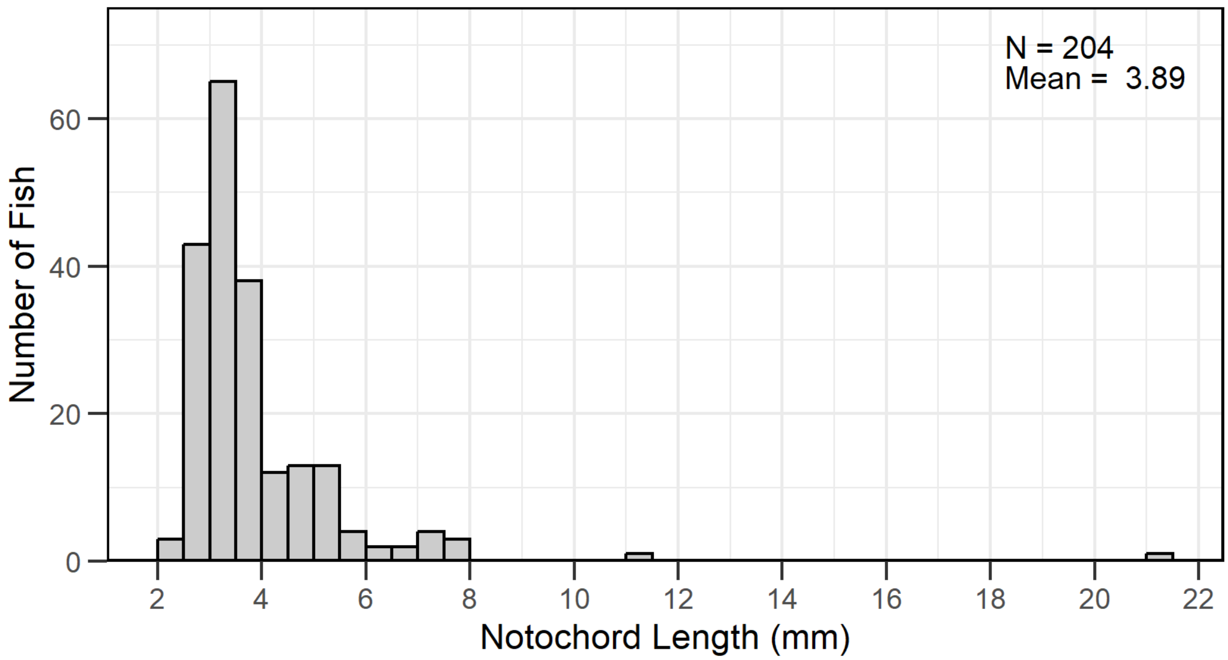
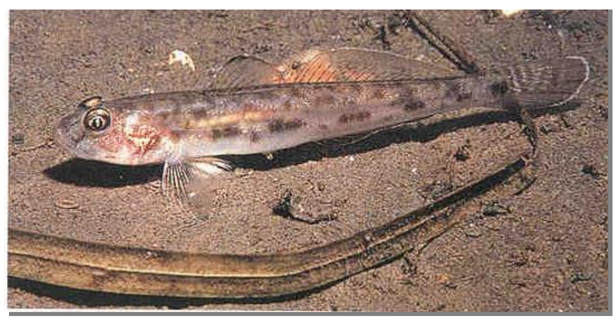


Figure 4-9. Length frequency of Arrow Goby measured from larvae collected from stations E1, E2, SW2, and SW3 from January 2022–December 2022.

4.2.2 **Bay Goby** *Lepidogobius lepidus*

Native distribution of the Bay Goby. Range of colors indicate degree of suitability of habitat which can be interpreted as probabilities of occurrence. Red indicates highest probability of occurrence, yellow indicates lowest. *(Kaschner et. al. 2019)*



Range: From Cedros Island, Baja California to Vancouver Island, British Columbia.

Life History: Size: to 4.3 in. (108 mm); age at maturity: one to two years old; fecundity: no information available; demersal, adhesive eggs; lifespan: seven plus years.

Habitat: Intertidal mudflats, shallow pools.

Fishery: None.

The Bay Goby is a common bottom-dwelling inhabitant of bays and estuaries along the Pacific Coast of North America. It ranges from Vancouver Island, British Columbia to Cedros Island, Baja California (Miller and Lea 1972). Bay Goby larvae were the most abundant taxon of fish larvae collected in 1969 in Humboldt Bay by Eldridge and Bryan (1972). They were not particularly abundant in the sampling of fish populations in Humboldt Bay by Gleason et al. (2007).

The Bay Goby is generally considered a shallow-water marine species but may occur on mud and mud-sand substrata down to depths of 200 ft (61 m) (Miller and Lea 1972). They are common on intertidal mudflats in invertebrate burrows and shallow pools when the tide is out (Grossman 1979). Like many marine-estuarine species they are tolerant of variations in salinity and temperature.

Reports differ on the longevity of Bay Goby. They are reported to live for about seven years, which is considered unusually long for a small fish species (Grossman 1979). Life span estimates of two to three years have been derived from length frequency data.

Based on differences in ova size/development from fish collected during April and May off Hunters Point Power Plant in San Francisco Bay and in Moss Landing Harbor, Bay Gobies have been characterized as asynchronous multiple spawners (Wang 1986). Most Bay Goby do not become reproductively mature until their second year, but a few mature during their first year (Wang 1986). Because Bay Goby use invertebrate burrows for predator avoidance and protection against dehydration during low tides, it is thought that this species, like many other goby species, may also use burrows for spawning (Grossman 1979, Wang 1986). No fecundity information is available for the species. Eggs are demersal, spherical/elliptical in shape, and have an adhesive anchoring point (Wang 1986).

Bay Goby larvae occur with the larvae of Arrow Goby, Cheekspot Goby, and Yellowfin Goby *Acanthogobius flavimanus* in San Francisco Bay (Wang 1986, Grossman 1979). In a study by Wang (1986), the greatest abundance of Bay Goby larvae was collected in San Francisco Bay from November through May, with peak numbers occurring in April and May. No data on the seasonality of Bay Goby were reported in the only available study on fish larvae from Humboldt Bay (Eldridge and Bryan 1972). Newly hatched larvae are small (0.12 in. [3 mm] or less) and nearly transparent (Wang 1986) and may have a planktonic life phase of 3 to 4 months (Grossman 1979, Wang 1986). Completion of the transformation stage (beginning of the juvenile phase) for Bay Goby larvae occurs around 1.1. in. (29 mm) (Moser 1996). There are no reported larval growth rates for Bay Goby, but a growth rate of 0.01 in. (0.22 mm) per day was calculated by using the size difference between hatch length (0.1 in. [2.85 mm]) and transformation length (1.0 in. [26.5 mm]) (Moser 1996, Wang 1986) divided by an average planktonic duration of three to four months (105 days) from Grossman (1979).

Juveniles (and adults) occupy the burrows of blue mud shrimp *Upogebia pugettensis*, geoduck clams *Panope generosa* and other burrowing animals for shelter and predator avoidance (Grossman 1979). Juvenile and adult Bay Goby growth was described by Grossman (1979). Growth is initially rapid, with 50% of their total growth (length) occurring within the first two years. Following this period of rapid growth, increases in length slow to about 0.24 in. (6 mm) per year.

Bay Goby are thought to be an important food item in the diet of a variety of vertebrate and invertebrate predators. Their abundance, small size, and extended planktonic duration make Bay

Goby larvae an important link in the food web of bay/estuarine systems (Wang 1986). Their abundance as juveniles and adults suggests that they remain an important forage species throughout all life stages. Pacific Staghorn Sculpin and California Halibut are among the many fish predators of other adult gobies (Brothers 1975). It is assumed that these fishes and sharks and rays that inhabit estuarine systems also prey on Bay Goby (Grossman 1979).

Sampling Results

Bay Goby was the second most abundant taxa of fish larvae collected during the sampling from January-December 2022 (**Table 4-2** and **Table 4-3**). A total of approximately 1.4 million Bay Goby were estimated to be entrained during the year, comprising about 8% of the total estimated entrainment of larval fishes. Bay Goby were the second most abundant taxa at all of the stations except for stations SW4 and SW5 (**Table 4-2**). At Station SW4, they were the third most abundant and at SW5 they ranked as the most abundant species collected. They were collected during all surveys from at least one of the entrainment stations except for the surveys done in February and March (**Figure 4-10**). The peak abundance for this taxon occurred during the August survey at entrainment Station E1 and during the September survey at entrainment Station E2. Bay Goby were collected in highest abundance at source water stations SW3 and SW5 (**Table 4-2** and **Figure 4-11**). Station SW5 is located near the entrance to the South Bay, which also has large areas mud flat habitat but also receives ocean influence since it is close to the Entrance Bay.

The length frequency of the 175 Bay Goby larvae measured from the study shows that a large number of the larvae were less than the estimated hatch NL of 0.1 in. (2.85 mm) (**Figure 4-12**). The average NL was 0.12 in. (3.06 mm) and the smallest and longest larvae measured were 0.08 and 0.18 in. (2.06 and 4.54 mm) NL, respectively. These measurements are used to calculate bootstrap estimates of the minimum and maximum lengths used in calculating the period of larval exposure to entrainment for the ETM.

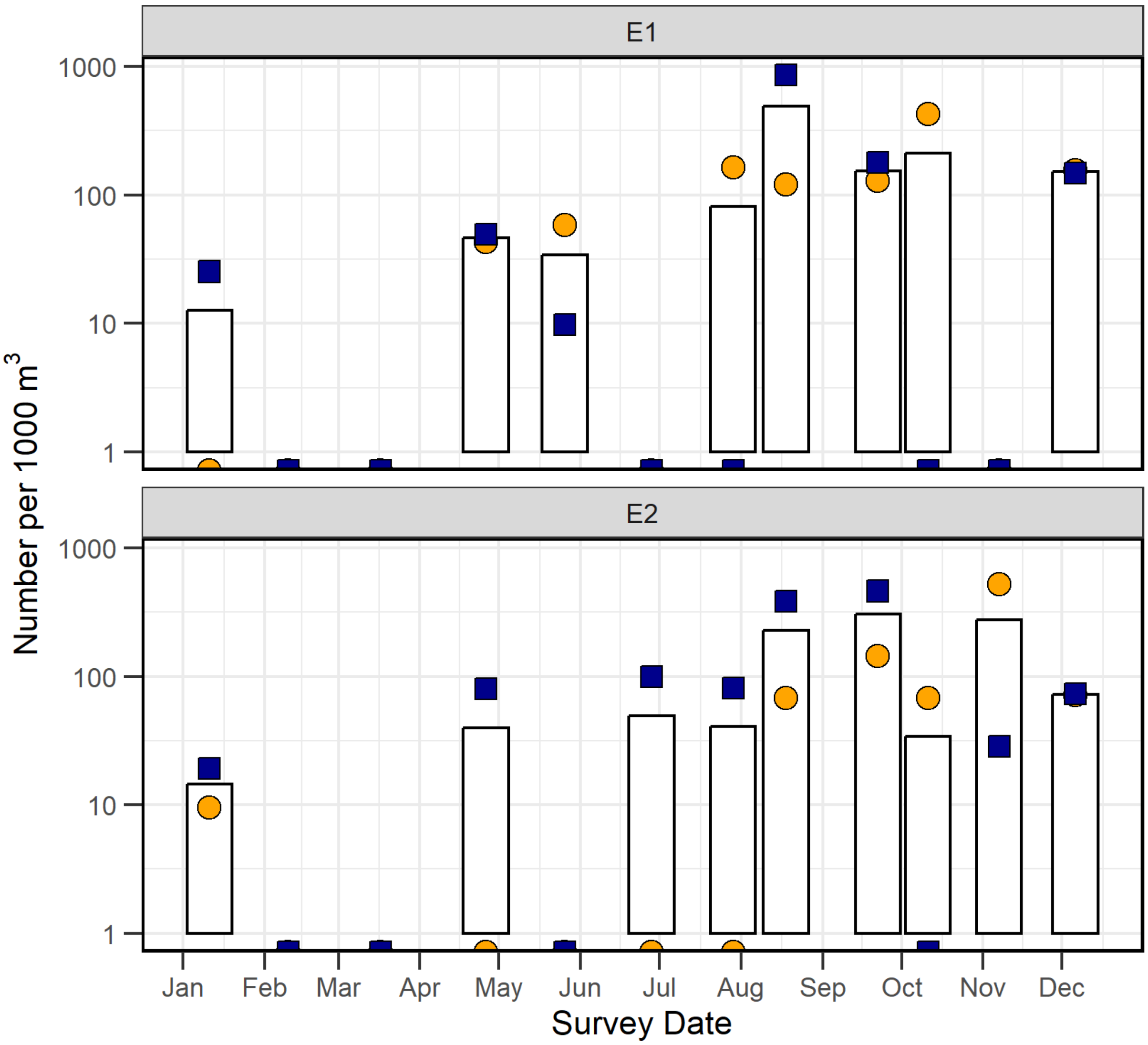


Figure 4-10. Total average concentrations of Bay Goby larvae (height of bar) collected during monthly surveys at entrainment stations E1 and E2 from January 2022–December 2022. Concentrations from daytime (orange circles) and nighttime (blue squares) are also shown. Dates of the surveys correspond to the centers of the bars. Note use of log-scale due to magnitude of some of the abundances.

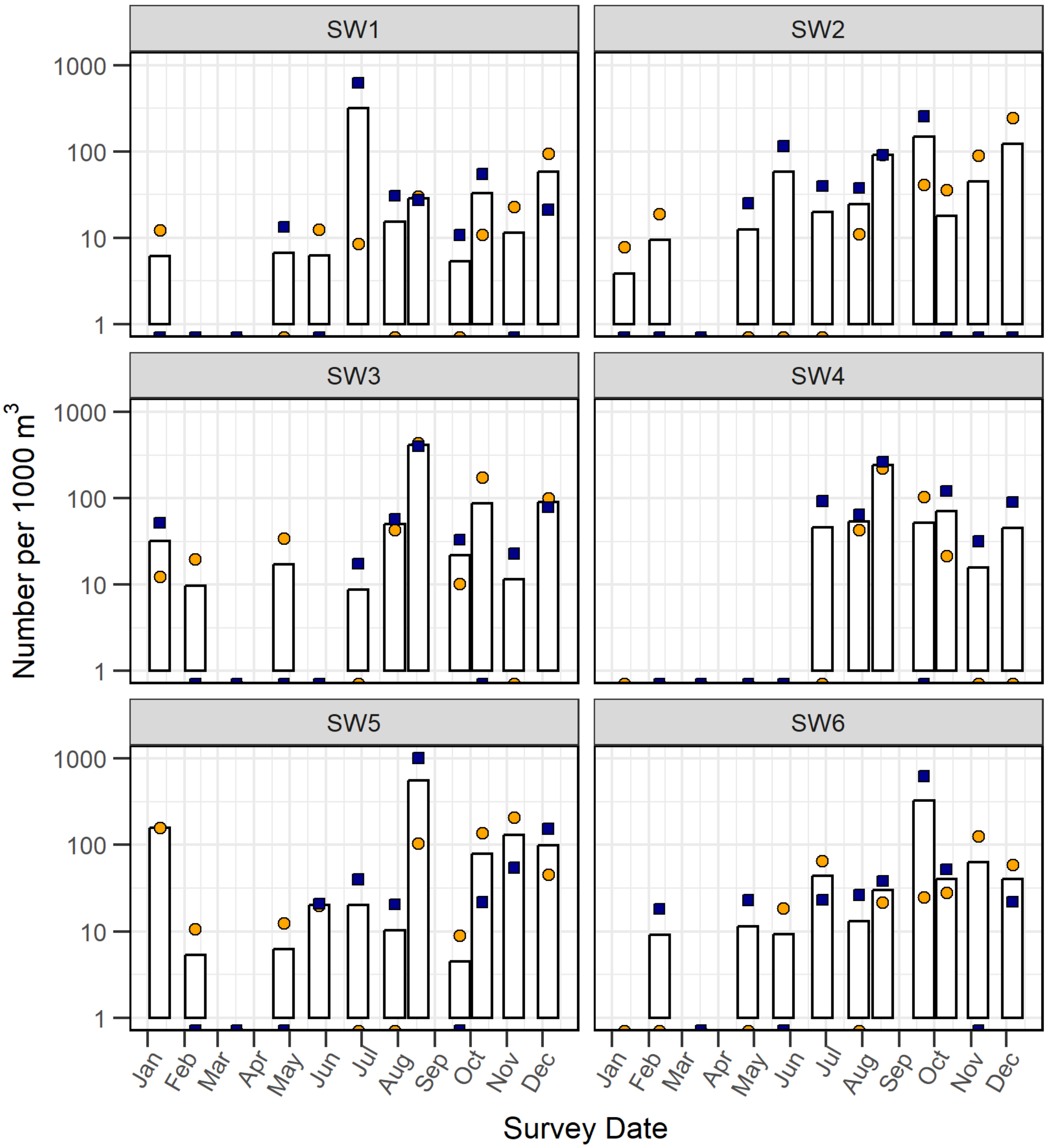


Figure 4-11. Total average concentrations of Bay Goby larvae (height of bar) collected during monthly surveys at source water stations SW1–SW6 from January 2022–December 2022. Concentrations from daytime (orange circles) and nighttime (blue squares) are also shown. Dates of the surveys correspond to the centers of the bars. Note use of log-scale due to magnitude of some of the abundances.

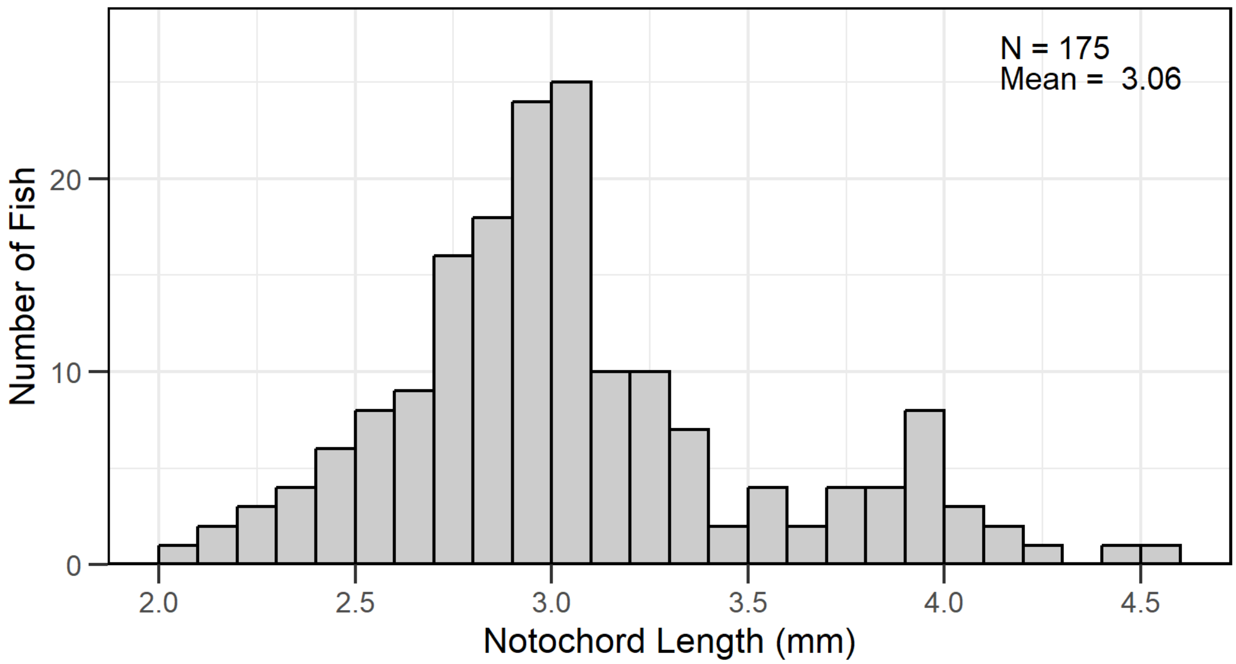


Figure 4-12. Length frequency of Bay Goby measured from larvae collected from stations E1, E2, SW2, and SW3 from January 2022–December 2022.

4.2.3 **Whitebait Smelt** *Allosmerus elongatus*

Native distribution of Whitebait Smelt. Range of colors indicate degree of suitability of habitat which can be interpreted as probabilities of occurrence. Red indicates highest probability of occurrence, yellow indicates lowest. *(Kaschner et. al. 2019)*

(Photo Credit: Guidesly, 2023)

Range: Vancouver Island, British Columbia to San Francisco, California.

Life History: Size up to 9 in. (228.6 mm) Life span: 1-3 years. Ocean spawner; spawns in subtidal banks. Osmerid eggs in general are 0.031-0.043 in. (0.8-1.1 mm) in diameter, demersal, adhesive, and have a characteristic double chorion and numerous oil globules.

Habitat: A schooling nearshore and pelagic fish, found in bays, estuaries, and along the open coast. Generally found in depths between 3-300 ft (0.9-91.4 m).

Fishery: Primarily, recreationally fished. A past commercial fishery did exist.

The family Osmeridae is composed of small, soft-rayed fishes that can be found in marine, estuarine, and freshwater habitats (Hart 1973). The family contains six genera with 15 species (Fricke et al. 2020). Six of these species are native to California's coastal and estuarine waters (Sweetnam et al. 2001). Of these six, four are commonly found in Humboldt Bay; Surf Smelt, Night Smelt (*Spirinchus starksi*), LFS, and Whitebait Smelt (Miller and Lea 1972). Whitebait Smelt are occasionally found within bays but are more common outside the bay (Fritzsche and Cavanagh 2007). However, in 2000-2001, they were observed in 3 different sites within Humboldt Bay during a fish diversity study but, their abundance ranked at less than <0.1% (Gleason et al. 2007).

There is very little known about Whitebait Smelt. They are considered to be a relatively uncommon species throughout their range with a few locally abundant areas such as San Francisco Bay, San Pablo Bay, and Humboldt Bay (Sweetnam et al. 2001). Whitebait Smelt are a pale, greenish, color, they have a small adipose fin that is directed backwards and a sharply marked silver stripe along their sides (Hart 1973). They can be differentiated from other osmerids by the unique presence of a large canine on the roof of their mouth (Miller and Lea 1972).

Like other smelt, they live in large schools and feed on zooplankton and small fishes (Love, 2011). They tend to favor productive inshore areas and bays; however, they are only rarely caught in estuaries or coastal waters. Spawning is thought to take place in sandy, subtidal areas. Young-of-the-year remain translucent and are considered "post-larval" until they are almost three inches (76.2 mm) in length (Sweetnam et al. 2001). They live one to three years and reach lengths of nine inches (Sweetnam et al. 2001, Love, 2011). The succession of even year classes in San Francisco Bay may suggest a two-year maturity schedule (Sweetnam et al. 2001).

Whitebait Smelt development has not yet been described, however, molecular and morphological analyses show that Whitebait Smelt and Longfin Smelt are sister taxa (McAllister 1963, Wilson and Williams 1991, Ilves and Taylor 2009), therefore for our modeling purposes we used the larval growth rates of Longfin Smelt, which were estimated at 0.01 in. (0.17 mm) per day based on data from studies in San Francisco Bay by Lewis (2020) and an estimated hatch length of 0.22 in. (5.5 mm).

Sampling Results

Whitebait Smelt was the third most abundant taxa of fish larvae collected during the sampling from January–December 2022 (**Table 4-2** and **Table 4-3**). A total of approximately 1.2 million Whitebait Smelt were estimated to be entrained during the year, comprising over 7% of the total estimated entrainment of larval fishes. They were the most abundant species collected at Station SW4 and were often the third most abundant taxa at many of the other stations (**Table 4-2**). They were collected during all the surveys from at least one of the entrainment stations except for the surveys in October, November, and December (**Figure 4-13**). The peak abundance for this taxon occurred during the June survey at both entrainment stations. Whitebait Smelt were collected in highest abundance at the source water station just upcoast from the Harbor Entrance along the North Sand Spit (SW4) (**Figure 4-14**). There is likely sandier habitat at this station than some of the other sites and this matches the preferred habitat and breeding ground for this taxon. Their lowest abundance levels were in Arcata Bay at stations; SW1, SW2, and SW6 which are dominated by mud flat habitat.

The length frequency of the 240 Whitebait Smelt larvae measured from the study had an average NL of 0.25 in. (6.41 mm) and the smallest and longest larvae measured were 0.16 and 0.63 in. (4.13 and 16.02 mm) NL, respectively (**Figure 4-15**). These measurements are used to calculate bootstrap estimates of the minimum and maximum lengths used in calculating the period of larval exposure to entrainment for the ETM.

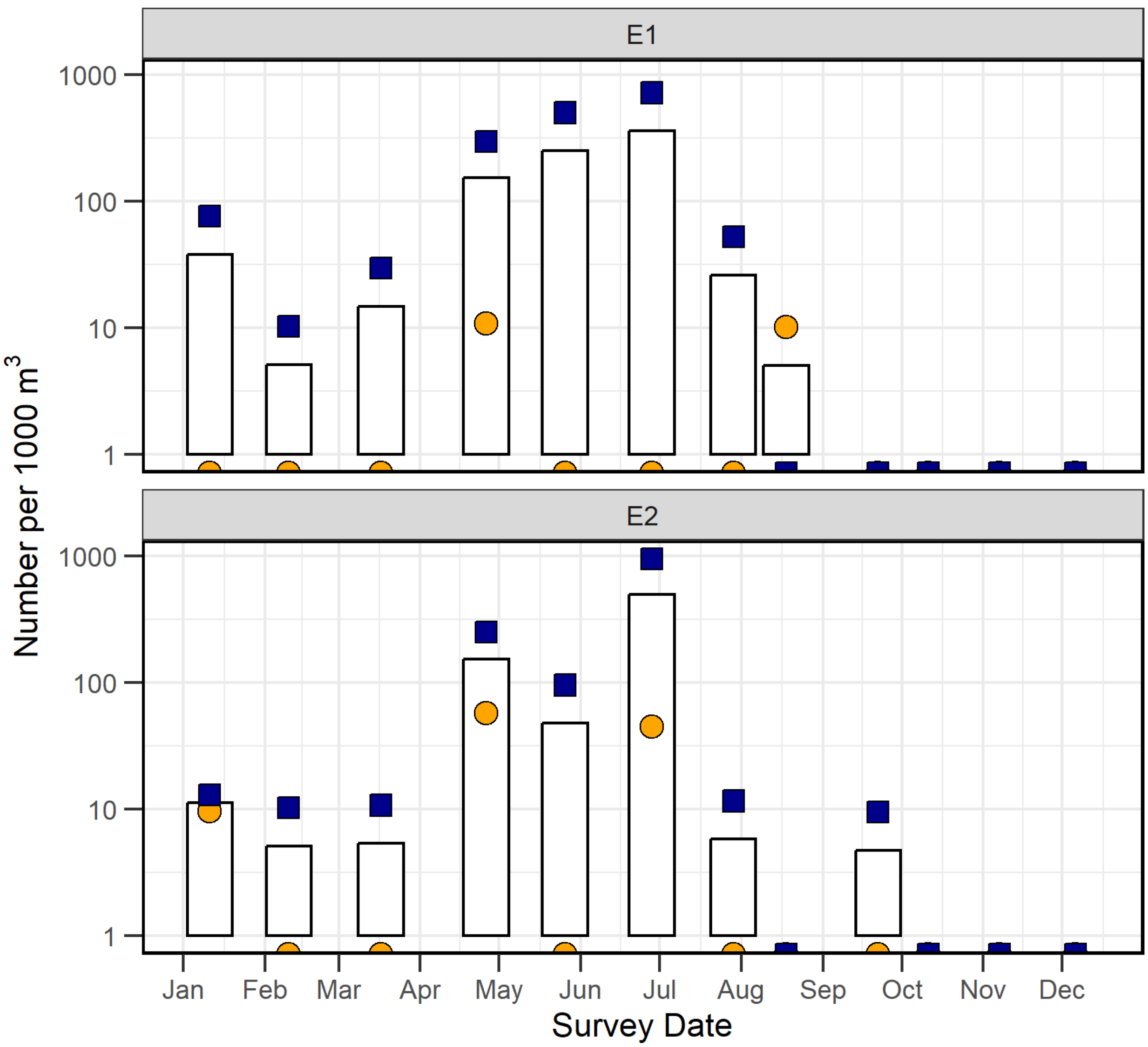


Figure 4-13. Total average concentrations of Whitebait Smelt larvae (height of bar) collected during monthly surveys at entrainment stations E1 and E2 from January 2022–December 2022. Concentrations from daytime (orange circles) and nighttime (blue squares) are also shown. Dates of the surveys correspond to the centers of the bars. Note use of log-scale due to magnitude of some of the abundances.

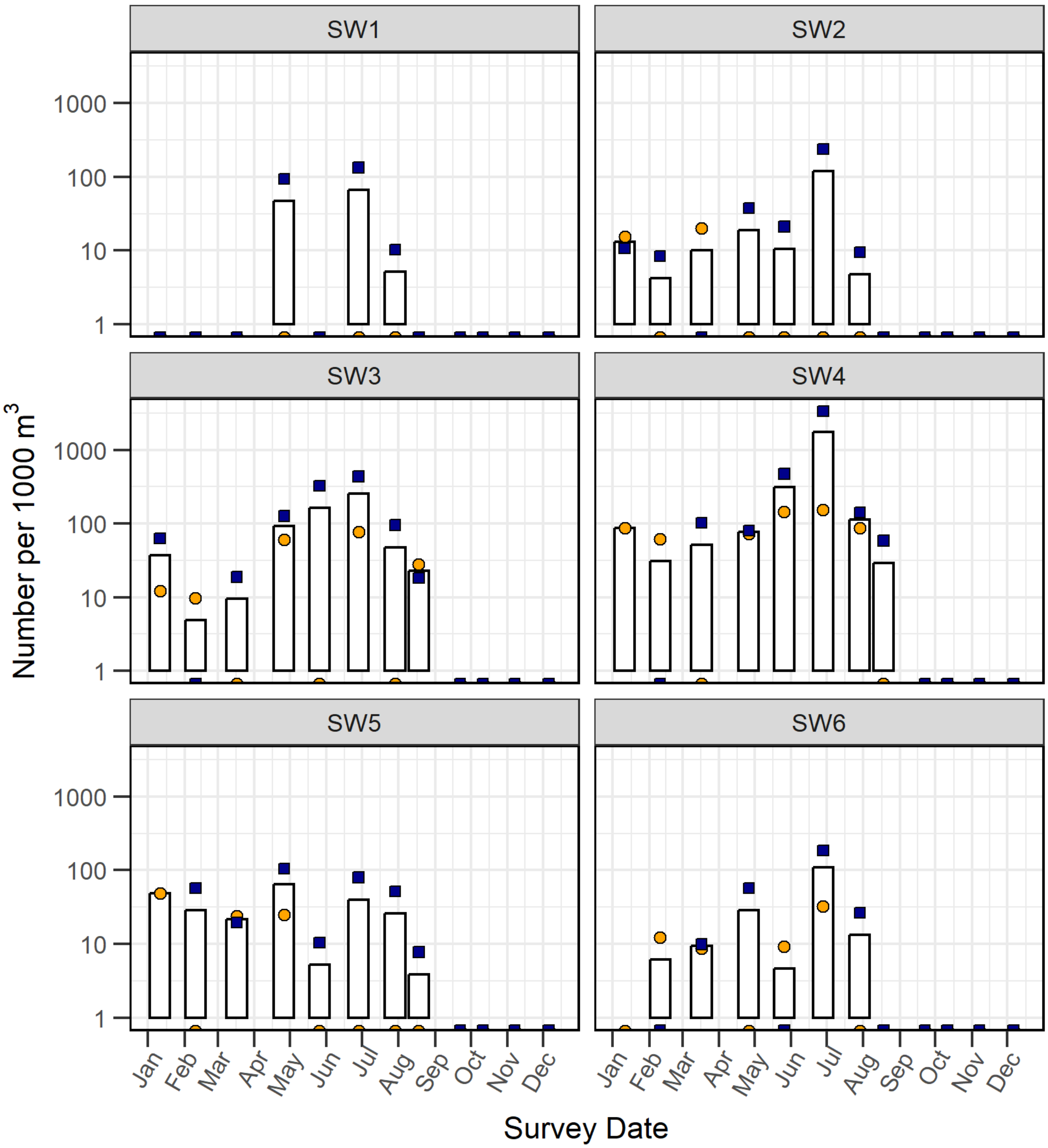


Figure 4-14. Total average concentrations of Whitebait Smelt larvae (height of bar) collected during monthly surveys at source water stations SW1–SW6 from January 2022–December 2022. Concentrations from daytime (orange circles) and nighttime (blue squares) are also shown. Dates of the surveys correspond to the centers of the bars. Note use of log-scale due to magnitude of some of the abundances.

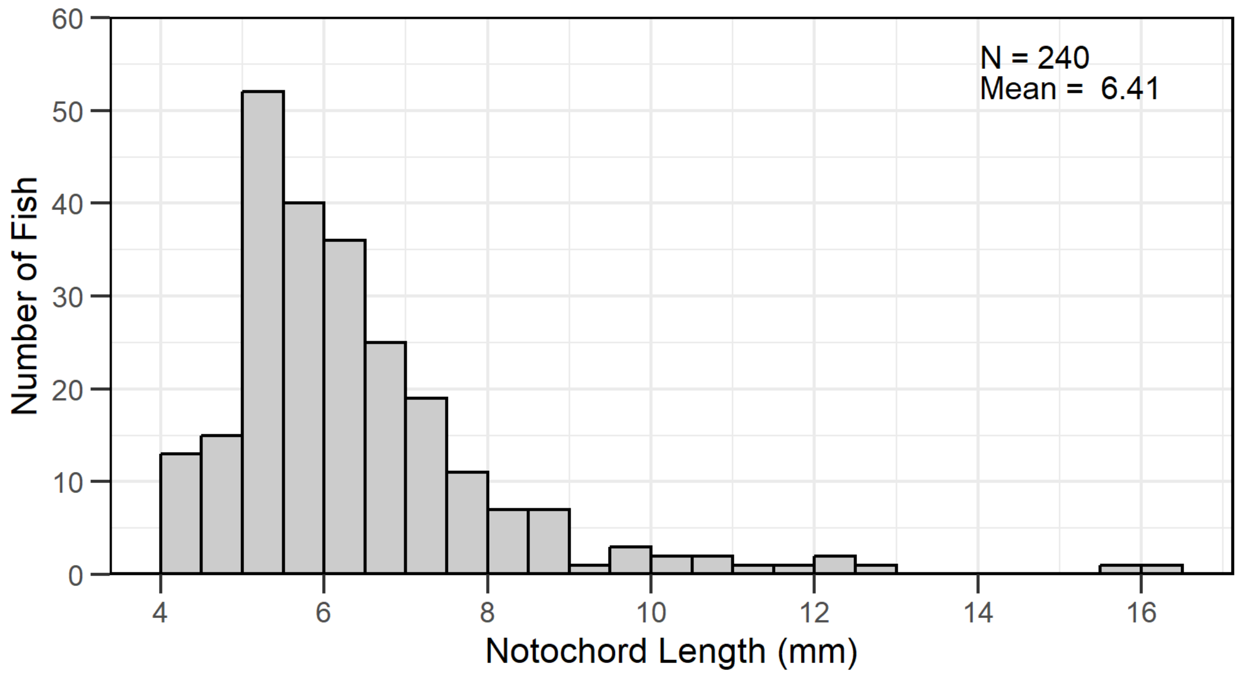
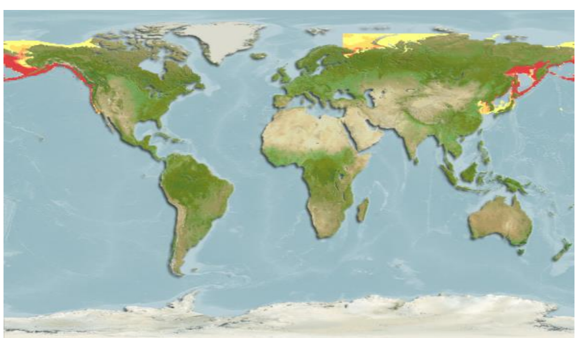


Figure 4-15. Length frequency of Whitebait Smelt measured from larvae collected from stations E1, E2, SW2, and SW3 from January 2022–December 2022.

4.2.4 **Pacific Herring** *Clupea pallasii*



Native distribution of Pacific Herring. Range of colors indicate degree of suitability of habitat which can be interpreted as probabilities of occurrence. Red indicates highest probability of occurrence, yellow indicates lowest. *(Kaschner et. al. 2019)*

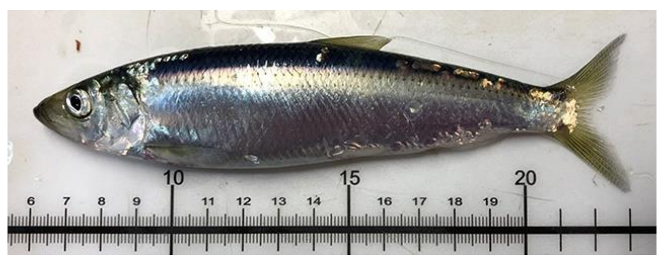


Photo credit: Todd Miller, 2019

Range: From northern Baja California to Toyama Bay, Japan, westward to the Yellow Sea.

Life History: Size: up to 18 in. (46 cm) and 1.2 lb (550 g); Age at maturity: two to three years old; Fecundity: 4,000 to 130,000 eggs; Life span: variable (Alaska to 19 years, California to 11 years)

Habitat: A schooling species found near shore to hundreds of miles offshore; spawns in intertidal and sub-tidal zones in bays and estuaries.

Fishery: Commercial: previously valuable roe fishery; Recreational: small pier and shore angler fishery.

Pacific Herring belong to the order Clupeiformes, which contains some of the world's most numerous and economically important fishes (e.g., herring, sardine, anchovy). The distribution of Pacific Herring extends from Baja California to the north Pacific and westward to Japan and the Yellow Sea (Miller and Lea 1972). In North America, Pacific Herring range from Baja California north to arctic Alaska (PSMFC 1999) and are most abundant off Alaska and British Columbia. In California, most of the populations are found in the San Francisco and Tomales bay areas (Fitch and Lavenberg 1975). Pacific Herring are found from nearshore areas to hundreds of miles off the coast (Love 1996). In Humboldt Bay, Pacific Herring was the tenth most abundant species of adult fish collected in a study from 2000–2001 (Gleason et al. 2007) and was the second most abundant taxon of fish larvae collected during a 1969 study (Eldridge and Bryan 1972).

Pacific Herring are small, streamlined marine fishes, measuring up to 18 in. (457.2 mm) in length and weighing up to 1.2 lb (550 g) (PSMFC 1999). Fitch and Lavenberg (1975) report that in California they may live to 11 years of age and may exceed 12 in. (304.8 mm) in length. More recently, Leet et al. (2001) indicated that herring may live nine to 10 years, but individuals older than seven years are rare. California Pacific Herring reach first maturity at two years, and 100% are mature by three years at a length of 6.5–7 in. (165.1–177.8 mm) (Love 1996, Leet et al. 2001).

In California, spawning is known to occur in San Diego Bay, San Luis River, Morro Bay, Elkhorn Slough, San Francisco Bay, Tomales Bay, Bodega Bay, Russian River, Noyo River, Shelter Cove, Humboldt Bay, and Crescent City Harbor (Leet et al. 2001). California's largest spawning population of Pacific Herring occurs in San Francisco Bay (Leet et al. 2001). Fish begin entering protected coastal bays, estuaries, and shallow nearshore environments as early as two months to three weeks prior to spawning (Eldridge 1977). Decreased salinity may be a cue to initiate spawning (Leet et al. 2001).

Males and females spawn simultaneously over a period of one to seven days (Miller and Schmidtke 1956). The fertilized eggs, broadcast mostly at night, are adhesive and commonly attach to eelgrass, algae, and other intertidal vegetation (Hardwick 1973), rocks, pilings and jetties. Thousands of females repeatedly deposit their eggs, which can result in egg masses from 10 to 15 layers thick (about 2 in. [50.8 mm]) (Love 1996). In large spawning runs, a 30 ft (9 m) wide band of herring eggs may span a distance of 20 miles (32.2 km) along the shoreline (Leet et al. 2001). Females are capable of spawning only once per season. After spawning, most herring return to the ocean (Eldridge 1977). The rate of egg development varies with surrounding water temperature; Pacific Herring eggs commonly hatch within 10 to 14 days at 53.2°–56.3°F (11.8°–13.5°C) (Wang 1986). Egg mortality has been estimated to range from 20% (Hourston and Haegele 1980) to as high as 99% (Hardwick 1973, Leet et al. 2001).

Pacific Herring early development is well described. The length at hatching is approximately 0.2–0.3 in. (5.6–7.5 mm) NL (Moser 1996). Shortly after hatching, and as the eyes become pigmented, the planktonic larvae move toward the surface. They tend to concentrate near the surface and can remain for a long time in the area of the spawning grounds. Some larvae, however, have been found several miles out to sea, drifting with the currents (Fitch and Lavenberg 1975). Stevenson (1962) cites Stevenson (1955), Outram (1958) and Tester (1948) to arrive at an estimate of larval herring mortality at 99.5%, with a range of 98.9 to 99.7%. It takes about 70 days (when they are approximately 1.0 in. [26 mm]) for the larvae to metamorphose into juveniles (Hay 1985). Metamorphosis is complete by 1.4 in. (35 mm) (Stevenson 1962). Juveniles range from 1.4–5.9 in. (35–150 mm), depending on geographical region (Reilly 1988).

The larval growth rate used to calculate the period of entrainment risk was based on data presented by Stevenson (1962) for larvae between 0.3 and 0.8 in. (8 and 20 mm). The average growth rate of 0.02 in. (0.52 mm) per day from his data is consistent with the rate reported by Alderdice and Hourston (1985) of 0.018 to 0.020 in. (0.48 to 0.52 mm) per day for the first 15 days after hatching. Based on these estimates, a larval growth rate of 0.019 in. (0.50 mm) per day was used to calculate the period of entrainment risk.

Humboldt Bay Pacific Herring Spawning and Fishery

Humboldt Bay is California’s second largest bay, and one of the marine habitats utilized by Pacific Herring for spawning. Intertidal mudflats that cover large areas in the Arcata and South bays support eelgrass beds that provide the substrate upon which the vast majority of herring eggs, or “roe,” are deposited (CDFW 2019). Approximately 4,700 acres of eelgrass habitat occur within Humboldt Bay (Merkel and Associates 2017). While spawning occurs yearly in both the Arcata and South bays, a higher biomass is typically observed in Arcata Bay, which was confirmed in a survey to determine areas utilized for spawning during the spawning seasons between 2014 and 2018 (CDFW 2019) (**Figure 4-16**).

A Pacific Herring fishery for herring roe has historically existed in Humboldt Bay. The fishery in the bay is minor compared to the fishery that previously existed in San Francisco Bay where most of the landings occurred (**Figure 4-17**). Spawning assessment surveys were conducted to produce a seasonal biomass quota for the bay’s small-scale commercial industry. A 20-ton quota was established initially, and then a two-year stock assessment commenced. The assessment estimated a spawning stock biomass (SSB) of 372 tons in Humboldt Bay during the 1974–1975 season, and a 232-ton SSB the following season. This led to the determination that the bay could support a fishery with a 50-ton quota, which was then increased to 60 tons in 1982. Landings mostly hovered between 40 and 70 tons for the 15 years that followed this quota increase and were sourced from 4 annual permits. In the late 1990’s and early 2000’s, fishing effort curtailed with the decline in observed spawning biomass, to the point where only one permit was actively in use. By the end of the 2005–2006 season the fishery was discontinued due to the decline in the abundance of Pacific Herring. In 2007 only 7 tons of SSB were observed in the spawning assessment. Although no fishing has occurred in Humboldt Bay since 2006, during the 2017–2018 season four Herring permits for the bay were held by commercial fisherman anyways (CDFW 2019), perhaps in the case that the fishery should again become lucrative, be it through a return in the natural supply or a rise in consumer demand for what would certainly qualify as artisanal seafood.

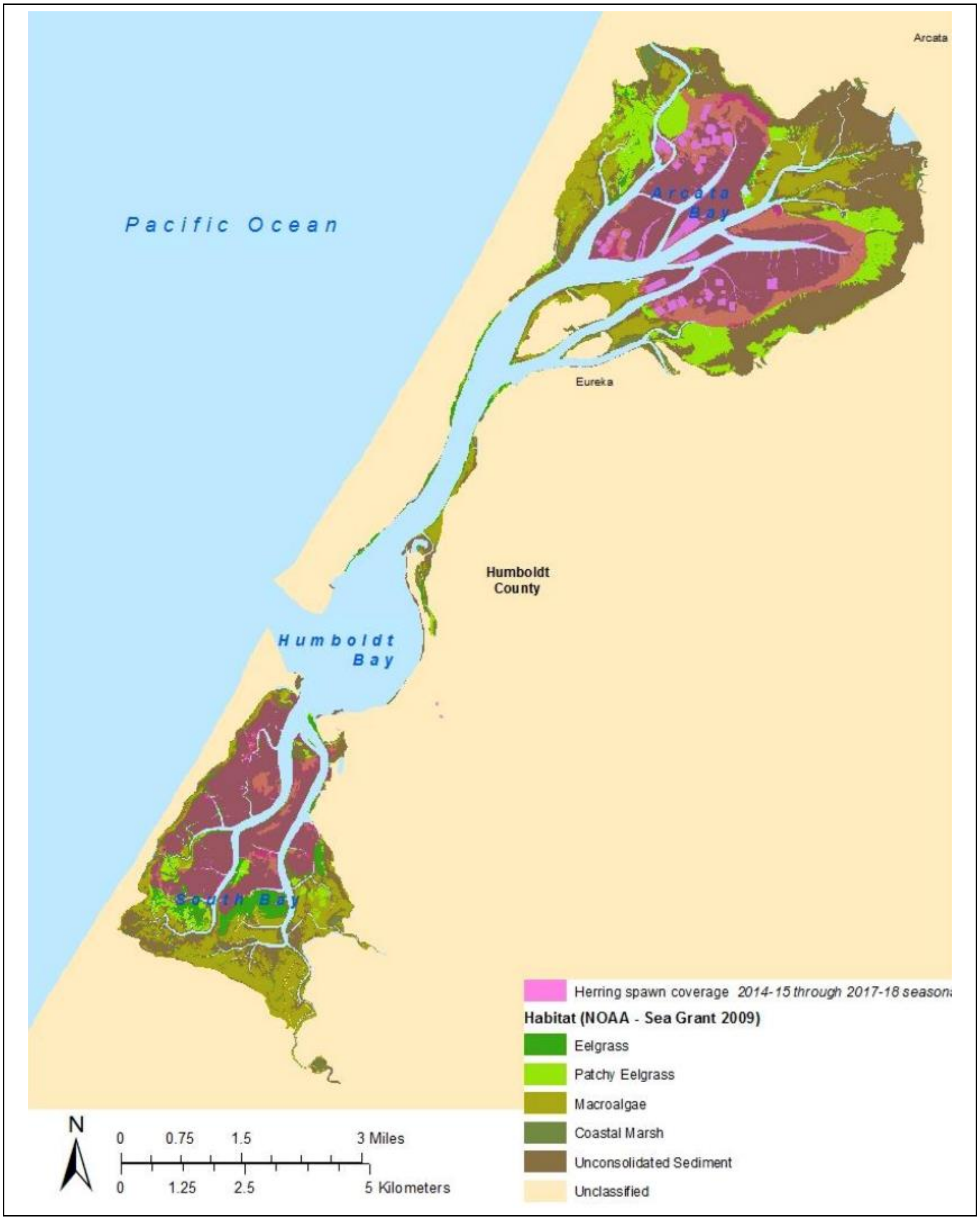


Figure 4-16. Map showing habitat areas in Humboldt Bay with spawning areas for Pacific Herring identified in pink. Figure from CDFW 2019.

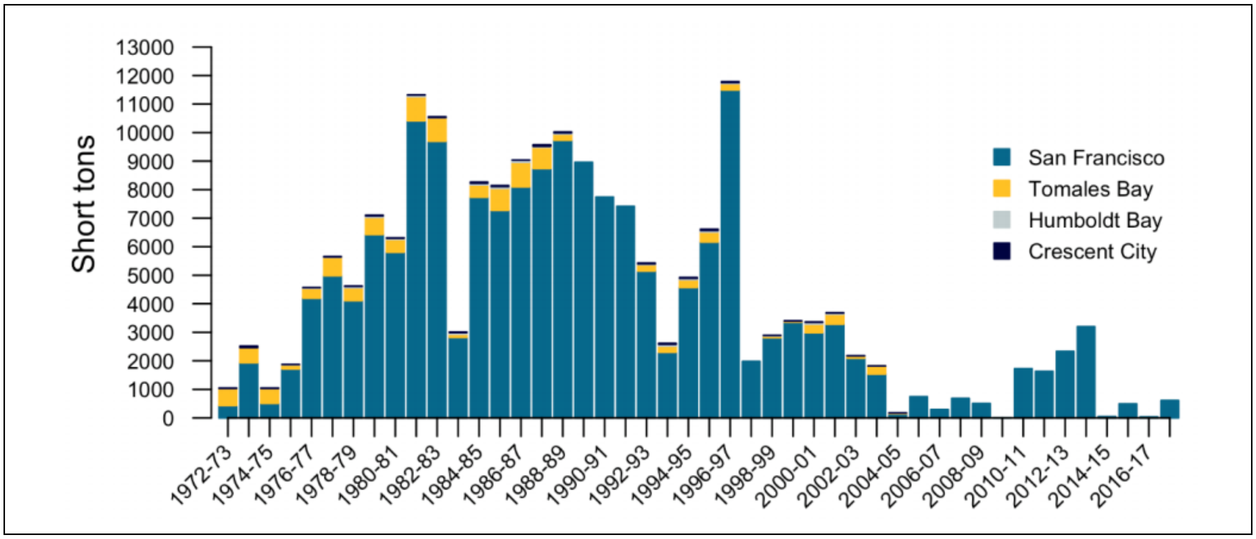


Figure 4-17. Pacific Herring landing in California in short tons (2,000 lb [907 kg]) between 1973 and 2017. The commercial fishery was closed for the 2009–2010 season. The figure does not include landings from the ocean waters fishery in Monterey, California. Figure from CDFW 2019.

Sampling Results

Pacific Herring was the fourth most abundant taxa of fish larvae collected during the sampling from January–December 2022 (**Table 4-2**) and the fifth highest estimated entrainment (**Table 4-3**). A total of 279 thousand Pacific Herring were estimated to be entrained during the year, comprising over 1.6% of the total estimated entrainment of larval fishes. They were the second most abundant taxa at stations SW4 and SW5 (**Table 4-2**). They were collected from at least one of the entrainment stations during the months of February through May (**Figure 4-18**). The peak abundance for this taxon occurred during the March survey at both entrainment stations. Pacific Herring were also in highest abundance at the source water stations during the month of March (**Figure 4-19**). They were collected in highest abundance at the source water stations near the Harbor Entrance and South Bay (SW4 and SW5). They were only present in the March surveys at stations SW4 and SW5.

The length frequency of the 126 Pacific Herring larvae measured from the study had an average NL of 0.33 in. (8.45 mm) and the smallest and longest larvae measured were 0.25 and 0.79 in. (6.24 and 20.15 mm) NL, respectively (**Figure 4-20**). Similar to the other taxa, a large number of the larvae were in the range of the reported length at hatching of approximately 0.22–0.30 in. (5.6–7.5 mm) NL (Moser 1996). These measurements are used to calculate bootstrap estimates of the minimum and maximum lengths used in calculating the period of larval exposure to entrainment for the ETM.

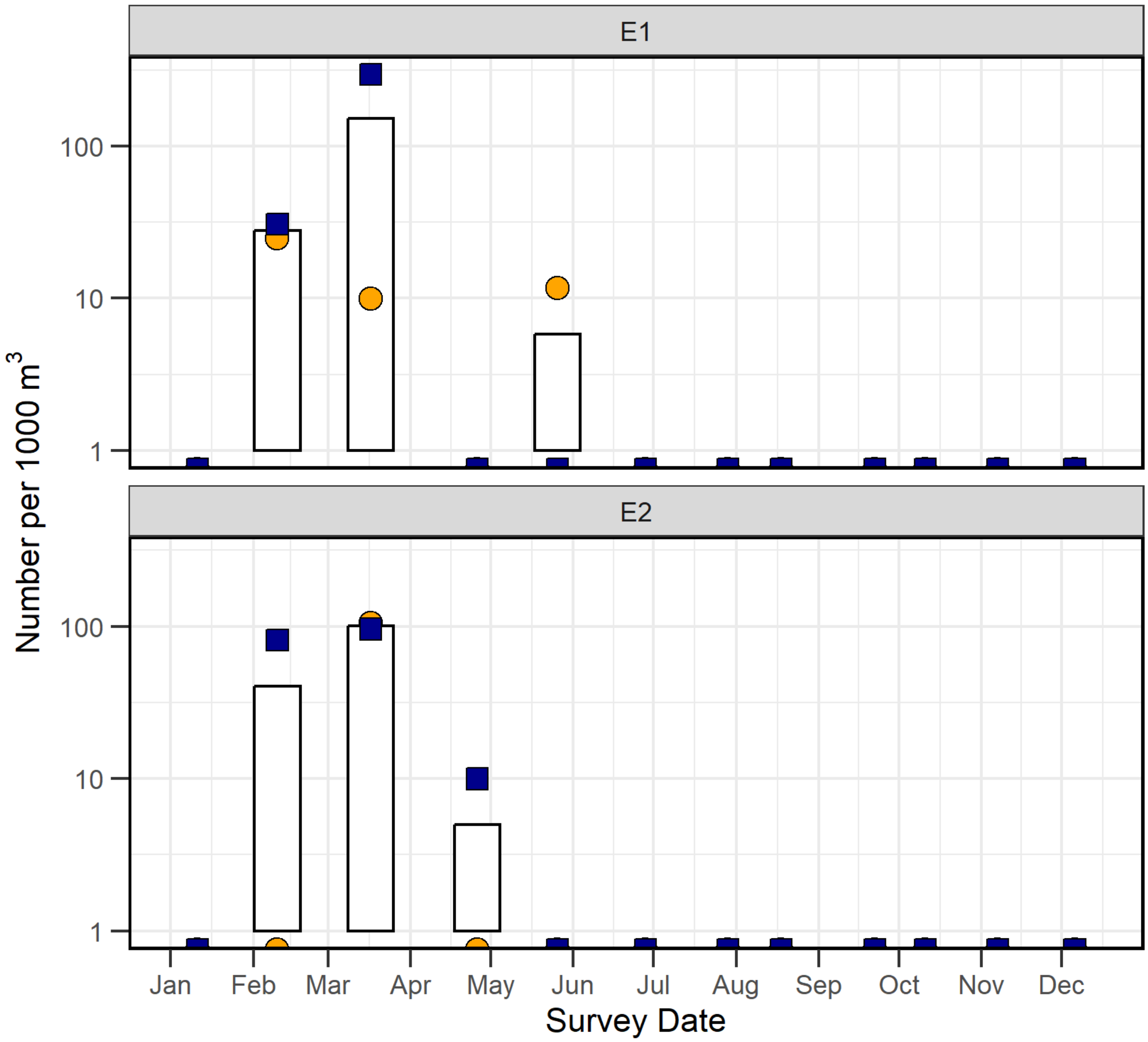


Figure 4-18. Total average concentrations of Pacific Herring larvae (height of bar) collected during monthly surveys at entrainment stations E1 and E2 from January 2022–December 2022. Concentrations from daytime (orange circles) and nighttime (blue squares) are also shown. Dates of the surveys correspond to the centers of the bars. Note use of log-scale due to magnitude of some of the abundances.

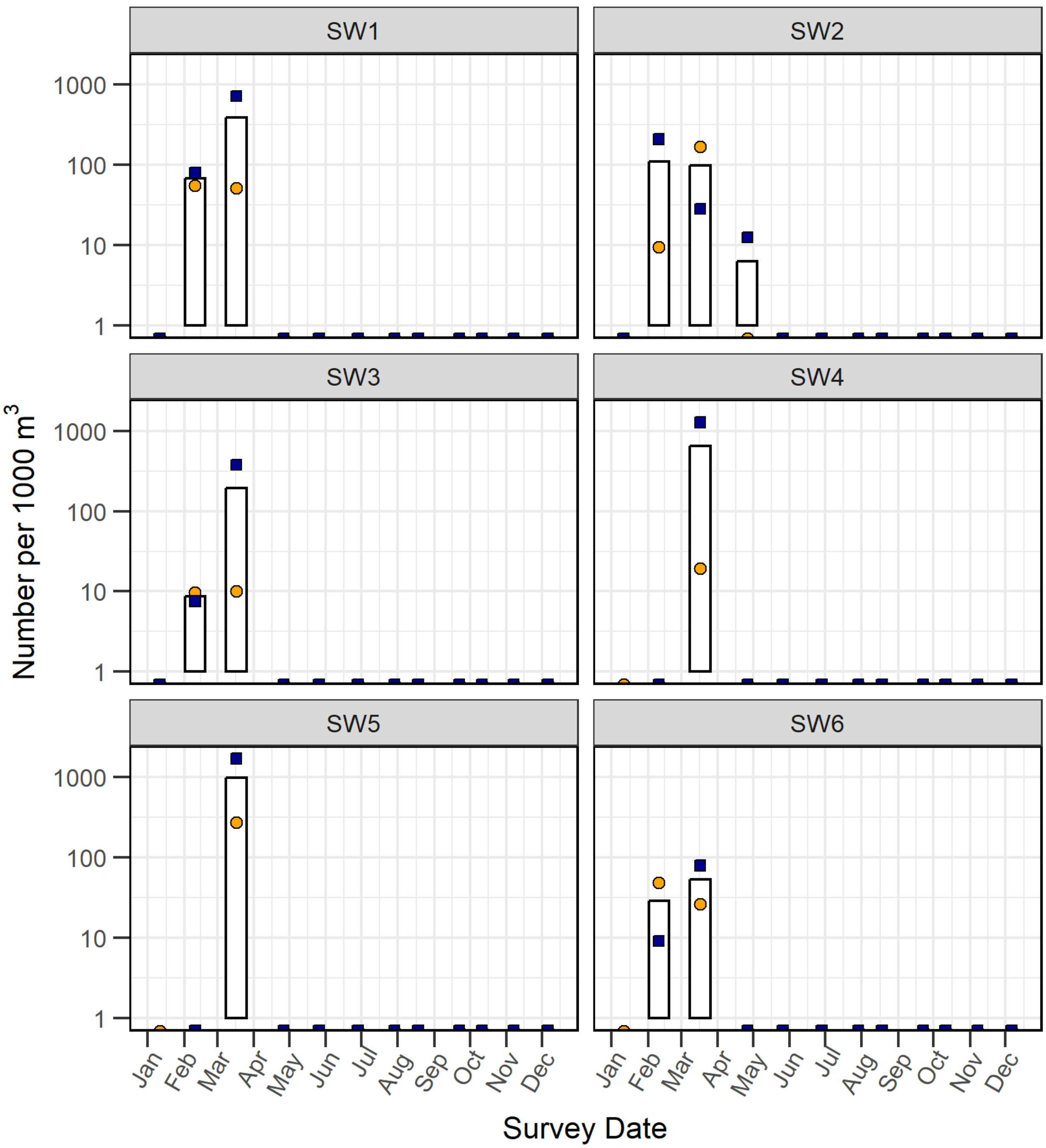


Figure 4-19. Total average concentrations of Pacific Herring larvae (height of bar) collected during monthly surveys at source water stations SW1–SW6 from January 2022–December 2022. Concentrations from daytime (orange circles) and nighttime (blue squares) are also shown. Dates of the surveys correspond to the centers of the bars. Note use of log-scale due to magnitude of some of the abundances.

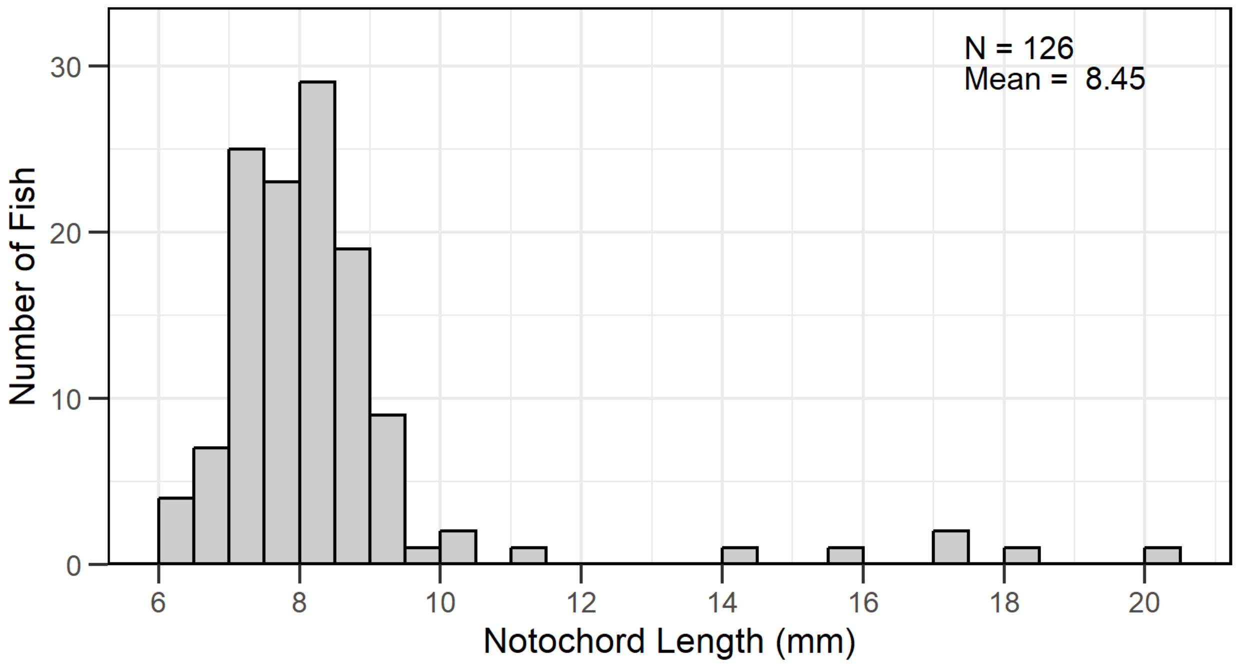
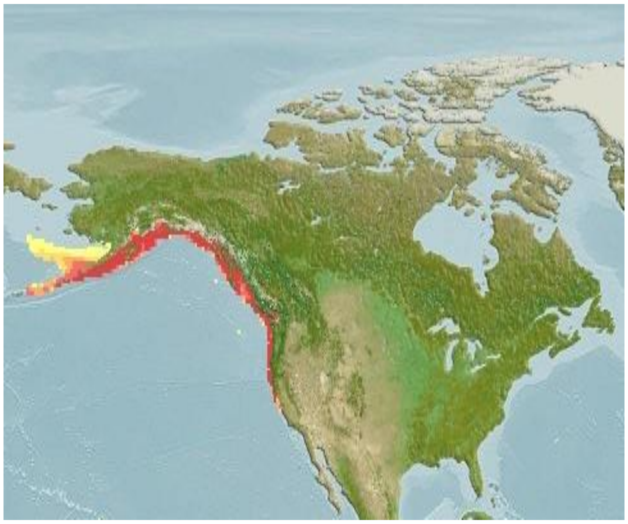


Figure 4-20. Length frequency of Pacific Herring measured from larvae collected from stations E1, E2, SW2, and SW3 from January 2022–December 2022.

4.2.5 **Pacific Tomcod** *Microgadus proximus*



Native distribution of the Pacific Tomcod. Range of colors indicate degree of suitability of habitat which can be interpreted as probabilities of occurrence. Red indicates highest probability of occurrence, yellow indicates lowest. *(Kaschner et. al. 2019)*

(iNaturalist, 2021)

Range: Southeastern Bering Sea and eastern Aleutian Islands to Central California

Life History: Size up to 12 in. (305 mm) SL; they exhibit prolonged spawning that extends over several months and occurs during both winter and spring; demersal; adhesive eggs with fecundity estimated to be similar to that of the Atlantic Tomcod *Microgadus tomcod* which ranges from 6,000–80,000 eggs per spawning event.

Habitat: Young recruit in shallow nearshore waters of bays and estuaries. Juveniles range from brackish waters to the open coast and are often found in midwater and near the surface. Adults are more demersal and can be found in depths of 853 ft (260 m) but mostly reside over sand or soft sediments at depths of 82–394 ft (25–120 m).

Fishery: Minor commercial importance. Common recreational sportfish.

The family Gadidae is further broken down into subfamilies, including Gadinae which consists of 22 species divided into 12 genera (Cohen et al. 1990). This subfamily is characterized by soft-rayed fishes with 3 dorsal fins and 2 anal fins (Miller and Lea 1972). Gadids are typically marine fish that reside in deeper waters, however, a few species including the Pacific Tomcod (*Microgadus proximus*) are generally found in more littoral or inshore waters. They are capable of tolerating low salinities and young recruits and juveniles are often found inhabiting estuaries (Hart, 1973). Adult Pacific Tomcod are more demersal and have been found to depths of 853 ft (260 m) but mostly reside over sand or soft sediments at depths of 82–394 ft (25–120 m) (Hart 1973). Some adults have also been found in the shallow channels of places like Humboldt Bay (Love 2011).

While many of the species in this family are of great commercial value, including cod, haddock, and pollock, Pacific Tomcod, are of minor commercial importance due to their small size. However, they are occasionally caught as a recreational sportfish. In Humboldt Bay young recruits and juveniles can be found during all seasons and anglers occasionally catch larger juveniles and some adults via hook and line (Fritzsche and Cavanagh 2007). In a study done by Gleason et al. 2007, that looked at fish diversity and abundance in Humboldt Bay, it was shown that Pacific Tomcod were one of the 67 species identified as appearing in trawls from both North

Bay and Entrance Bay, however, they only ranked <0.1% in overall abundance among the fishes collected. Outside the bay it is reported that these fish are numerous and serve as important prey to a host of predators (Fritzsche and Cavanagh 2007). In a study completed by Richardson and Pearcy (1977), planktonic larvae of Pacific Tomcod were the dominant gadid and fourth most abundant taxon in a coastal assemblage of fish larvae occurring off Yaquina Bay, Oregon. No juvenile or larval Pacific Tomcod were collected during a larval fish study of Humboldt Bay conducted in 1969 (Eldridge and Bryan 1972).

Pacific Tomcod range in color from olive green to a brownish color dorsally with a creamy white ventral side. Adult Pacific Tomcod may be confused with small Pacific Cod (*Gadus macrocephalus*) or Walleye Pollock (*Gadus chalcogrammus*) but can be distinguished from the other two species by their chin barbel length. Pacific Tomcod have a chin barbel with a length that is about one-half the diameter of their eye or shorter, while Pacific Cod have a chin barbel that is rarely shorter than the diameter of their eye, and Walleye Pollock lack a chin barbel (Miller and Lea 1972). The most useful trait to separate Pacific Tomcod larvae from Pacific Cod and Walleye Pollock is by the length and position of the anterior and posterior postanal pigment bars (Matarese et al. 1981). Additionally, depending upon the size of the larvae, other differentiating characteristics that could be used to separate these species include, head, gut, and caudal pigmentation and differences in the number of rays on their superior hypural element (Matarese et al. 1981).

The growth rates and estimated life span of Pacific Tomcod have thus far been undocumented but may be similar to that of the Atlantic Tomcod (*Microgadus tomcod*), which have an average lifespan of 4 years (Salinas and McLaren 1983). Adult Atlantic Tomcod mature at 9 months and are capable of spawning at 11 months (Waldman 2006). Female Atlantic Tomcod range from 6.69–13.4 in. (170–340 mm) in length and produce an average of 20,000 benthic eggs (Matarese et al. 1981). The eggs of Pacific Tomcod are demersal and adhesive with a diameter of 0.12 in. (3 mm) and the larvae at hatching are ~0.11 in. (2.7 mm) NL (Dunn and Matarese 1987). The length of the larvae at transformation is >1.8 in. (46 mm) standard length (SL). Summary data in Dunn and Matarese (1987) on early life history of northeast Pacific Gadid fishes indicates that the larval development of Pacific Tomcod and Pacific Cod are similar. Data from laboratory studies on the development of Pacific Cod were used to calculate an estimated daily growth rate of 0.163 mm per d for larvae from hatch through 30 d (Tomoda and Dan 2014). This estimate is used in calculating larval duration in Pacific Tomcod for the ETM.

Sampling Results

Pacific Tomcod was the sixth most abundant taxa of fish larvae collected during the sampling from January-December 2022 (**Table 4-2**) and the fourth most abundant in the entrainment sampling (**Table 4-3**). A total of 285 thousand Pacific Tomcod were estimated to be entrained during the year, comprising 1.6% of the total estimated entrainment of larval fishes. They were the fourth most abundant taxa at stations E1 and SW3 (**Table 4-2**). They were collected from at least one of the entrainment stations during the months of January through April and also in June (**Figure 4-21**). The peak abundance for this taxon occurred during the April survey at both entrainment stations, however, there was an additional peak in abundance at the E1 station during the month of January. Pacific Tomcod were collected in highest abundance at the source water stations just upcoast from the Harbor Entrance along the North Sand spit (SW4) and a little further North near the main channel (SW3) (**Figure 4-22**). These areas are dominated by sand, making them the preferred habitat for this species. They were collected in only the April survey at source water stations SW1, SW2, and SW6, which are areas predominantly dominated by mudflats.

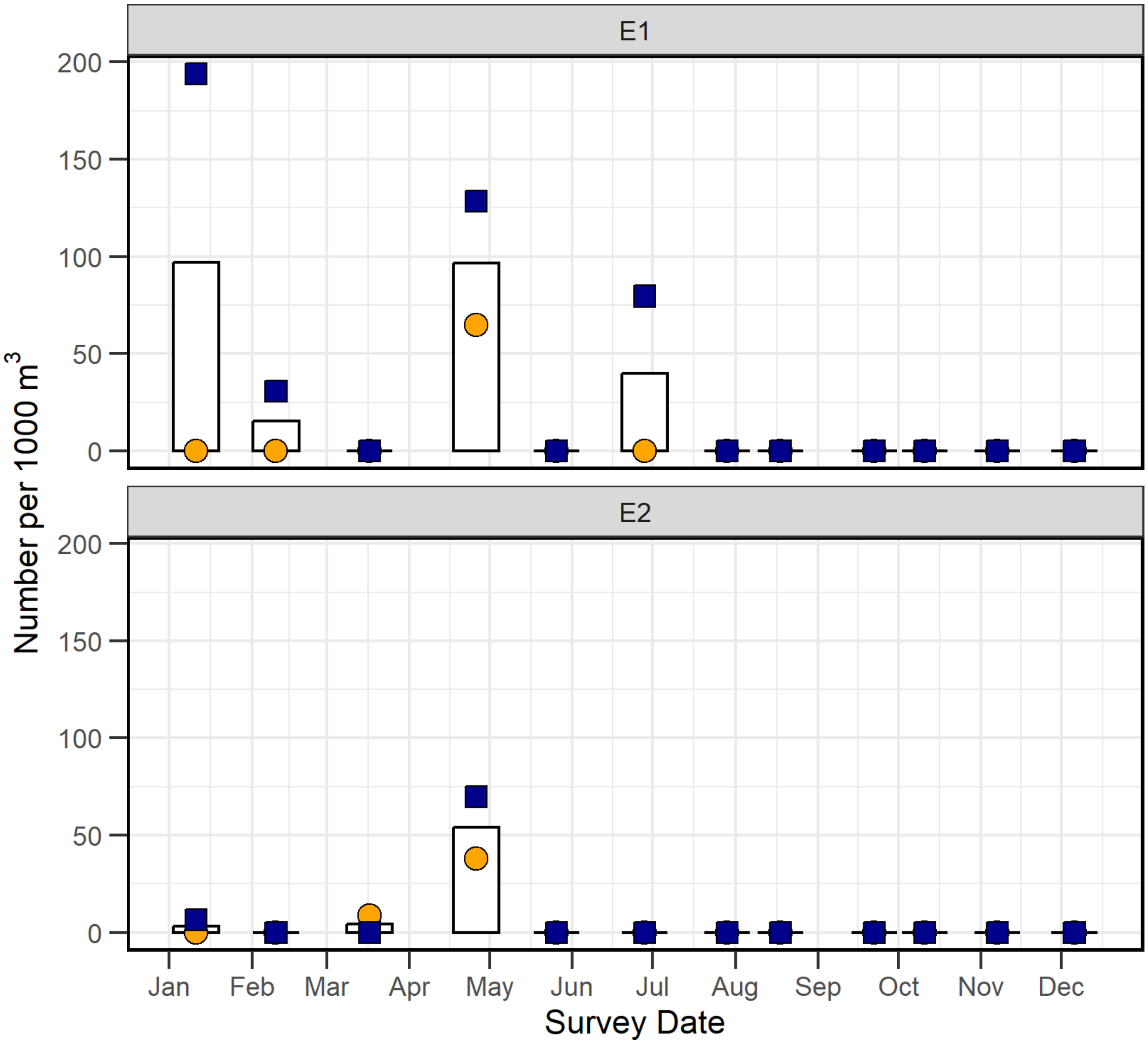


Figure 4-21. Total average concentrations of Pacific Tomcod larvae (height of bar) collected during monthly surveys at entrainment stations E1 and E2 from January 2022–December 2022. Concentrations from daytime (orange circles) and nighttime (blue squares) are also shown. Dates of the surveys correspond to the centers of the bars.

The length frequency of the 112 Pacific Tomcod larvae measured from the study had an average NL of 0.125 in. (3.17 mm) and the smallest and longest larvae measured were 0.08 and 0.16 in. (2.09 and 3.95 mm) NL, respectively (**Figure 4-23**). Similar to the other taxa several of the measured larvae were in the range of the estimated hatch length from Atlantic Tomcod of 2.7

mm (0.11 in.) NL from Dunn and Matarese (1987). These measurements are used to calculate bootstrap estimates of the minimum and maximum lengths used in calculating the period of larval exposure to entrainment for the ETM.

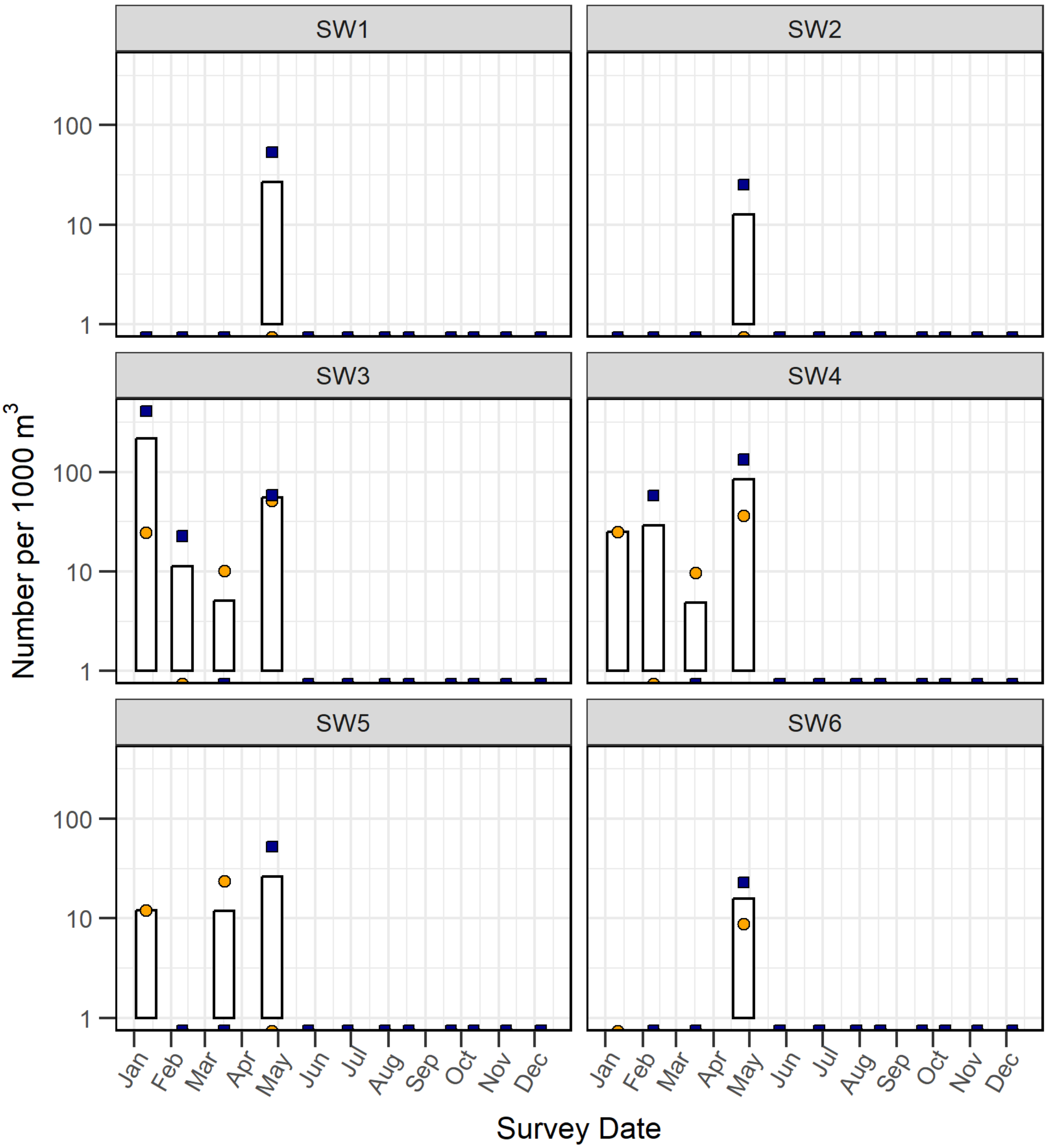


Figure 4-22. Total average concentrations of Pacific Tomcod larvae (height of bar) collected during monthly surveys at source water stations SW1–SW6 from January 2022–December 2022. Concentrations from daytime (orange circles) and nighttime (blue squares) are also shown. Dates of the surveys correspond to the centers of the bars. Note use of log-scale due to magnitude of some of the abundances.

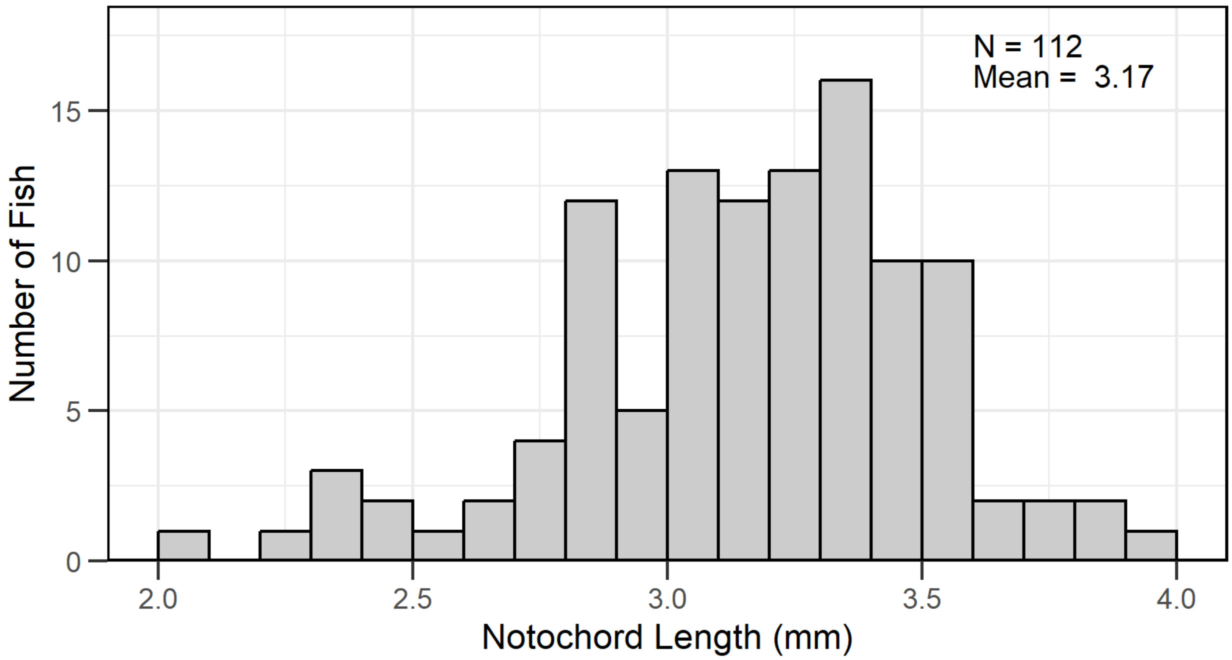


Figure 4-23. Length frequency of Pacific Tomcod measured from larvae collected from stations E1, E2, SW2, and SW3 from January 2022–December 2022.

4.2.6 Surf Smelt *Hypomesus pretiosus*

Native distribution of Surf Smelt. Range of colors indicate degree of suitability of habitat which can be interpreted as probabilities of occurrence. Red indicates highest probability of occurrence, yellow indicates lowest. From Fishbase.org *(Kaschner et. al. 2019)*

(David Ayers, USGS)

Range: From southeast Alaska to southern California

Life History: Size up to 12 in. (305 mm); age at maturity from 1– 2 yr; Life span ≥5 yr; spawning occurs in the surf along open coast coarse sand beaches from April to September; demersal; adhesive eggs with fecundity from 1,320-36,000 eggs per season.

Habitat: Nearshore species, commonly found in estuaries. Schools of juveniles and adults are common in kelp and eelgrass.

Fishery: Commercial and recreational fisheries

Surf Smelt, like the Whitebait Smelt discussed previously, belong to the family Osmeridae. The small, soft-rayed fishes with an adipose fin that can be found in marine, estuarine, and freshwater habitats (Hart 1973). Surf Smelt are another one of the six species of osmerids that are native to California's coastal and estuarine waters (Sweetnam et al. 2001). Surf Smelt was the fifth most abundant species collected during a study in 2000-2001 on the fishes of Humboldt Bay (Gleason et al. 2007). Surf Smelt was the second most abundant juvenile fish collected during a study of marine resources during 1969 in Humboldt Bay by Eldridge and Bryan (1972).

Surf Smelt are a silvery, streamlined fish, with a small mouth and short lateral line (Love 2011). They are sexually dimorphic with males having a more brownish back compared to the brighter green back in the females, both have a silver band running along their sides (Schaefer 1936). Surf Smelt are distinguished from other California osmerids by having a head length more than 4 times the eye diameter and 2.5 times the longest anal fin soft ray (Fitch and Lavenberg 1975; Miller and Lea 1972). They look similar to Night Smelt but can be further differentiated by the size of their mouth: in Surf Smelt, the mouth does not reach past the pupil of the eye; in Night Smelt the mouth extends at least to the back edge of the pupil (Love and Passarelli 2020).

Surf Smelt can live up to five years, reaching maturity between one and two years (Love 2011). Spawning generally occurs between April to September along coarse sand and fine gravel beaches (Hart and McHugh 1944, Levy 1985). Females produce between 2,500-37,000 eggs per season, in more than one batch (Hart and McHugh 1944, Love, 2011). Females spawn demersal semi-adhesive eggs with a shell diameter of 0.004 in. (1.1 mm) (Moser 1996). Unlike other demersal fish eggs, which are adhesive all around, Surf Smelt eggs are unique and form an extremely adhesive peduncle that attaches to the beach substrate (Penttila 1978). Eggs hatch in 9-56 days depending on water temperature (Love 2011). Estimated lengths for the larvae at various developmental stages are hatching length at 0.12–0.20 in. (3–5 mm), flexion length at 0.51–0.60 in. (13–15 mm), and transformation length at 1.57 in. (40 mm) (Hearne 1983, Matarese et a1. 1989, Saruwatari and Okiyama 1988, Moser, 1996). Penttilla (1978) determined that recruitment to the spawning population may occur for age 1, which would be equivalent to Surf Smelt measuring approximately 3.9–4.7 in. (100–120 mm) SL. Length frequency analyses of Surf Smelt sampled from the California recreational fishery indicated that age 2 individuals in the 6.7 in. (170 mm) FL range comprised the bulk of the sampled catch.

Sampling Results

Surf Smelt was the fifth most abundant taxa of fish larvae collected during the sampling from January–December 2022 (**Table 4-2**) and the sixth most abundant in the entrainment sampling (**Table 4-3**). A total of 205 thousand Surf Smelt were estimated to be entrained during the year, comprising approximately 1.2% of the total estimated entrainment of larval fishes. They were often within the top seven of the most abundant taxa at the different stations (**Table 4-2**). They were collected from at least one of the entrainment stations during the months of May through July, and in September, November, and December (**Figure 4-24**). The peak abundance for this taxon occurred during the June survey at both entrainment stations. Surf Smelt were collected in highest abundance at the source water stations at the Entrance Bay (SW4), South Bay (SW5), and Arcata Bay (SW6) (**Figure 4-25**). They appeared to be most abundant at source water stations during the month of June, however, at Station SW2 they were most abundant in August.

The length frequency of the 31 Surf Smelt larvae measured from the study had an average NL of 0.56 in. (14.31 mm) and the smallest and longest larvae measured were 0.15 and 0.98 in. (3.90 and 24.96 mm) NL, respectively (**Figure 4-26**). The small number of measurements and the large variation in NL make it difficult to calculate the period of larval exposure to entrainment for the ETM.

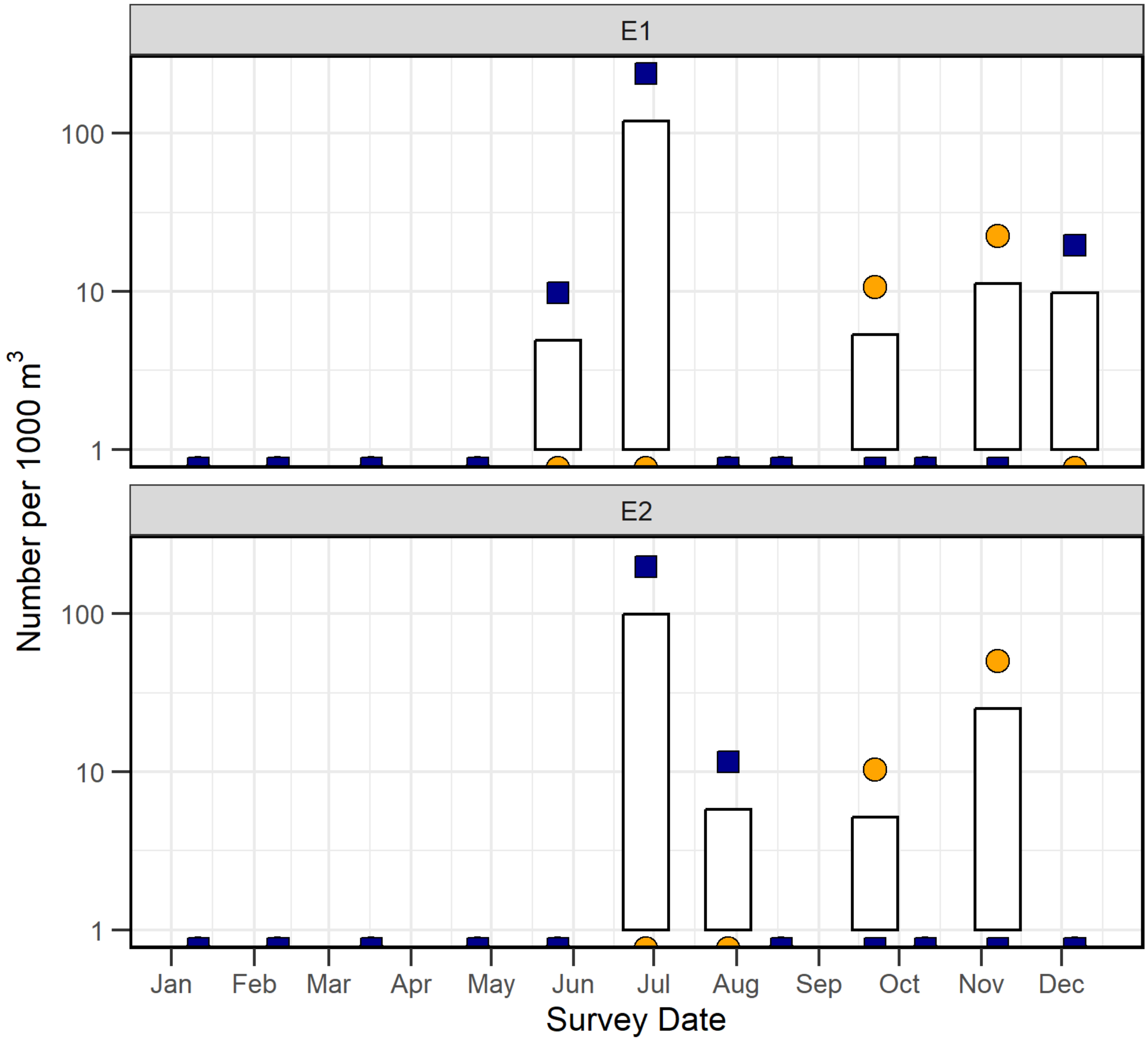


Figure 4-24. Total average concentrations of Surf Smelt larvae (height of bar) collected during monthly surveys at entrainment stations E1 and E2 from January 2022–December 2022. Concentrations from daytime (orange circles) and nighttime (blue squares) are also shown. Dates of the surveys correspond to the centers of the bars. Note use of log-scale due to magnitude of some of the abundances.

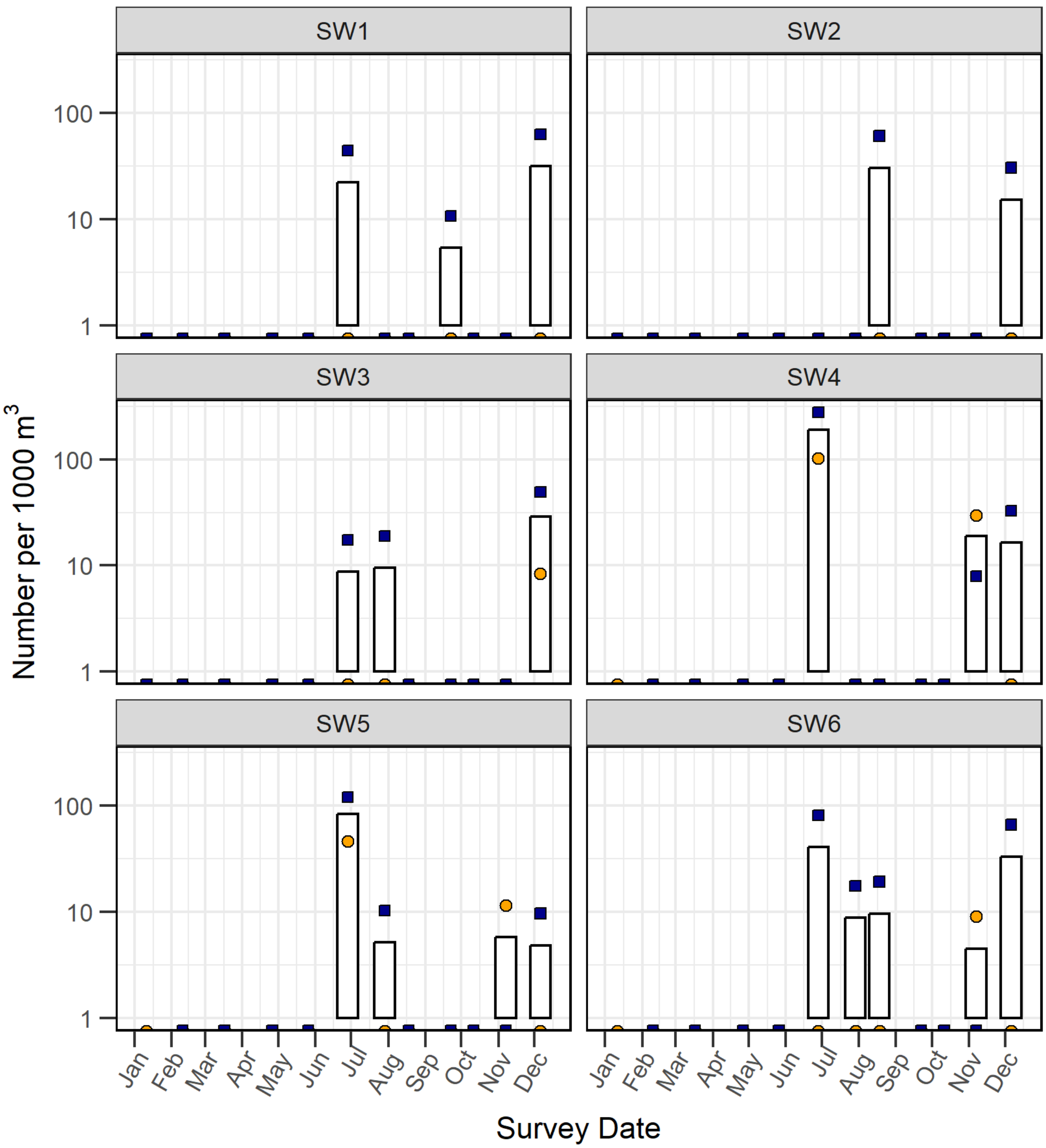


Figure 4-25. Total average concentrations of Surf Smelt larvae (height of bar) collected during monthly surveys at source water stations SW1–SW6 from January 2022–December 2022. Concentrations from daytime (orange circles) and nighttime (blue squares) are also shown. Dates of the surveys correspond to the centers of the bars. Note use of log-scale due to magnitude of some of the abundances.

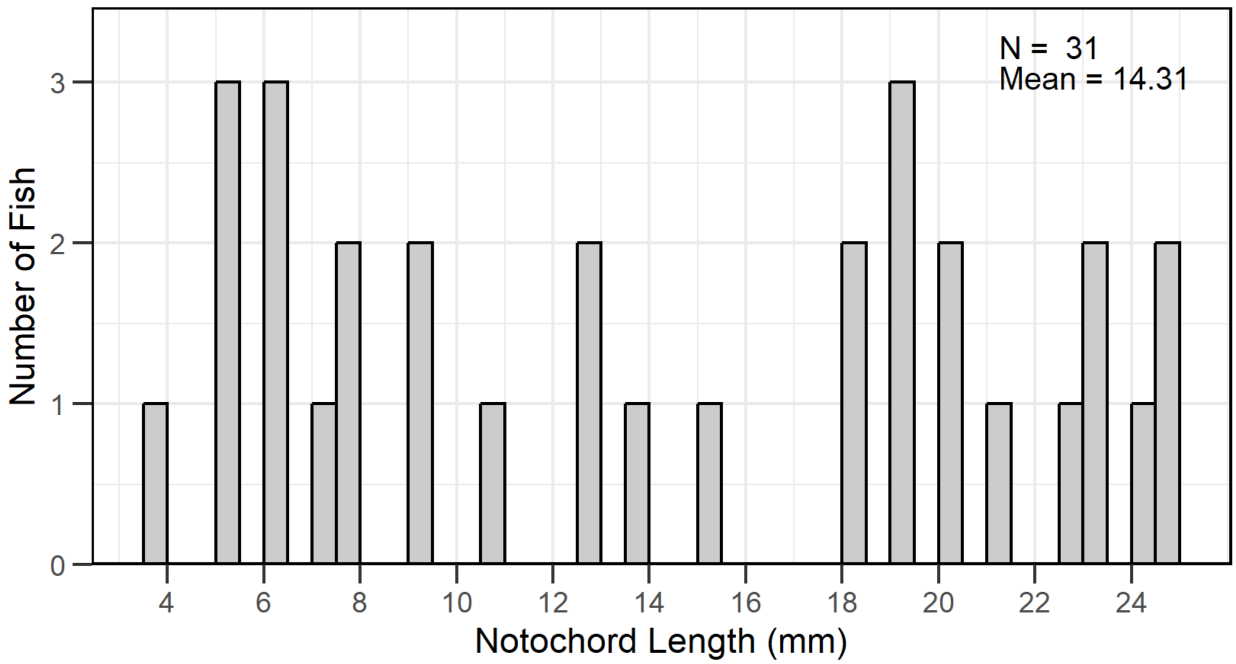
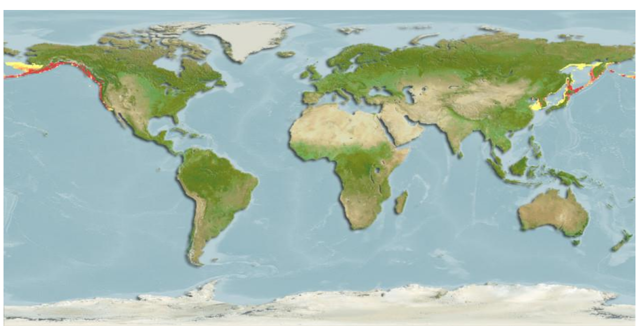


Figure 4-26. Length frequency of Surf Smelt measured from larvae collected from stations E1, E2, SW2, and SW3 from January 2022–December 2022.

4.2.7 Pacific Staghorn Sculpin *Leptocottus armatus*



Native distribution of Pacific Staghorn Sculpin. Range of colors indicate degree of suitability of habitat which can be interpreted as probabilities of occurrence. Red indicates highest probability of occurrence, yellow indicates lowest. From Fishbase.org *(Kaschner et. al. 2019)*

(Photo credit: Rene Reyes))

Range: From southeastern Bering Sea to northern Baja California.

Life History: Size up to 19 in. (482.6 mm); age at maturity 1 yr; Life span ≥10 yr; spawning takes place from October through April, peaking in January and February. Females spawn demersal adhesive eggs, once per season, with fecundity from 2,000-11,000 eggs.

Habitat: Nearshore species, commonly found in bays and estuaries; most frequently on sandy or muddy bottoms. Can seasonally be found in brackish and freshwater, including lower portions of coastal rivers and streams.

Fishery: Recreational; frequently caught by shore anglers fishing in bays but considered a nuisance fish and not often retained. Commercial; bycatch in trawl fishery, small bait-fish market.

The Pacific Staghorn Sculpin belongs to the family Cottidae, a large group (more than 300 species) of bottom-dwelling fishes. This estuarine fish ranges from the Pribilof Islands and Port Moller in the Bering Sea to Bahia San Quintin in Baja California and can often be found in tidepools (Love 2011). In the southern half of their range they commonly occur in freshwater (Moyle 1976). Pacific Staghorn Sculpin are abundant in San Francisco, San Pablo, and Tomales bays, Moss Landing Harbor and the Elkhorn Slough (Jones 1962). Pacific Staghorn Sculpin were also found to be the seventh most abundant species collected during a study in 2000–2001 on the fishes of Humboldt Bay (Gleason et al. 2007) and the fifth most abundant taxon of larval fish collected during a study of ichthyoplankton during 1969, also in Humboldt Bay, by Eldridge and Bryan (1972).

Pacific Staghorn Sculpin have a tan, brown, or grayish coloring above and white or yellow below. They have a large flat head, with small eyes. They can be identified by the large upper preopercular spine and by the large, dark spot on the posterior part of their spiny dorsal fin (Miller and Lea 1972, Morrow 1980). The Pacific Staghorn Sculpin is classified as a nondependent marine fish, meaning that although commonly found in estuarine environments, it does not require this habitat type to complete its life cycle (Moyle and Cech 1988). They are usually found in shallow subtidal waters but may be found as deep as 300 ft (91 m). They commonly burrow into sandy mud bottoms of bays and estuaries leaving only their head and eyes exposed. The prey of Pacific Staghorn Sculpin includes amphipods, nereid worms, and small anchovy (Jones 1962).

Pacific Staghorn Sculpin can live up to 10 years and typically mature at age one (Love 2011). Spawning takes place from October through April, with a peak in January and February. Spawning locations tend to be shallow coastal bays, inlets, sounds, and sloughs with optimal salinity measurements between 27 to 28.3 ppt (Jones 1962). Their preferred substrate varies from mud and sand bottoms to firmer rocky areas. The females spawn only once a season, producing between 2,000 to 11,000 spherical eggs, which are deposited in clusters on substrate. After spawning, the adults leave the shallow spawning areas for deeper offshore waters (Tasto 1975). Eggs hatch in about 10 days and the larvae (averaging 0.2 in. [4.5 mm] NL in length) swim to the surface, becoming planktonic (Jones 1962). It has been suggested (Wang 1986) that the larvae may remain on the bottom for a short period of time before they ascend to the surface. It takes approximately eight weeks from the time of hatching until larvae metamorphose to juveniles, at a length of 0.6 –0.8 in. (15–20 mm) TL (Matarese et al. 1989). Jones (1962) reports an estimated growth rate of 0.01 in./day (0.25 mm/day) (reported as R.W. Morris personal communication in Jones 1962). It has been reported that juveniles move up estuaries and into freshwater and remain there for about three months before moving to a more saline environment (Moyle 1976, Love 1996). Juveniles probably become demersal after reaching 0.4–0.6 in. (10–15 mm) in length (Wang 1986).

Sampling Results

Pacific Staghorn Sculpin was the eight most abundant taxa of fish larvae collected during the sampling from January–December 2022 (**Table 4-2**) and the eighth most abundant in the entrainment sampling (**Table 4-3**). A total of 143 thousand Pacific Staghorn Sculpin were estimated to be entrained during the year, comprising less than 1% of the total estimated entrainment of larval fishes. They were often within the top eight of the most abundant taxa at the different stations (**Table 4-2**). They were collected from at least one of the entrainment stations during the months of January through March, September, and November through December (**Figure 4-27**). The peak abundance for this taxon occurred during the January survey at both entrainment stations. Pacific Staghorn Sculpin were collected in highest abundance at the source water stations during January and February with the highest abundances occurring at stations SW1 and SW5 (**Figure 4-28**).

The length frequency of the 77 Pacific Staghorn Sculpin larvae measured from the study had an average NL 0f 0.23 in. (5.91 mm) and the smallest and longest larvae measured were 0.16 and 0.44 in. (4.01 and 11.08 mm) NL, respectively (**Figure 4-29**). Many of the larvae were smaller than the reported hatch length of 0.2 in. [4.5 mm]. These measurements are used to calculate bootstrap estimates of the minimum and maximum lengths used in calculating the period of larval exposure to entrainment for the ETM.

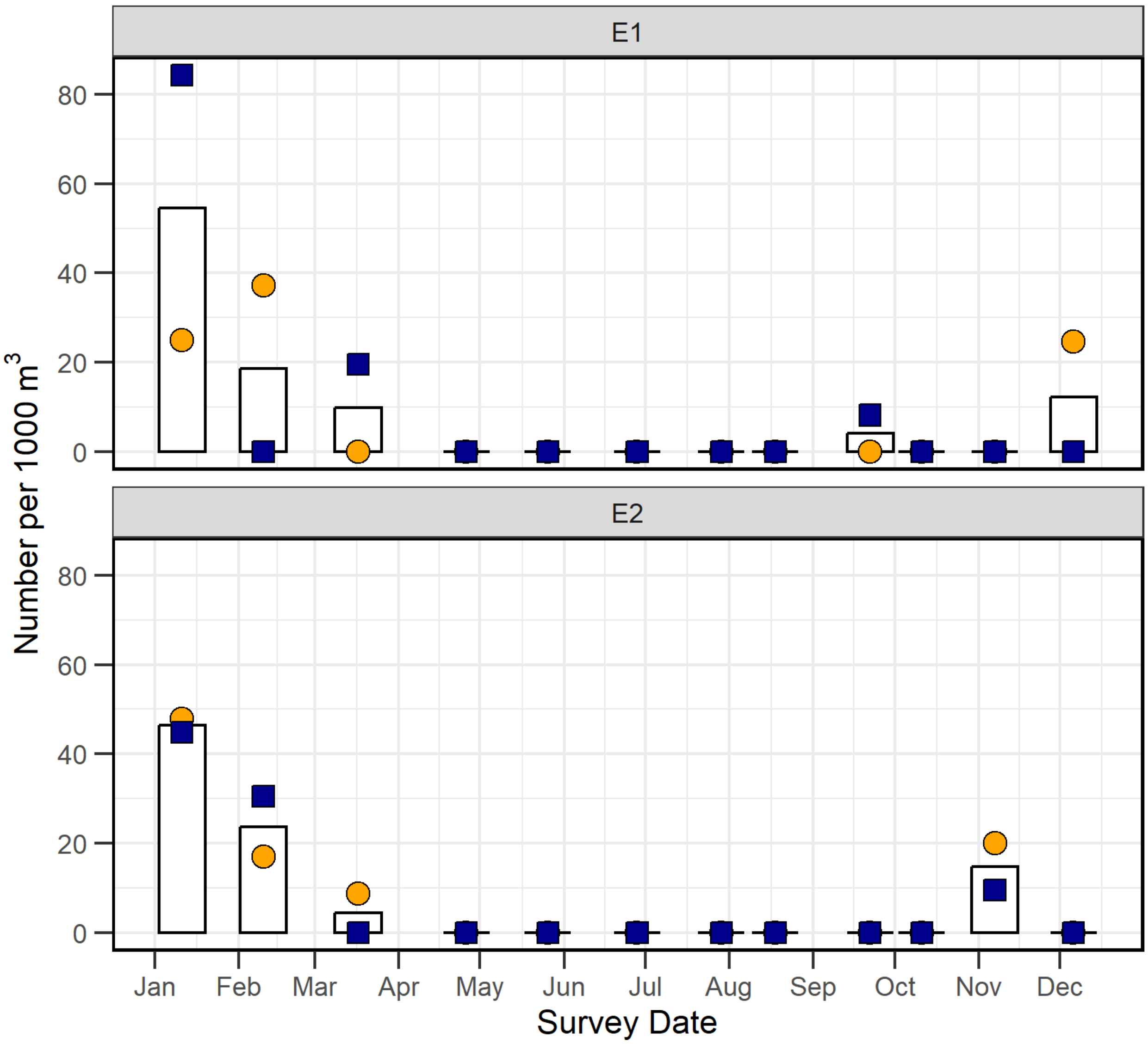


Figure 4-27. Total average concentrations of Pacific Staghorn Sculpin larvae (height of bar) collected during monthly surveys at entrainment stations E1 and E2 from January 2022–December 2022. Concentrations from daytime (orange circles) and nighttime (blue squares) are also shown. Dates of the surveys correspond to the centers of the bars.

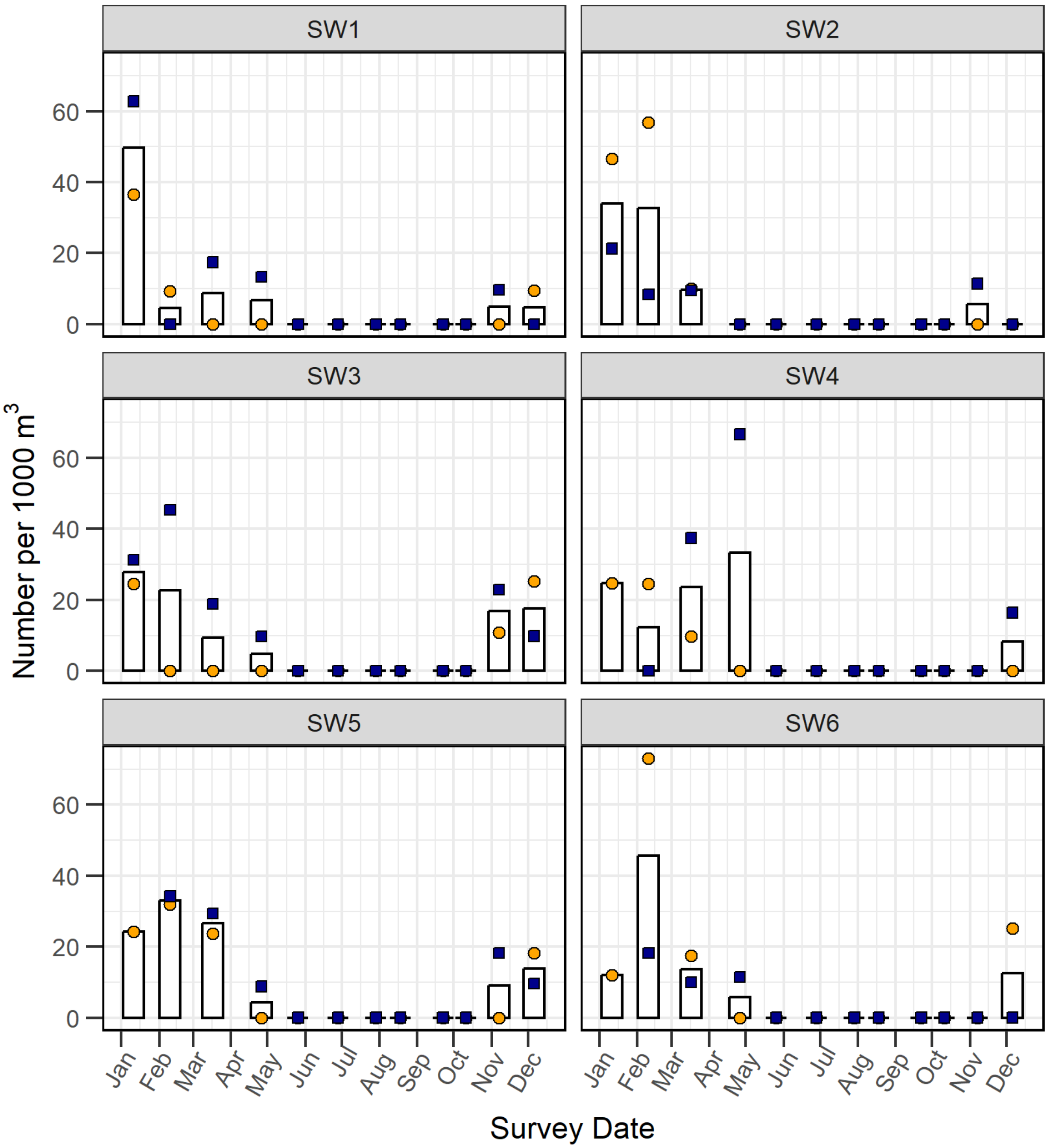


Figure 4-28. Total average concentrations of Pacific Staghorn Sculpin larvae (height of bar) collected during monthly surveys at source water stations SW1–SW6 from January 2022–December 2022. Concentrations from daytime (orange circles) and nighttime (blue squares) are also shown. Dates of the surveys correspond to the centers of the bars.

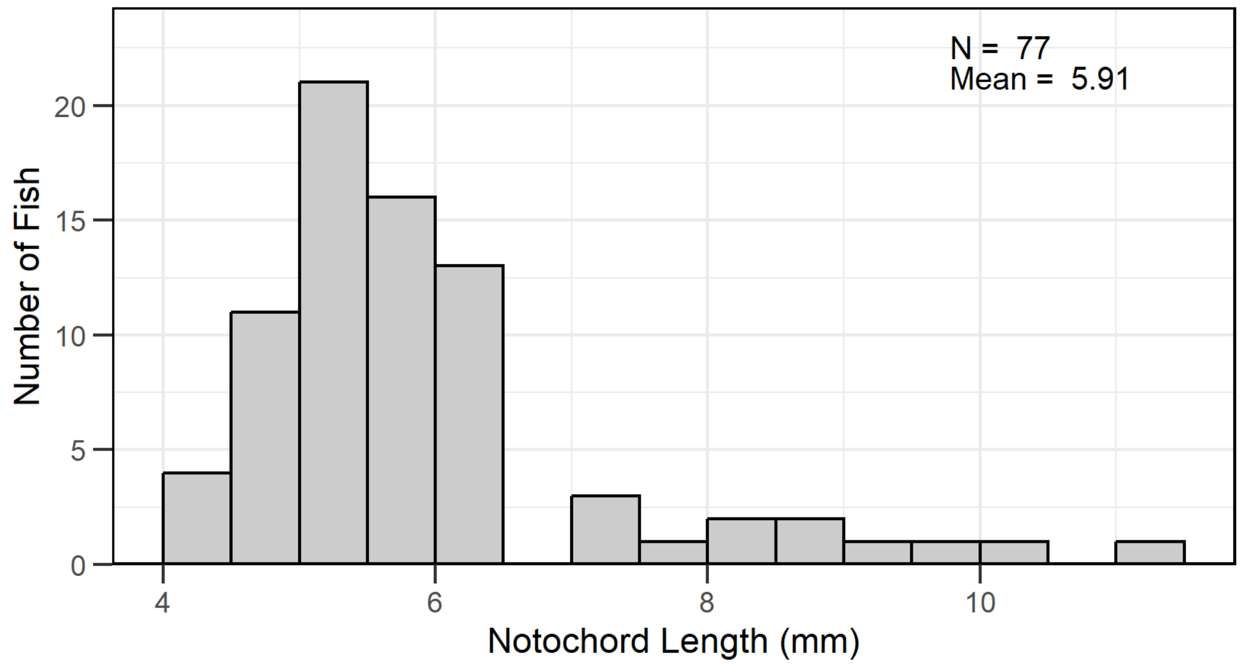


Figure 4-29. Length frequency of Pacific Staghorn Sculpin measured from larvae collected from stations E1, E2, SW2, and SW3 from January 2022–December 2022.

4.2.8 Longfin Smelt *Spirinchus thaleichthys*

Native distribution of LFS. Range of colors indicate degree of suitability of habitat which can be interpreted as probabilities of occurrence. Red indicates highest probability of occurrence, yellow indicates lowest. From Fishbase.org *(Kaschner et. al. 2019)*

(Photo credit: Bill Stagnaro)

Range: From Prince William Sound, Alaska to Monterey Bay, California.

Life History: Size 4.9–5.5 in. (124–140 mm) SL; age at maturity 2 yrs; Life span ≥3 yrs; Spawning occurs primarily from January through March, after which most adults die. Each female can lay between 5,000 and 24,000, adhesive eggs.

Habitat: They spend their adult life in bays, estuaries, and nearshore coastal areas, and migrate into freshwater rivers to spawn.

Fishery: None. LFS are listed as a Threatened Species under the California Endangered Species Act (CESA).

Longfin Smelt (LFS) is one of the seven recognized species of the family Osmeridae that occur in California (Moyle 2002). They are a euryhaline, planktivorous silver fish with a pinkish or olive iridescent hue with distinctive long pectoral fins hence their common name. Adult LFS occur in freshwater, brackish waters and seawater from Alaska to Monterey Bay (Moyle 2002). The San Francisco Bay and Sacramento-San Joaquin Delta (SF Bay Estuary) is currently the southernmost spawning location for this species and supports the largest population of LFS in California. LFS are pelagic and anadromous, although some subpopulations live their entire lifecycle in freshwater lakes and streams. Although populations are present in Humboldt Bay, nearly all information available on LFS comes from either the SF Bay Estuary or Lake Washington populations (Baxter et. al. 1999, Bennett et al. 2002, Chigbu and Sibley 1994, Moulton 1974, Nobriga and Rosenfield 2016, Stevens and Miller 1983).

A more recent study on the distribution of LFS in areas north of SF Bay Estuary included larval sampling of 16 sites from Tomales Bay north to the Smith River (Brennan et al. 2022). Sampling was conducted during the winter months of 2019 and 2020 in areas of the sites that had salinities of 2–12 psu. Due to heavy rainfall in 2019, freshwater flows into estuarine areas including Humboldt Bay were much higher in 2019 than in 2020. As a result, LFS larval abundances across all of the sampling sites were much higher in 2020, which was likely due to high flows in 2019 flushing many of the larvae out of the sampling areas. In Humboldt Bay, slightly more LFS larvae were collected during 2020 (61 vs. 65), but the sampling in 2020 collected LFS larvae at many more sites, including sites further upstream. During both years, the only locations where LFS larvae were collected in Humboldt Bay was in Eureka Slough. No LFS larvae were collected in the Mad River Slough or South Bay. LFS larvae were collected at several sampling locations in the Eel River with most of the larvae collected in 2020. LFS larvae were only collected at one location in the Mad River in 2020, which was near the mouth of the river.

Although, specific locations of LFS spawning events vary with a multitude of conditions including substrate type, flow, temperature, and salinity (Rosenfield 2010), shallow brackish tidal marshes and sloughs are identified as important spawning and recruitment areas (Lewis et al. 2020). Spawning occurs from November through May peaking around March (CDFW 2009). Most fish die after spawning but some females have been found to live another year. Females lay 1,900 to 18,000 adhesive eggs on sandy or grassy substrate that hatch after ~40 days (CDFW 2009). The average fecundity for an average length female (~4 inches [101.6 mm]) is approximately 5,000 eggs (Figure 3 in CDFW 2009). Data on laboratory studies from Yanagitsuru et al. (2021a) found hatching success for LFS eggs averaged 59%, which would result in the hatching of 2,950 larvae from the 5,000 eggs for each average length female. Data in Yanagitsuru et al. (2021a) was used to calculate an average length at hatching of 0.22 in. (5.6 mm), which is the same as an estimate from data in Lewis et al. (2020). Data from Lewis et al. (2020) were also used to estimate the daily growth for LFS as 0.0067 in.$^{-d}$ (0.17 mm^{-d}).

Newly hatched LFS larvae have a salinity tolerance of 2–6 psu and move downstream into more saline water and after a few weeks can tolerate salinities around 8 psu (Baxter et al. 1999). This is consistent with sampling in the SF Bay Estuary that showed the density of LFS larvae was negatively affected in areas with salinities less than 2 psu and greater than 12 psu (Grimaldo et al. 2017). Grimaldo et al. (2017) indicate that the collections in areas with salinities up to 12 psu drew into question previous results from Hobbs et al. (2010) that survival of small larvae (<0.39 in. [10 mm] TL) was limited in salinities greater than 5 psu. This was based on results from investigations on the chemical signatures of otoliths from adult and sub-adult LFS that used strontium isotope ratios ($^{87}Sr/^{86}Sr$) of waters across the estuarine salinity gradient to reconstruct the larval salinity history of LFS from 4 year-classes (1999, 2000, 2003 and 2006) in the SF Bay Estuary. The results from Hobbs et al. (2010) suggest that LFS larvae that occur in locations with high salinities are unlikely to survive to adulthood. It is likely that these larvae are undergoing physiological stresses due to osmotic pressures. This is supported by more recent laboratory studies on salinity tolerances of early LFS larvae which showed highest survival and growth at salinities of 5 and 10 psu, while salinities of 20 psu presented osmoregulatory problems for the larvae and levels of 32 psu resulted in almost 100% mortality (Yanagitsuru et al. 2021a and Yanagitsuru et al. 2021b). After around 90 days the larvae mature into the juvenile stage and can tolerate normal ocean salinities. Therefore, although the sources for the LFS larvae are not in the vicinity of the intakes, it is likely that daily tidal flows could transport larvae for these species into the area of the intakes. Larvae transported into the vicinity of the intake may only be able to survive salinities in this area during periods when extreme freshwater inflows into the bay result in reduced salinities tolerated by the larvae.

Sampling Results

Longfin Smelt were not collected in high abundance during the sampling from January–December 2022 (**Table 4-2** and **Table 4-3**). A total of approximately 28,000 LFS was estimated to be entrained during the year, comprising approximately 0.2% of the total estimated entrainment of larval fishes. They were only collected at the entrainment stations during surveys done in January and February, with the peak abundance for this taxon occurring in January (**Figure 4-30**). Longfin Smelt were only collected in source water stations during the January survey and the highest abundance was found in SW5, the South Bay Station (**Figure 4-31**).

The salinity data for the periods that the samples at the entrainment stations were collected was approximately 30 PSU during the January survey and close to 33 PSU during the February survey (Appendix B). Based on a study described by Yanagitsuru et al. (2021a and 2021b), LFS larvae would not be able to survive at these salinities.

The average NL of the nine LFS larvae collected at the two entrainment stations and source water stations SW2 and SW3 was 0.33 in. (8.45 mm). The NLs ranged from 0.28 to 0.51 in. (7.19 to 12.87 mm) NL.

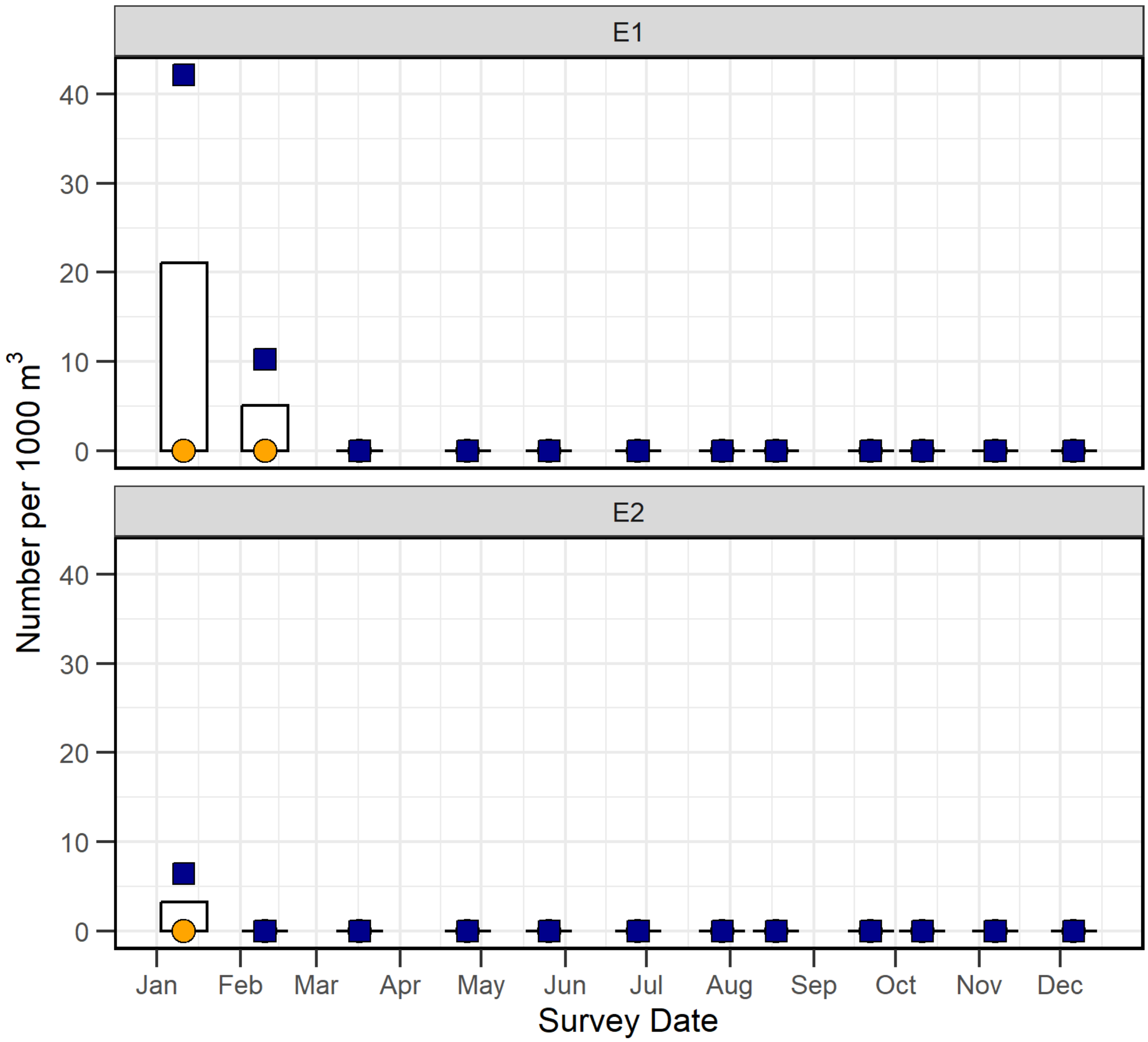


Figure 4-30. Total average concentrations of Longfin Smelt larvae (height of bar) collected during monthly surveys at entrainment stations E1 and E2 from January 2022–December 2022. Concentrations from daytime (orange circles) and nighttime (blue squares) are also shown. Dates of the surveys correspond to the centers of the bars.

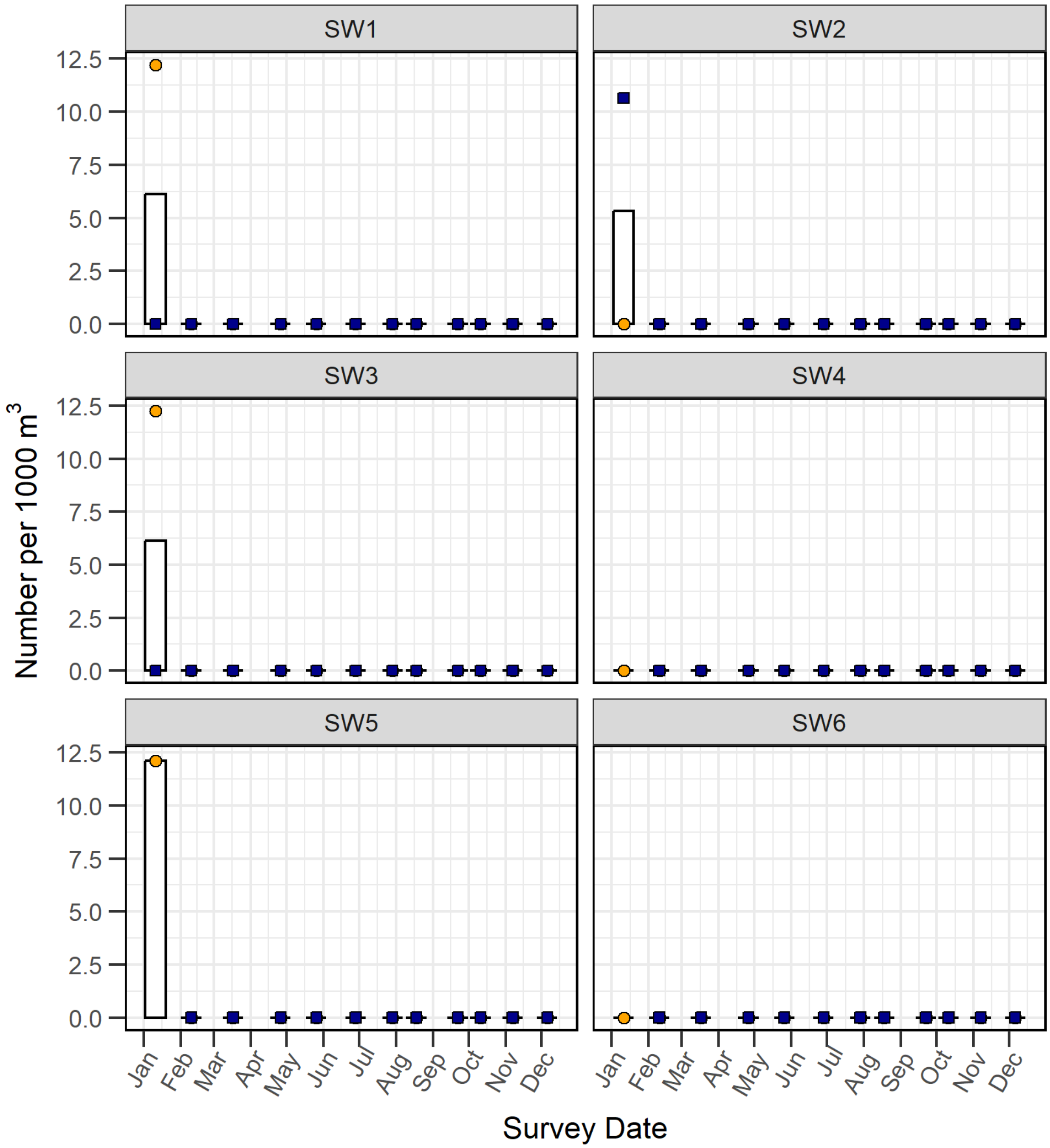


Figure 4-31. Total average concentrations of Longfin Smelt larvae (height of bar) collected during monthly surveys at source water stations SW1–SW6 from January 2022–December 2022. Concentrations from daytime (orange circles) and nighttime (blue squares) are also shown. Dates of the surveys correspond to the centers of the bars.

4.3 Source Water Verification

Results of the Bray-Curtis similarities from the 189 samples and 60 different taxa on fish larvae collected during the 12 surveys were reduced down to the paired similarities between stations with distances that could be estimated as a straight line with a focus on the stations along the north sand spit. Therefore, the paired similarities did not include stations SW1, SW5, and SW6 (**Figure 3-1**). The average Bray-Curtis similarities for the different sampling pairs across all the sampling survey, stations, and cycles resulted in up to 24 similarities per station pair (**Table 4-4**). Correlations for the Bray-Curtis similarity and distance between stations was calculated between sample pairs for data that excluded samples with large differences in tidal heights and conditions at the two locations, but the strongest correlation was detected when using the entire set of data. The correlation among the station pairs for all the samples along the north sand spit was -0.93.

Table 4-4. Average Bray-Curtis similarities and distances (m) between stations pairs for samples collected from January – December 2022 in Humboldt Bay along the north sand spit. Correlation between Bray-Curtis similarity and distance also shown.

Station Pair	Average BC Similarity	Distance (m)	N	Correlation
SW2-SW4	11.96	9691	23	
E2-SW4	27.05	6360	23	
SW2-SW3	26.22	5840	24	
E1-SW4	29.73	5507	23	
E1-SW2	27.24	4202	24	
SW3-SW4	38.28	3856	23	
E2-SW2	41.33	3425	24	
E2-SW3	41.29	2597	24	
E1-SW3	51.19	1705	24	N Sand Spit
E1-E2	41.91	898	24	-0.93

The data for the paired stations in **Table 4-4** are presented in **Figure 4-32** to show the relationship between station pair separation and Bray-Curtis similarity. A mixing model (Model M3 in **Table 3-1**) that is assumed to best represent mixing patterns in Humboldt Bay was calculated for this study. An estimate of flushing time, known as the e-folding time, can be derived from solving the differential equation in the mixing model. The e-folding time within the M3 mixing model also implies an e-folding distance, which represents the distance from the bay mouth that the mixing model predicts flushing will not occur. The Bray-Curtis similarity data provide an independent estimate of that length scale. The similarity results and estimate of the e-folding distance (shown in red) points to a mixing length along the main channel that is greater than the distance between the entrance bay and the proposed seawater intakes of approximately 4.7 mi (7.5 km). This estimate is consistent with the estimates based on physical data collected during the study and the results from Brown and Caldwell (2014) and Claasen (2003), which indicate that particles within the tidal flow would be displaced between 4.3 mi (7 km) and 8.7 mi

(14 km) every tidal cycle. As shown in **Figure 4-32**, the stations with the lowest similarity, SW2 and SW4, are the only station pair outside of this distance. If the results had pointed to a mixing length that was much shorter than the length of the main channel, then it would not be possible to rule out that isolated populations exist near the proposed intake location that are not mixed away by ocean waters within a few tidal cycles. The results indicate that the closed source water model used in the Initial ETM Assessment (Tenera 2021) is not realistic (Model M1 in **Table 3-1**). The results shown in **Figure 4-32** are supported by the biological data which shows a mix of both ocean and bay fishes with the relative abundances at the stations generally reflective of the taxa associated with the habitats in proximity to those stations. These differences are not static as would be expected in a closed system represented by Model M1 as the results in **Figure 4-32** also indicate that the mixing results in a gradient of taxa differences along the north sand spit. The results also indicate that the mixing along the north sand spit is not strong enough to provide complete turnover during each tidal exchange, which is considered as a possibility in Model 2 in **Table 3-1** (i.e., the full tidal prism volume model) in the Initial ETM Assessment. Therefore, the most realistic characterization of impacts is provided by the model in Equation 6 that accounts for the differences in tidal flushing for the different regions of the bay (Model M3 in **Table 3-1**). Those results are reproduced and highlighted in **Table 3-1** alongside the results for the unrealistic, most conservative (closed bay volume) and probably optimistic (full tidal prism volume) results.

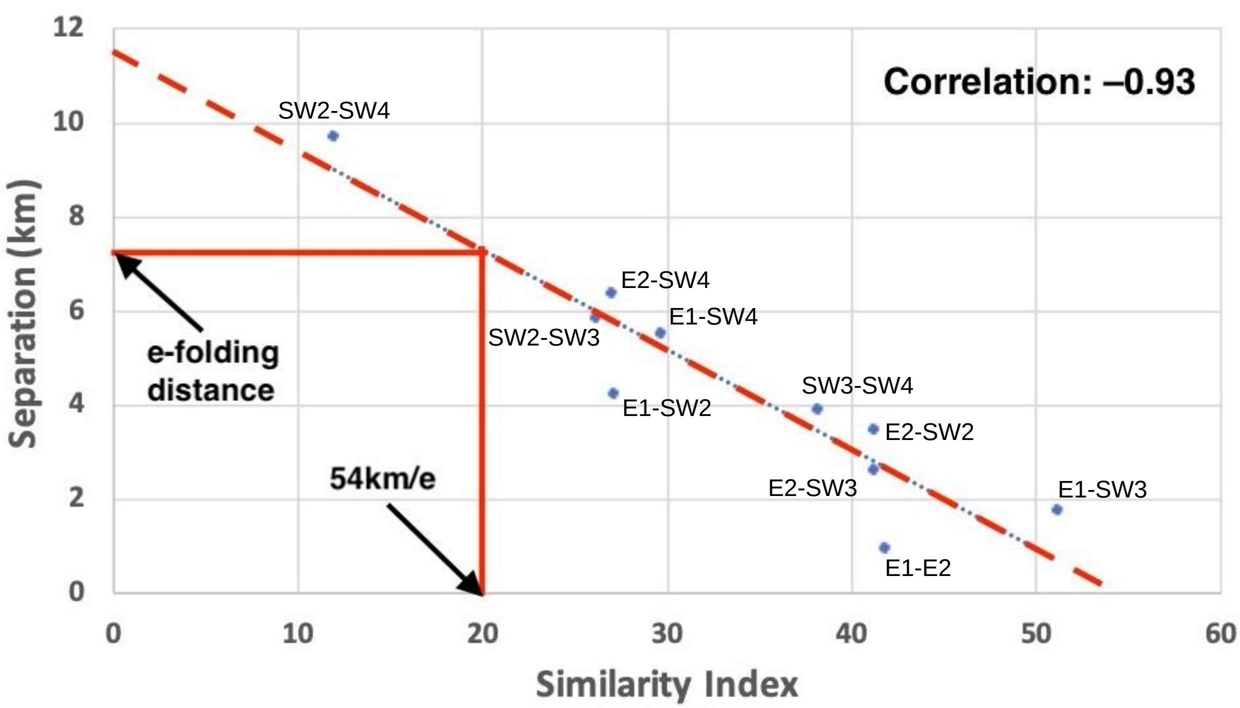


Figure 4-32. Plot showing relationship between distance (km) between station pairs and Bray-Curtis similarity based on data in Table 4-4. The estimate of the e-folding distance is shown by the red solid lines.

5.0 Impact Assessment

The results from the ETM analyses for each taxon are provided in this section and APF estimates for the taxa analyzed using the ETM. The data for Longfin Smelt (LFS) were not analyzed using the ETM because very few larvae were collected, and these larvae were present in only the surveys in January and February. Surveys are used as replicates in the ETM and therefore low replication results in high error in the estimation of P_M. Generally, at least three replicates should be used in any statistically valid parameter estimation. Therefore, the impact assessment for LFS is based solely on the estimated entrainment for the species.

5.1 Estimates of Period of Exposure to Entrainment

The method for deriving the number of days the larvae would be exposed to entrainment is described in Section 3.1.7 Larval Age Estimation and the data used to derive the number of days the larvae would be exposed to entrainment are presented in Section 4.2.

The estimated number of days larvae would be exposed to entrainment for each taxon analyzed in the ETM were calculated using the data on the lengths of the larvae presented in Section 4.2 using the average values from the 1000 bootstrap samples calculated for each taxon as described in Section 3.1.6. The average values from the 1000 bootstrap samples for the seven taxa show that the estimated hatch lengths from the data are within the range of reported hatch lengths from Moser (1996) and other sources reported in Section 4.2 for all of the taxa except Surf Smelt (**Table 5-1**).

Table 5-1. Average estimates from 1000 bootstrap samples of larval lengths for the seven fish taxa analyzed using the ETM. All of the measurements are in mm. The calculated hatch lengths and larval durations are calculated using the methods described in Section 3.1.6. The sources of the estimated growth rates for each taxon are described in the taxa profiles in Section 4.2.

Taxa	Mean	Max	Min	q1	q5	q10	q25	q50	q75	q90	q95	q99	Calculated Hatch Length (mm)	Reported Hatch Length (mm)	Analysis Hatch (mm)	Estimated Growth Rate (mm/d)	Duration (d)
Arrow Goby	3.86	9.28	2.48	2.59	2.75	2.85	3.05	3.44	4.17	5.45	6.48	7.97	3.02	2 - 3	3.02	0.20	17.49
Bay Goby	3.05	4.44	2.10	2.16	2.35	2.50	2.76	2.97	3.22	3.83	4.00	4.32	2.57	3	2.57	0.22	6.53
White Bait Smelt	6.24	13.64	4.16	4.20	4.44	4.75	5.18	5.83	6.81	8.06	9.47	11.93	5.01	5.5	5.01	0.17	26.23
Pacific Herring	8.38	20.15	6.30	6.38	6.68	6.98	7.42	7.97	8.55	9.23	11.87	17.31	7.17	5.6 - 7.5	7.17	0.50	9.39
Pacific Tomcod	3.12	3.90	2.17	2.24	2.29	2.52	2.90	3.18	3.38	3.54	3.63	3.83	2.71	2.7	2.71	0.16	5.66
Surf Smelt	13.67	24.95	4.20	4.68	5.76	6.19	7.73	12.29	19.50	23.13	23.72	24.90	8.48	3 - 5	4.68	0.17	87.18
Pac. Stag. Sculpin	5.88	10.88	4.03	4.08	4.48	4.72	5.12	5.55	6.10	7.71	8.95	10.48	4.81	4 - 5	4.81	0.25	16.56

There were only a limited number of Surf Smelt larvae from the two entrainment stations and the two nearby source water stations. The calculated hatch NL of 0.33 in. (8.5 mm) was much larger than the reported hatch NL of 0.12–0.20 in. (3–5 mm), therefore, the length at the 1st quantile was used as the hatch length. Over a quarter of the Surf Smelt larvae were large enough to have very low probabilities of entrainment through the 0.04 in. (1.0 mm) slot openings based on the Monte Carlo simulation of the results of the allometric regression of NL and head capsule dimensions presented in Section 6.0 (**Figure 6-2**c and **Table 6-1**). Even using the estimated length at the 75th quartile as the maximum length with the adjusted hatch length in the calculation of the larval duration resulted in an estimate of over 87 d which is clearly incorrect and exceeds the expected period of approximately 30 days for the maximum turnover of water within the bay (Swanson 2015). The most likely explanation for the estimated hatch length for Surf Smelt being so high compared to the reported hatch length range is that there were only a limited number of Surf Smelt larvae from the two entrainment stations and the two nearby source water stations. A low number of measured larval fish for Surf Smelt would introduce error into the bootstrap technique, so the estimated values may be wrong. Therefore, the duration for Surf Smelt used in this study is 30 days.

5.1 ETM Assessments

This section presents and discusses the results of the ETM for each of the taxa.

5.1.1 Arrow Goby

The ETM analysis of the data for Arrow Goby using a period of larval exposure of 17.5 d results in an estimate of entrainment mortality to the source water population of approximately 0.376% for the two intakes if operated at full capacity the entire year (**Table 5-2**). The difference between the estimates of P_M for the two intakes partially reflects the higher intake volume at the RMT II intake (Station E1; P_M = 0.301%), but also the lower entrainment estimates at Station E2 (P_M = 0.075%), especially during the June survey when the largest proportion of the source water population was present. The *PE* estimates for that survey received a weight (f_i) of 0.55 in the ETM calculations. The highest concentrations of any of the larvae collected during the study occurred during the June survey at Station E1 for Arrow Goby (10,673 per 1,000 m^3). This resulted in the high entrainment estimate for that survey, but high concentrations at the source water stations during that survey resulted in an estimate of *PE* that was only 40% higher than the estimate for the July survey.

Table 5-2. ETM results for Arrow Goby showing survey estimates of numbers of larvae for the total Humboldt Bay source water and the estimated entrainment at the two intake locations, E1 and E2. The estimated daily entrainment for the two intakes were based on daily intake volumes for the RMT II (Station E1) and RTD (Station E2) intakes of $7.92x10^6$ gal (29,980 m^3) and $3.96x10^6$ gal (14,990 m^3) per day, respectively.

Survey	Total Source Water (1000s)	Station E1 (1000s)	Station E2 (1000s)	f_i	*PE* Estimate Station E1	*PE* Estimate Station E2	Survey ETM Estimate Station E1	Survey ETM Estimate Station E2
Jan	114.8	0.00	0.00	0.0002	0.000000	0.000000	0.000247	0.000247
Feb	58.7	0.00	0.00	0.0001	0.000000	0.000000	0.000126	0.000126
Mar	5,006.9	1.47	1.12	0.0108	0.000105	0.000080	0.010739	0.010744
Apr	6,520.3	0.59	0.36	0.0140	0.000044	0.000027	0.014000	0.014005
May	48,586.0	0.70	0.85	0.1044	0.000008	0.000010	0.104390	0.104387
June	257,755.8	319.98	31.14	0.5539	0.000252	0.000024	0.551447	0.553643
July	31,700.0	27.26	0.97	0.0681	0.000177	0.000006	0.067909	0.068111
Aug	108,821.8	17.86	25.83	0.2338	0.000076	0.000110	0.233533	0.233395
Sept	3,306.7	0.00	0.21	0.0071	0.000000	0.000038	0.007106	0.007101
*Oct	2,391.1	0.62	0.40	0.0051	0.000083	0.000053	0.005131	0.005133
Nov	800.1	0.18	0.43	0.0017	0.000079	0.000189	0.001717	0.001714
Dec	301.3	0.15	0.00	0.0006	0.000156	0.000000	0.000646	0.000647
	Sums of Survey Estimates				**Average *PEs***		**P_M Estimates**	
	465,363.5	368.81	61.31		0.000082	0.000045	0.003010	0.000747
							0.3010%	**0.0747%**
							Total P_M =	**0.3757%**

5.1.2 Bay Goby

The ETM analysis of the data for Bay Goby using a period of larval exposure of 6.5 d results in an estimate of entrainment mortality to the source water population of approximately 0.117% (**Table 5-3**). This is the P_M due to entrainment for both intakes if operated at full capacity the entire year. The P_M estimates for Bay Goby at the RMT II intake, represented by Station E1, and at the RTD intake, represented by Station E2 are 0.076% and 0.040%, respectively. The difference between the estimates of P_M for the two intakes reflects the higher intake volume at the RMT II intake (Station E1). The estimate of the proportion of the source water population exposed to entrainment (f_i) during the year shows that the highest source water abundances and highest entrainment occurred during the surveys from August through October and also in December.

Table 5-3. ETM results for Bay Goby showing survey estimates of numbers of larvae for the total Humboldt Bay source water and the estimated entrainment at the two intake locations, E1 and E2. The estimated daily entrainment for the two intakes were based on daily intake volumes for the RMT II (Station E1) and RTD (Station E2) intakes of 7.92x10^6 gal (29,980 m^3) and 3.96x10^6 gal (14,990 m^3) per day, respectively.

Survey	Total Source Water (1000s)	Station E1 (1000s)	Station E2 (1000s)	f_i	*PE* Estimate Station E1	*PE* Estimate Station E2	Survey ETM Estimate Station E1	Survey ETM Estimate Station E2
Jan	4,902.0	0.38	0.22	0.0433	0.000045	0.000026	0.043329	0.043335
Feb	484.7	-	-	0.0043	0.000000	0.000000	0.004285	0.004285
Mar	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
Apr	1,972.2	1.39	0.60	0.0174	0.000328	0.000141	0.017400	0.017421
May	1,814.2	1.02	0.00	0.0160	0.000307	0.000000	0.016008	0.016041
June	7,057.5	-	0.74	0.0624	0.000000	0.000042	0.062401	0.062383
July	6,153.6	2.44	0.61	0.0544	0.000116	0.000029	0.054368	0.054399
Aug	45,518.9	14.64	3.39	0.4025	0.000114	0.000026	0.402170	0.402399
Sept	13,326.5	4.61	4.55	0.1178	0.000150	0.000148	0.117715	0.117716
Oct	12,045.3	6.35	0.51	0.1065	0.000174	0.000014	0.106381	0.106493
Nov	7,996.2	-	4.12	0.0707	0.000000	0.000295	0.070701	0.070565
Dec	11,828.3	4.55	1.08	0.1046	0.000151	0.000036	0.104480	0.104559
	Sums of Survey Estimates				**Average *PE*s**		**P_M Estimates**	
	113,099.3	35.37	15.82		0.000115	0.000063	0.000762	0.000404
							0.0762%	**0.0404%**
							Total P_M =	**0.1166%**

5.1.3 Whitebait Smelt

The ETM analysis of the data for Whitebait Smelt using a period of larval exposure of 26.2 d results in an estimate of entrainment mortality to the source water population of approximately 0.046% (**Table 5-4**). This is the P_M due to entrainment for both intakes if operated at full capacity the entire year. The P_M estimates for Whitebait Smelt at the RMT II intake, represented by Station E1, and at the RTD intake, represented by Station E2 are 0.032% and 0.014%, respectively. The difference between the estimates of P_M for the two intakes reflects the higher intake volume at the RMT II intake (Station E1). The estimate of the proportion of the source water population exposed to entrainment (f_i) during the year shows that the highest source water abundances and highest entrainment occurred during the June survey.

Table 5-4. ETM results for Whitebait Smelt showing survey estimates of numbers of larvae for the total Humboldt Bay source water and the estimated entrainment at the two intake locations, E1 and E2. The estimated daily entrainment for the two intakes were based on daily intake volumes for the RMT II (Station E1) and RTD (Station E2) intakes of 7.92x10^6 gal (29,980 m^3) and 3.96x10^6 gal (14,990 m^3) per day, respectively.

Survey	Total Source Water (1000s)	Station E1 (1000s)	Station E2 (1000s)	f_i	*PE* Estimate Station E1	*PE* Estimate Station E2	Survey ETM Estimate Station E1	Survey ETM Estimate Station E2
Jan	7,042.7	1.14	0.17	0.0430	0.000013	0.000002	0.042973	0.042986
Feb	2,534.8	0.15	0.08	0.0155	0.000005	0.000003	0.015470	0.015471
Mar	3,730.2	0.44	0.08	0.0228	0.000009	0.000002	0.022763	0.022768
Apr	12,164.6	4.60	2.29	0.0743	0.000043	0.000021	0.074168	0.074210
May	23,302.6	7.48	0.71	0.1422	0.000024	0.000002	0.142148	0.142228
June	105,139.2	10.73	7.39	0.6418	0.000007	0.000005	0.641638	0.641675
July	7,836.0	0.78	0.09	0.0478	0.000007	0.000001	0.047821	0.047829
Aug	2,034.9	0.15	-	0.0124	0.000005	0.000000	0.012419	0.012421
Sept	45.5	-	0.07	0.0003	0.000000	0.000773	0.000277	0.000272
Oct	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
Nov	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
Dec	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
	Sums of Survey Estimates				**Average *PEs***		**P_M Estimates**	
	163,830.6	25.48	10.88		0.000009	0.000067	0.000323	0.000142
							0.0323%	0.0142%
							Total PM =	**0.0464%**

5.1.4 Pacific Herring

The ETM analysis of the data for Pacific Herring using a period of larval exposure of 9.4 d results in an estimate of entrainment mortality to the source water population of approximately 0.031% (**Table 5-5**). This is the P_M due to entrainment for both intakes if operated at full capacity the entire year. The P_M estimates for Pacific Herring at the RMT II intake, represented by Station E1, and at the RTD intake, represented by Station E2 are 0.021% and 0.010%, respectively. The difference between the estimates of P_M for the two intakes is likely due to the difference in volume between the two intakes. The estimate of the proportion of the source water population exposed to entrainment (f_i) during the year shows that over 95% of the Pacific Herring larvae occurred during the March survey.

Table 5-5. ETM results for Pacific Herring showing survey estimates of numbers of larvae for the total Humboldt Bay source water and the estimated entrainment at the two intake locations, E1 and E2. The estimated daily entrainment for the two intakes were based on daily intake volumes for the RMT II (Station E1) and RTD (Station E2) intakes of 7.92×10^6 gal (29,980 m^3) and 3.96×10^6 gal (14,990 m^3) per day, respectively.

Survey	Total Source Water (1000s)	Station E1 (1000s)	Station E2 (1000s)	f_i	*PE* Estimate Station E1	*PE* Estimate Station E2	Survey ETM Estimate Station E1	Survey ETM Estimate Station E2
Jan	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
Feb	3,028.9	0.83	0.61	0.0422	0.000150	0.000110	0.042122	0.042138
Mar	68,564.8	4.56	1.51	0.9548	0.000016	0.000005	0.954704	0.954801
Apr	108.5	-	0.07	0.0015	0.000000	0.000506	0.001511	0.001504
May	104.8	0.17	-	0.0015	0.000472	0.000000	0.001452	0.001459
June	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
July	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
Aug	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
Sept	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
Oct	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
Nov	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
Dec	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
	Sums of Survey Estimates				**Average *PEs***		**P_M Estimates**	
	71,807.0	5.56	2.19		0.000053	0.000052	0.000210	0.000098
							0.0210%	0.0098%
							Total PM =	**0.0308%**

5.1.5 Pacific Tomcod

The ETM analysis of the data for Pacific Tomcod using a period of larval exposure of 5.66 d results in an estimate of entrainment mortality to the source water population of approximately 0.084% (**Table 5-6**). This is the P_M due to entrainment for both intakes if operated at full capacity the entire year. The P_M estimates for Pacific Tomcod at the RMT II intake, represented by Station E1, and at the RTD intake, represented by Station E2 are 0.075% and 0.009%, respectively. The difference between the estimates of P_M for the two intakes partially reflects the difference in volume between the two intakes but is also due to the much lower entrainment at Station E2 (7,450 vs 920), which far exceeds the difference in the volumes. The difference in entrainment estimates for the two intakes is especially apparent in the estimates for the January, February, and June surveys. The estimate of the proportion of the source water population exposed to entrainment (f_i) during the year shows that the largest proportions of the larvae occurred during the January and April surveys.

Table 5-6. ETM results for Pacific Tomcod showing survey estimates of numbers of larvae for the total Humboldt Bay source water and the estimated entrainment at the two intake locations, E1 and E2. The estimated daily entrainment for the two intakes were based on daily intake volumes for the RMT II (Station E1) and RTD (Station E2) intakes of 7.92x10^6 gal (29,980 m^3) and 3.96x10^6 gal (14,990 m^3) per day, respectively.

Survey	Total Source Water (1000s)	Station E1 (1000s)	Station E2 (1000s)	f_i	*PE* Estimate Station E1	*PE* Estimate Station E2	Survey ETM Estimate Station E1	Survey ETM Estimate Station E2
Jan	7,158.6	2.91	0.05	0.3763	0.000145	0.000002	0.376012	0.376316
Feb	1,899.2	0.46	-	0.0998	0.000062	0.000000	0.099804	0.099839
Mar	663.6	-	0.07	0.0349	0.000000	0.000037	0.034883	0.034876
Apr	8,586.7	2.89	0.81	0.4514	0.000106	0.000029	0.451127	0.451322
May	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
June	714.5	1.19	-	0.0376	0.000660	0.000000	0.037420	0.037560
July	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
Aug	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
Sept	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
Oct	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
Nov	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
Dec	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
	Sums of Survey Estimates				**Average *PEs***		**P_M Estimates**	
	19,022.5	7.45	0.92		0.000081	0.000006	0.000754	0.000088
							0.0754%	0.0088%
							Total PM =	**0.0842%**

5.1.6 Surf Smelt

The ETM analysis of the data for Surf Smelt using a period of larval exposure of 30 d results in an estimate of entrainment mortality to the source water population of approximately 0.078% (**Table 5-7**). This is the P_M due to entrainment for both intakes if operated at full capacity the entire year. The duration of 30 d was used because of the small number of Surf Smelt larvae collected and the large variation in lengths made calculation of a duration difficult to apply using the methods employed for the other taxa. The P_M estimates for Surf Smelt at the RMT II intake, represented by Station E1, and at the RTD intake, represented by Station E2 are 0.053% and 0.025%, respectively. The difference between the estimates of P_M for the two intakes reflects the difference in volume . The estimate of the proportion of the source water population exposed to entrainment (f_i) during the year shows that the largest proportion of the larvae occurred during the June survey ($f_i = 0.75$).

Table 5-7. ETM results for Surf Smelt showing survey estimates of numbers of larvae for the total Humboldt Bay source water and the estimated entrainment at the two intake locations, E1 and E2. The estimated daily entrainment for the two intakes were based on daily intake volumes for the RMT II (Station E1) and RTD (Station E2) intakes of 7.92x106 gal (29,980 m3) and 3.96x106 gal (14,990 m3) per day, respectively.

Survey	Total Source Water (1000s)	Station E1 (1000s)	Station E2 (1000s)	f_i	*PE* Estimate Station E1	*PE* Estimate Station E2	Survey ETM Estimate Station E1	Survey ETM Estimate Station E2
Jan	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
Feb	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
Mar	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
Apr	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
May	87.9	0.15	-	0.0043	0.000183	0.000000	0.004308	0.004332
June	15,239.6	3.58	1.49	0.7510	0.000017	0.000007	0.750581	0.750808
July	437.4	-	0.09	0.0216	0.000000	0.000038	0.021555	0.021531
Aug	385.9	-	-	0.0190	0.000000	0.000000	0.019018	0.019018
Sept	197.3	0.16	0.08	0.0097	0.000147	0.000071	0.009680	0.009702
Oct	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
Nov	1,554.9	0.34	0.38	0.0766	0.000016	0.000018	0.076585	0.076581
Dec	2,390.1	0.29	-	0.1178	0.000012	0.000000	0.117736	0.117780
	Sums of Survey Estimates				**Average *PEs***		**P_M Estimates**	
	20,293.3	4.51	2.03		0.000031	0.000011	0.000535	0.000248
							0.0535%	0.0248%
							Total PM =	**0.0783%**

5.1.7 Pacific Staghorn Sculpin

The ETM analysis of the data for Pacific Staghorn Sculpin using a period of larval exposure of 16.6 d results in an estimate of entrainment mortality to the source water population of approximately 0.096% (**Table 5-8**). This is the P_M due to entrainment for both intakes if operated at full capacity the entire year. The P_M estimates for Surf Smelt at the RMT II intake, represented by Station E1, and at the RTD intake, represented by Station E2 are 0.064% and 0.032%, respectively. The difference between the estimates of P_M for the two intakes reflects the difference in their volumes. The estimate of the proportion of the source water population exposed to entrainment (f_i) during the year shows that the largest proportion of the larvae occurred during the January and February surveys (f_i = 0.3194 and 0.2180 respectively).

It is likely that the estimates of P_M for the two intakes are conservative since the head capsule dimensions for larvae at the length of the 95th quantile (0.35 in. [8.9 mm]) in **Table 5-1** are close to, and may exceed, the 0.04 in. (1.0 mm) width of the slot openings on the intakes as shown in **Figure 5-1**. The analysis on the efficiency of the WWS modules in Section 6.0 indicate that the probability of entrainment at the length of the 95th quantile is reduced to 63% (**Table 6-1**).

Table 5-8. ETM results for Pacific Staghorn Sculpin showing survey estimates of numbers of larvae for the total Humboldt Bay source water and the estimated entrainment at the two intake locations, E1 and E2. The estimated daily entrainment for the two intakes were based on daily intake volumes for the RMT II (Station E1) and RTD (Station E2) intakes of 7.92x10^6 gal (29,980 m^3) and 3.96x10^6 gal (14,990 m^3) per day, respectively.

Survey	Total Source Water (1000s)	Station E1 (1000s)	Station E2 (1000s)	f_i	*PE* Estimate Station E1	*PE* Estimate Station E2	Survey ETM Estimate Station E1	Survey ETM Estimate Station E2
Jan	4,662.3	1.64	0.69	0.3194	0.000065	0.000028	0.319089	0.319288
Feb	3,182.2	0.56	0.36	0.2180	0.000039	0.000025	0.217885	0.217936
Mar	2,507.2	0.29	0.07	0.1718	0.000018	0.000004	0.171728	0.171768
Apr	1,953.3	-	-	0.1338	0.000000	0.000000	0.133832	0.133832
May	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
June	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
July	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
Aug	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
Sept	73.3	0.12	-	0.0050	0.000305	0.000000	0.004997	0.005022
Oct	-	-	-	0.0000	0.000000	0.000000	0.000000	0.000000
Nov	770.7	-	0.22	0.0528	0.000000	0.000086	0.052802	0.052726
Dec	1,446.5	0.37	-	0.0991	0.000044	0.000000	0.099032	0.099104
	Sums of Survey Estimates				Average *PE*s		P_M Estimates	
	14,595.5	2.98	1.34		0.000039	0.000012	0.000636	0.000324
							0.0636%	0.0324%
							Total PM =	0.0960%

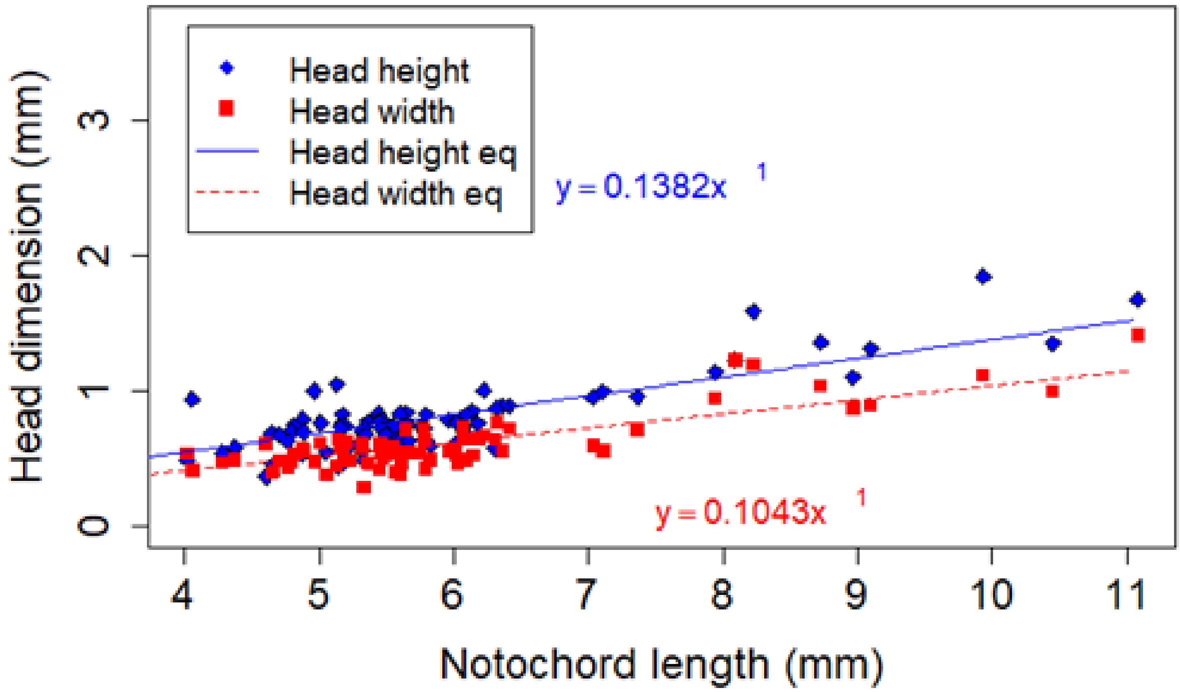


Figure 5-1. Plot of head capsule height and width against notochord length for Pacific Staghorn Sculpin. The allometric regression equations for the measurements are shown on the graph.

5.1.8 ETM Summary

The ETM estimates of P_M for the seven taxa presented in the previous sections are presented in **Table 5-9**. The average P_M from the estimates for the combined volume for the two intakes (0.118%) was similar in value to the results from the volumetric results for Model M3 in the Initial ETM Assessment (**Table 3-1**). The results from the Initial ETM Assessment ranged from 0.062% to 0.104% depending on the larval durations used in the analysis.

The highest ETM estimate of P_M from this study was 0.376% for Arrow Goby (**Table 5-9**). This is because, compared to other taxa, Arrow Goby were in high abundance at the entrainment stations compared to the source water stations (**Table 4-2**). Therefore, the intakes would be predicted to entrain a higher proportion of the population of Arrow Goby in the bay than the other taxa analyzed. Arrow Goby live on mudflats, which are one of the predominant habitat types in Arcata Bay. In the habitat areas shown in **Figure 2-2**, mudflats would occur in the areas designated as macroalgae, eelgrass, and intertidal. These areas comprise most of Arcata Bay and also occur on Tuluwat Island and in areas along the Main Channel. The prevalence of mudflat habitat near the location of the intakes explains the high P_M for Arrow Goby compared to the other species. Arrow Goby may spawn multiple times per year (Brothers 1975) and this may explain why they were collected during all 12 surveys at both the intake and source water stations (**Table 5-2**). This high number of surveys means the ETM estimate for Arrow Goby is likely to be less error prone than taxa collected from fewer surveys. They occurred in highest abundance at the stations in Arcata Bay (Stations SW1, SW2, and SW6 **Figure 4-8**) and also at the two entrainment stations (**Figure 4-7**), which are located in or near Arcata Bay (see also

Table 4-2). Source water stations outside of Arcata Bay had lower concentrations of Arrow Goby than the entrainment stations. Furthermore, Arrow Goby had a relatively low larval duration compared with Whitebait and Surf Smelt (**Table 5-1**). Typically, a lower larval duration would result in a lower P_M, but Arrow Goby has a higher P_M than both these taxa.

The Bay Goby has less specific habitat preferences than the Arrow Goby. The sampling results show that the number of Bay Goby throughout Humboldt Bay are much more evenly distributed than Arrow Goby, which were more abundant at the Arcata Bay and intake stations. Because of this, the P_M for Bay Goby is 0.117% (**Table 5-9**), which is less than Arrow Goby and closer the volumetric estimates calculated in the Initial ETM Assessment. For example, the estimate in the Initial ETM Assessment for Pacific Herring was 0.075% (**Table 3-1**). The results for these two taxa are comparable because Pacific Herring has a similar larval duration (6.8 days) to the duration used for Bay Goby (6.5 days) in these studies (**Table 5-1**). Arrow Goby, Bay Goby, and Pacific Herring all produce demersal eggs that are negatively buoyant and/ or remain close to the substrate. Unlike gobies, which are presumed to use their burrows to harbor fertilized demersal eggs, Pacific Herring attach fertilized eggs to submerged vegetation such as algae and seagrass where they remain unattended during development. Pacific Herring eggs are also found attached to submerged hard habitat including rocks, pier pilings, and other structures. Once hatched, larval Pacific Herring remain in the plankton for up to 70 days and are generally surface-oriented. Pelagic durations of gobies are less well understood. Based on the results of this study, it appears that Arrow Goby larvae are more discretely distributed in Humboldt Bay relative to Bay Goby, which appears to have a distribution pattern more similar to species like Pacific Herring.

The NL measurements for most of the taxa occurred within a very narrow range compared to previous entrainment studies (e.g., Tenera 2005, Tenera 2011). Many of these studies were conducted at power plants with large volume intakes where the frequency and scope of the sampling was justifiably more extensive than the sampling for this study due to the potential for greater impacts. The volumes of the intakes at some of the power plants are two orders of magnitude greater than the volumes for the Humboldt Bay intakes, and as a result, some of the power plant studies included biweekly and sometimes weekly sampling at the intakes with four or more samples per day. Therefore, due to the narrow range of measurements in this study, no attempt was made to adjust the ETM estimates based on the potential for reduced entrainment impacts to larger larvae as a consequence of the WWS modules.

Estimates of APF for each of the taxa analyzed are shown in **Table 5-9**. The ETM estimates were based on the approximate surface area of Humboldt Bay at MSL which is consistent with the estimates of the volumes at MSL for the different areas of the bay used in the ETM analyses. The average estimate of APF from the seven taxa was 17.9 acres (7.2 hectares). On previous projects where APF has been used (MBC and Tenera 2005), the amount of habitat area required as compensation for the effects of entrainment has been based on the average APF from the taxa analyzed for the study. The APF is a conservative estimate of the area required to compensate for entrainment losses because, as discussed above, the actual spawning habitat for the species being analyzed is much more limited than the entire bay. This is evident in the sampling results for Arrow Goby, but in fact none of the seven taxa occur throughout the bay in all habitats. The APF is conservative and is based on the entire source water because it is meant to compensate for entrainment losses to a much broader range of planktonic organisms than just the ichthyoplankton sampled in the study.

Table 5-9. Summary of ETM results for taxa analyzed from sampling in Humboldt Bay from January–December 2022 with ETM estimates of P_M for the RMT II (Station E1) and RTD (Station E2) intakes. Area Production Foregone (APF) estimates were calculated based on an estimate of the surface area of Humboldt Bay at MSL of 15,098 acres (6,110 hectares).

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

5.2 Longfin Smelt Assessment

The total estimated entrainment totals for the study year of 2022 from **Table 4-3** for LFS for the two intakes was 28,013 (SE = 22,086). A total of six LFS larvae were collected from Station E1 (RMT II Intake) which equated to an estimated annual entrainment of 26,380 (Std. Err. = 22,026) larvae, and one larva was collected from Station E2 (RTD Intake) which equates to an estimated annual entrainment of 1,633 (SE = 1,633) larvae. The estimates are based on the study year period calculated using the survey intervals in **Table 4-1**.

In Appendix N of the Final Environmental Impact Report (FEIR) for this project,[15] an approach was presented for estimating the number of female adult LFS required to produce the estimated entrainment of LFS larvae. The method for extrapolating the larval losses to adult females is termed fecundity hindcasting (FH) (Steinbeck et al. 2007). Fecundity hindcasting can be more broadly categorized as adult equivalent modeling which has historically been used in intake assessments at large power plants (Steinbeck et al. 2007). The approach used in this study is explained in the following paragraphs.

The average NL of the LFS larvae collected during the sampling at the two entrainment stations and the two closest source water stations (SW2 and SW3) was 0.33 in. (8.5 mm). Using the life

[15] Appendix N - Tenera Humboldt Bay Piling Removal Restoration for Longfin Smelt and other Marine Resources. In Final Environmental Impact Report Samoa Peninsula Land-based Aquaculture Project, County of Humboldt, Planning and Building Department, June 30, 2022, Samoa Peninsula Land-based Aquaculture Project, SCH#: 2021040532. Prepared by GHD, Eureka, CA

history information on hatch length and larval growth for LFS in Section 4.2.8, the estimated age of the entrained larvae was 17.7 d. The calculations in Appendix N were based on an estimated larval growth rate of 0.005 in. per d (0.14 mm per d) from CDFW (2009). More recent information presented in Section 4.2.8 from Lewis et al. (2020) indicate a larval growth rate of 0.0067 in. per d (0.17 mm per d), which was used to estimate the duration for this analysis.

The approach in Appendix N of the FEIR used the following life history information for LFS: 1) an average fecundity of 5,000 eggs for an average sized female (Figure 3 in CDFW 2009); 2) an estimated hatching success rate for LFS eggs of 59% (Yanagitsuru et al. 2021b); and 3) an estimated daily survival rate for the larvae of 0.862. The estimate of daily survival in this report was based directly on an estimate of mortality of approximately 90% of early-stage larvae through day 20 from Tigan et al. (2019) that was cited in Yanagitsuru et al. (2021b). The daily survival over the 20 days was calculated as 0.891 and the estimated survival over 17.7 days was 0.130 ($0.891^{17.7}$ = Survival of 13.0 % and Mortality of 87.0%). These life history parameters were used to estimate that 383 17.7-day old larvae would result from the spawning of an average size female LFS. Therefore, the estimated take of 28,013 17.7-day LFS larvae is equivalent to the take of 73 average size, reproductive age, female LFS.

Similar to the APF that provides estimates of habitat that could be used in determining the amount of habitat required to compensate for entrainment losses, the FH estimate calculated in Section 5.2 of 73 average size female LFS from the LFS entrainment estimate can be used to determine appropriate compensation for the take of LFS. Based on the conservative estimate of the required spawning area for a female LFS of 43 ft^2 (4 m^2) used in the Project FEIR, a mitigation area of 3,139 ft^2 (292 m^2) of LFS spawning, rearing, and nursery habitat would compensate for the entrainment losses from the intake when operated at full capacity.

This estimate does not account for the limited tolerances of the small LFS collected during the study to salinities greater than 10–12 psu (see Baxter 1999, Grimaldo et al. 2017, Yanagitsuru et al. 2021a cited in Section 4.2.8). The information presented in Section 4.2.8 indicates that the LFS larvae collected during the sampling would not survive the salinities levels that are close to seawater (~32 psu) which normally occur in the area of the intake. The salinity levels during the sampling indicate that the LFS collected at the two entrainment stations during the study were likely dead or in severe physiological stress at the time of collection.

6.0 Impact Assessment Discussion

This section includes a discussion of the results presented in sections 4 and 5. It also includes projections on the effectiveness of entrainment reductions using the proposed WWS modules and a conclusion that integrates the material.

6.1 Discussion

This study provides estimates of the potential effects to planktonic marine organisms resulting from the predicted entrainment of larvae during the operation of two intakes located off the Samoa Peninsula in Humboldt Bay (**Figure 1-1**). The proposed intake design capacities are 5,500 gallons per minute (gpm) (20.8 m^3 per minute) for the RMT II intake and 2,750 gpm (10.4 m^3 per minute) for the RTD intake for a total capacity of 8,250 gpm (31.2 m^3 per minute) or 11.88 million gallons per day (mgd) (44,970 m^3 per day). The total daily capacities for the RMT II and RTD intakes are 7.92 and 3.96 mgd (29,980 and 14,990 m^3), respectively. The ETM approach used in this study to estimate the effects of the intakes is the standard approach approved by California resource agencies for estimating the effects of entrainment. The ETM has been used on intake projects ranging from desalination plants with intake volumes similar to this project to large power plants with intake volumes of 2,500 mgd (9.5 million m^3) (Steinbeck et al. 2016). An Initial ETM Assessment that provided estimates for the initial permitting stages of the project used a simplified approach to the ETM that assumed that the concentration of larvae at the intake and in the source water are approximately equal. This allowed the ratio of the volumes of the intakes to the source water to be used as the estimates of *PE* for the analysis, an approach that was also used in the original formulation of the ETM (Boreman et al. 1978, 1981).

The ETM estimates of P_M from the Initial ETM Assessment were calculated using three source water models (**Table 3-1**). The results for the source water model based on the estimated tidal exchange ratios for the different areas of Humboldt Bay varied from 0.062% to 0.104% depending on the periods of larval exposure to entrainment used in the calculations. The average ETM estimate of P_M for the taxa analyzed from the sampling conducted during January–December 2022 for this study was 0.118% which was higher than the estimates in the Initial ETM Assessment (**Table 5-9**), but for all of the taxa except for Arrow Goby were within the range of the estimates (0.062 – 0.104%) from the earlier report. These results verify the usefulness of the volumetric ETM model in the initial permitting efforts. As discussed in Steinbeck et al. (2016), the use of the volumetric model is especially applicable in locations, such as open coastal habitats, where the source water areas are relatively homogeneous. Therefore, it is encouraging to see that the model may be applicable even in source water areas with varied habitats such as Humboldt Bay. As expected, the model is more applicable for species such as Bay Goby (P_M = 0.117) and Pacific Staghorn Sculpin (P_M = 0.096) that are associated with a broader range of habitats than Arrow Goby ((P_M = 0.376), which is more generally associated with mudflat habitats. The intakes are located in an area of the bay with large areas of mudflat habitats, which helps explain the higher estimate of P_M for Arrow Goby.

Although ETM estimates of P_M are typically used on projects in California to provide a basis for calculating mitigation (Raimondi 2011), the P_M also provides important information that should be used in the initial determination of whether the losses might be significant to the population and whether mitigation should be required for a project. The estimate of P_M provides the same type of information used by resource scientists in managing fisheries. Estimates of P_M are similar to estimates of the effects of fishing mortality on a population and, in this context, can be interpreted relative to other sources of mortality, except, in the case of P_M, the mortality due to entrainment is occurring to the population of larvae in the source water, and not an adult population that may include reproductive adults. In fact, one of the primary goals of fishery management is to have a good estimate of the proportional mortality due to fishing for individual fish stocks. This is often difficult due to the costs of obtaining good estimates of the stock of fish. The *PE* estimates of daily entrainment mortality in the ETM can also be compared directly to estimates of natural daily mortality This allows resource managers to determine if entrainment represent a large incremental increase in mortality compared to natural mortality rates. If estimates of instantaneous natural mortality (Ricker 1975) or natural variation in abundances for the larvae and adult populations are available, then these estimates provide additional context for interpreting the effects of P_M. ETM estimates of P_M that are sufficiently small compared to natural mortality or natural variation in larval population size provide evidence that the effects of entrainment are negligible and therefore compensation for entrainment losses is not necessary. All of the ETM estimates of P_M represent percentage losses to larval populations due to entrainment of less than 0.4% for all the taxa with an average loss of only 0.118%. Average annual larval fish abundances off the coast of California were shown to vary by as much as four orders of magnitude among years in a study by McClatchie et al. (2018). This large variation is likely due to differences in larval production and mortality among years due to changes in ocean conditions. Therefore, an additional source of mortality that averages only 0.118% is unlikely to have any significant effect on biological populations in the bay.

In considering impacts on source water populations of fishes it is also important to recognize that not all populations of fishes in Humboldt Bay will be susceptible to impacts from the intakes caused by entrainment or impingement. The intake design utilizes small slot openings (0.04 in. [1.0 mm]) and has a large enough surface area that velocities at the screen face are reduced to levels that should eliminate any effects of impingement. As a result, there are many fishes in Humboldt Bay that should not be affected by the intake. These groups include sharks and rays that either have large egg cases or give birth to small but fully formed juveniles that would not be subject to entrainment. Similar to sharks and rays, surfperches give birth to fully formed juveniles that are too large to be subject to entrainment. In the study of the fishes of Humboldt Bay by Gleason et al. (2007), sharks, rays and surfperch made up almost 16% of the total fishes collected including Shiner Surfperch that had the second highest abundance of the 67 species collected.

The only adjustment to the ETM analyses to account for the small size of the slot openings on the screens involved limiting the data used in the calculations to larvae less than approximately one inch (25 mm) NL. At power plants with intake screens that use larger square mesh with openings of 0.375 in. (9.5 mm), a larval NL of 1.2 in. (30 mm) is used as the upper limit of the larvae used in ETM assessments. Most fish larvae larger than approximately one inch (25 mm) NL are able to swim and avoid entrainment. Therefore, this was the upper NL limit of the larvae used in this assessment, because the two Humboldt Bay intakes are planned to use small slot openings of 0.04 in. (1.0 mm) and have very low velocities at the screen surface. The limits on the size of the larvae included in the analyses are difficult to implement in the field, so during the processing of the samples, larvae larger than one inch (25 mm) NL were identified as not entrainable and were not included in any of the data summaries or analyses in this report. Of the 1,044 larvae measured as part of the sample processing, only six larvae, all Surf Smelt, were larger than one inch (25 mm) NL. Only the larvae with NL less than one inch (25 mm) were included in the calculations of the larval periods of entrainment exposure. As discussed in the results for Pacific Staghorn Sculpin, the dimensions of the larvae at the length of the 95th quantile (0.35 in. [8.9 mm]) used in calculating the larval period of exposure are close to the 0.04 in. (1.0 mm) width of the slot openings on the intakes (**Table 5-1**). Therefore, the ETM estimates of P_M for this species are conservative since some percentage of the larger larvae for this species would not pass through the intakes. The estimates of the reductions due to the WWS for each of the seven taxa are presented in the next section.

The same allometric regression model used in the analysis of head capsule height and width shown in **Figure 5-1** for Pacific Staghorn Sculpin larvae measured during the study was also used for the other species analyzed using the ETM. These analyses were used to estimate the proportion of the larvae at different lengths that would be entrained through the small WWS slot openings (0.04 in. [1.0 mm]) planned to be used at the two intakes. The analyses of the projected efficiency of the WWS for the fish taxa analyzed for the study are provided in the next section.

6.1.1 Estimated Wedgewire Screen Efficiency

The potential for WWS systems, such as the modules proposed for the two Humboldt Bay intakes, to reduce the effects of entrainment of larval fishes has been investigated using field (Ehrler and Raifsnider 2000, Weisberg et al. 1987) and laboratory (EPRI 2003, Amaral 2005) studies. Ehrler and Raifsnider (2000) undertook a field evaluation of WWS technology on the Delaware River which indicated an approximate 50% reduction in total annual entrainment of striped bass larvae with the use of 0.04 in. (1.0 mm) WWS. Field studies by Weisberg et al. (1987) using WWS with slot sizes of 0.04, 0.08, and 0.12 in. (1, 2, and 3 mm) detected statistically significant reductions for Bay Anchovy (*Anchoa mitchilli*) larvae longer than 0.43 in. (11 mm) and Naked Goby (*Gobiosoma bosci*) larvae longer than 0.28 in. (7 mm). Amaral (2005) used laboratory flume studies to estimate the combined entrainment and impingement reductions due to cylindrical WWS modules with three slot sizes (0.02, 0.04, and 0.08 in. [0.5, 1.0, and 2.0 mm]) and compared these to the results with an unscreened intake. Larvae from eight species of fish were used to estimate entrainment and impingement of species across a range of life histories and swimming capabilities (Striped Bass [*Morone saxatilis*], Winter Flounder [*Pleuronectes americanus*], Yellow Perch [*Perca flavescens*], Rainbow Smelt [*Osmerus mordax*], Common Carp [*Cyprinus carpio*], White Sucker [*Catostomus commersoni*], Alewife [*Alosa pseudoharengus*], and Bluegill [*Lepomis macrochirus*]). Testing at different channel and through-screen velocities showed significant reductions in combined impingement and entrainment at all screen conditions (slot size and through-screen velocity) relative to the un-screened alternative.

The results from studies by Amaral (2005) and Weisberg et al. (1987) concluded that the exclusion efficiency of WWS is highly dependent on the interaction between the length of the organisms exposed to entrainment and the WWS slot size. The length and overall morphology of the organisms exposed to entrainment may vary between WWS locations and times of the year because of differences in the species of larval fish present throughout the year and between locations.

Although previous studies on the effectiveness of WWS at reducing entrainment have focused on fish length (Weisberg et al. 1987, Amaral 2005), there has also been a general recognition that larval morphology, and not just length, is important in estimating the effectiveness of different screen openings at reducing entrainment (Schneeburger and Jude 1981, EPRI 2005). Normandeau (2009) used a metric called "greatest body depth" (GBD) to model WWS entrainment benefits, where GBD is defined as either the thickness of the head or the deepest part of the body. While the body depth of fish larvae has been measured and used in estimating the potential effectiveness of different screen openings at reducing entrainment (Schneeburger and Jude 1981, Normandeau 2009), Bell (1973) also pointed out that larvae are prevented from passing through a screen based on the dimensions of the head capsule, which in larval fishes is the only part of the body that is not easily compressed.

A recent review on the effectiveness of cylindrical screening systems at reducing entrainment of fishes by Coutant (2020) presents several examples and reasons why the reductions by the systems exceed the expected levels based on screen size and larval dimensions. Coutant (2020) discusses the design of cylindrical intake screen systems and the features that help reduce entrainment. These features include the cylindrical shape of the intakes, their alignment relative to existing tidal or river currents, and their low through-screen velocities. In a summary of lab studies on entrainment by cylindrical WWS, similar to the design proposed for the Humboldt Bay intakes, Coutant (2020) concludes that the contribution of screen-size opening, and through-screen velocity was a minor factor in the reduction in entrainment. The major factor was the cylindrical design of the intake and its orientation parallel to ambient current which creates a bow wave and the resulting flow dynamics help move larvae and other objects away from the screen surface where they may be subject to entrainment. The increased turbulence probably decreased the likelihood that larvae would be oriented exactly parallel to the screen slots where they could be more easily entrained. Although not as large a factor as the cylindrical design of the screen, sweeping currents along the screen surface that far exceed through-screen velocities also made entrainment unlikely. Therefore, entrainment loss estimates solely on larval size are likely to be highly conservative especially due to the proposed placement of the intake screens in an area of Humboldt Bay where they will be subject to strong sweeping velocities on ebb and flood tides.

Unfortunately, most of the taxa used in the analysis of screen efficiency in Tenera (2011) did not occur in large enough abundance during the Humboldt Bay study to allow for comparison except for gobies. Most of the data used in Tenera (2011) were from locations in central and southern California which is outside of the range where species of smelt and Pacific Tomcod found in Humboldt Bay are abundant. Therefore, the comparison with the data from this study is limited to gobies.

A pilot study on the efficiency of WWS modules at reducing entrainment for California coastal fishes was conducted for a planned desalination project to be placed offshore of Santa Cruz, California (Tenera 2010). A series of tests were conducted using a small WWS module using a slot width of 0.08 in. (2 mm) with a through-screen velocity of 0.3 fps. Although not statistically significant due to highly variable results, a reduction of nearly 20% in total entrainment of all fish larvae was calculated between samples collected through the WWS module relative to an unscreened intake. The two intakes were placed below a pier and therefore did not benefit from the hydrodynamic flushing described by Coutant (2020) that would also benefit the WWS modules used for the Humboldt intakes due to the presence of strong tidal currents at the intake locations.

The same allometric regression model used in the analysis of notochord length and head capsule dimensions in Tenera (2011) was used in the regressions using the NL and head capsule measurements from the data collected during this study that are shown in **Figure 6-1** and **Figure 6-2**. The same plot and regressions for the Pacific Staghorn Sculpin head capsule dimensions are shown in **Figure 5-1**. The regression parameters were used to estimate the probabilities of entrainment and are presented in **Table 6-1**. The entrainment probabilities were calculated out to a length of 25 mm over the range of NL measurements available for each of the seven taxa.

The probabilities across the size range of entrainable larvae for a taxon can be used to assess the effects on population mortality when using a particular WWS slot width for reducing the entrainment of larvae. Two simple assumptions to calculate the reduction of mortality are: 1) linear growth over time; and 2) constant exponential natural mortality. These assumptions are reasonable because the period of time that the larvae are vulnerable to being entrained is likely to be very short. The period of time may only be a few days for fishes that are only subject to entrainment over a narrow size range, but for other fishes the period of time would likely never extend beyond one or two months. By assuming linear growth, length becomes directly proportional to age. As a larval cohort progresses through consecutive length classes it follows an exponential decrease in numbers over time due to natural mortality. Under these assumptions, each length (or age) would produce the same number of fishes at a length when they are not subject to entrainment. A first approximation of the reduction in entrainment for each screen mesh dimension can be made by averaging the length-specific entrainment probabilities. The inverse of this proportion ($1 - p$; where p is the average length-specific entrainment probability) determines the reduction of mortality due to the screen for the total cohort of larvae that would survive to the length or age when they are no longer subject to entrainment. The average reduction in mortality would need to be adjusted for the composition and size structure of the fish larvae for a specific location and sample year, but otherwise it provides an estimate of the population-level mortality identical to an adult equivalent model using constant growth and survival rates extrapolated to the length or age that the fish are no longer subject to entrainment (estimated to be 0.79–0.98 in. [20–25 mm] NL for this analysis). Fishes larger than this NL have swimming abilities that allow them to potentially avoid entrainment, especially at the reduced intake velocities that will occur at the Humboldt Bay intakes.

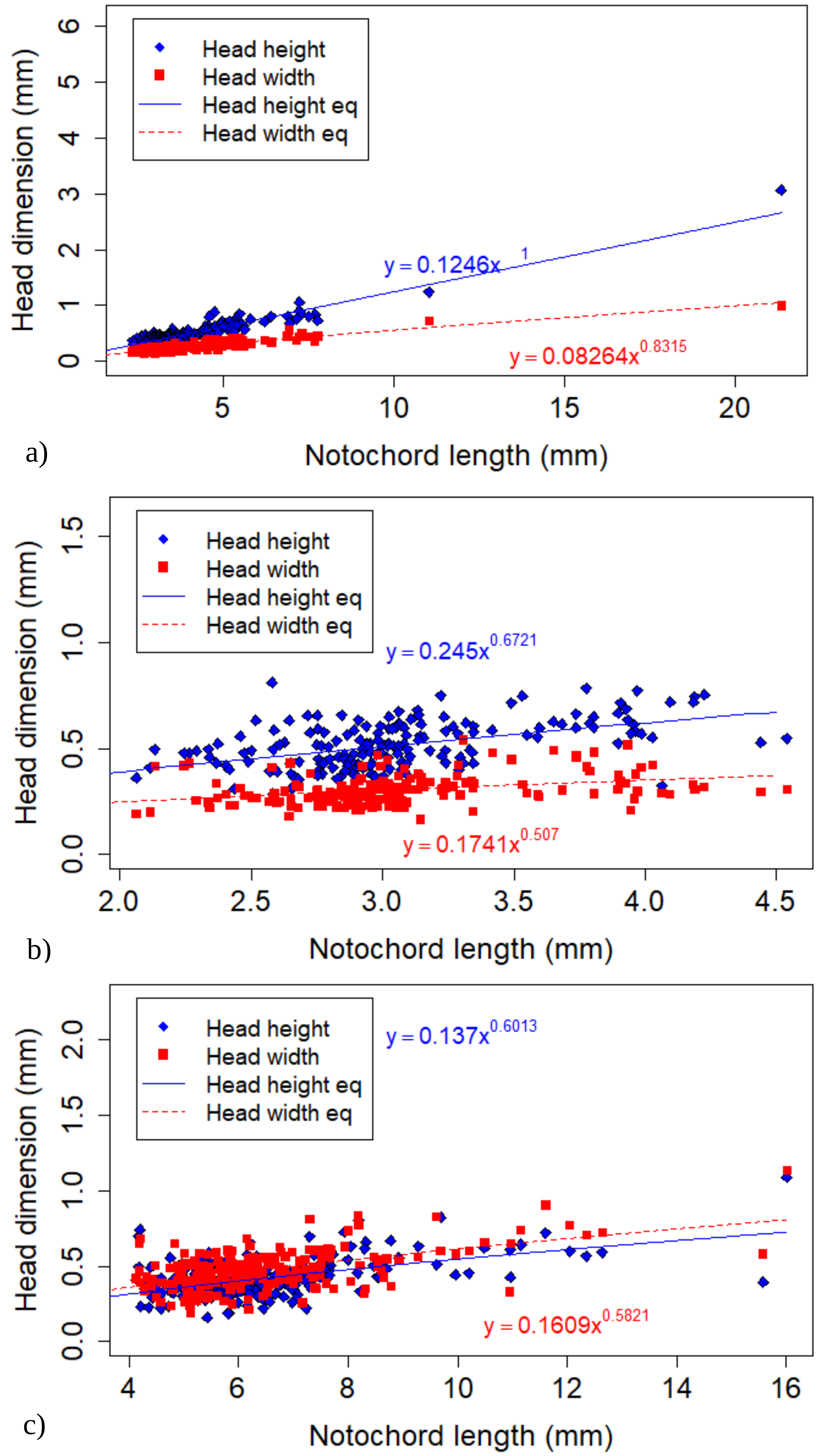


Figure 6-1. Plots of head capsule height and width against notochord length for a) Arrow Goby, b) Bay Goby, and c) Whitebait Smelt. The allometric regression equations are shown on the graphs.

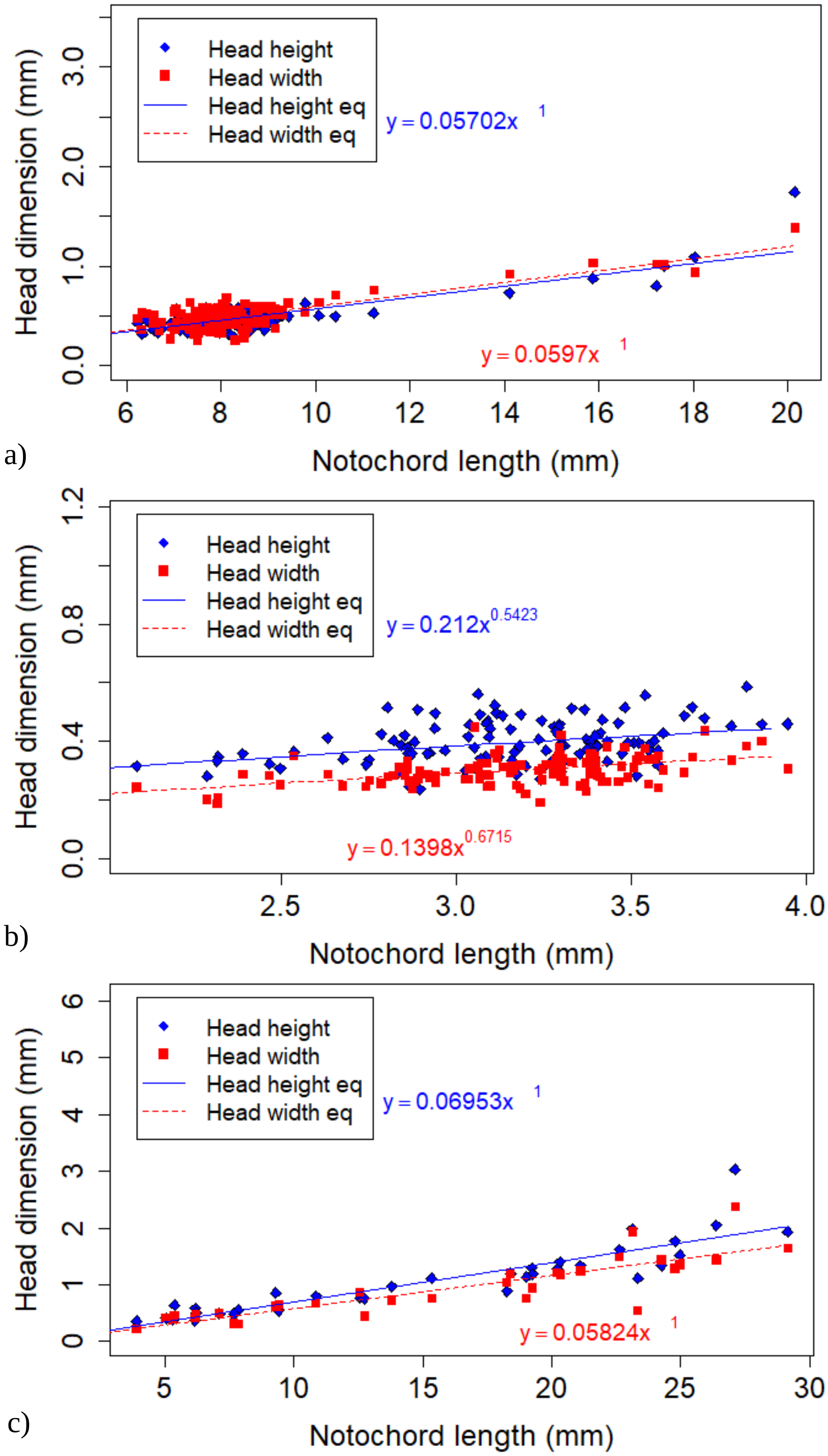


Figure 6-2. Plots of head capsule height and width against notochord length for a) Pacific Herring, b) Pacific Tomcod, and c) Surf Smelt. The allometric regression equations are shown on the graphs.

Table 6-1. Estimated probabilities of entrainment for fish larvae analyzed for the Humboldt Bay entrainment study at mm NL intervals from estimated hatch NL through 25 mm for a wedgewire slot size of 0.04 in. (1 mm) using estimates of variability around the allometric regressions shown in **Figure 5-1**, **Figure 6-1**, and **Figure 6-2**. Average proportion entrained of fishes from hatch length to 25 mm, and subsequent mortality reduction (the inverse of average proportion entrained) are also shown.

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

The problems of calculating the probabilities of entrainment with the limited range of larvae collected during the sampling in Humboldt Bay is shown by comparing the results presented in the Initial ETM Assessment for goby larvae from Tenera (2011) with the results from this study. The probabilities calculated using the data from the allometric regressions presented in the Initial ETM Assessment for goby larvae indicate that no larvae with a NL larger than 0.52 in. (13 mm) would be entrained through a screen with a slot opening of 0.04 in. (1.0 mm) (Table 5-3 in Tenera [2021]). This was due to a pronounced increase in the allometric growth of goby larvae that starts at a NL of approximately 0.28 in. (7 mm). Unfortunately, all the Arrow Goby and Bay

Goby collected during the present study were too small to exhibit this increase in growth rate. Therefore, while the results for Arrow Goby and Bay Goby indicate that larvae are still susceptible to entrainment at a NL of 0.98 in. (25 mm) (**Table 6-1**), it is more likely that the larvae are too large at this NL to be entrained based on the results from the Initial ETM Assessment.

Even with the limitations on the analysis of WWS efficiency due to the small size range of larvae collected which results in conservative estimates, the results in **Table 6-1** indicate large reductions in mortality for Pacific Herring and Pacific Staghorn Sculpin. It is also important to recognize that these probabilities are based on the conservative assumption that larvae close to the screen are orientated so that the only factor limiting entrainment is the head capsule dimension. Therefore, the probabilities in **Table 6-1** represent extremely conservative estimates of the potential effectiveness of WWS. The average reduction from the seven taxa is 38% which is almost twice the reduction in entrainment measured in testing of WWS modules associated with the study in Santa Cruz previously mentioned. Similar to the estimates in **Table 6-1**, the estimated reduction from the Santa Cruz study did not incorporate any of the hydrodynamic benefits of the WWS modules discussed by Coutant (2020).

In reality, observations show that properly designed WWS intake systems, similar to the system proposed for Humboldt Bay, likely far exceed the theoretical entrainment performance estimated based on head capsule dimensions. Video cameras installed on a WWS intake system for a pilot desalination project in southern California showed that small, entrainable, early post larval fishes were able to swim away from the screen if they drifted too close or made screen contact even when the intake system was operating, thereby avoiding entrainment or impingement (Tenera 2014b) (**Figure 6-3**). The intake system for this project was designed with a maximum through-slot velocity of 0.33 ft/sec (10 cm/sec), which is higher than the low design approach velocity of 0.2 ft/sec (6 cm/sec) of the proposed project screens. Therefore, the actual effectiveness of the screens proposed for the Humboldt Bay project assessed here should exceed the estimates based solely on head capsule dimensions.

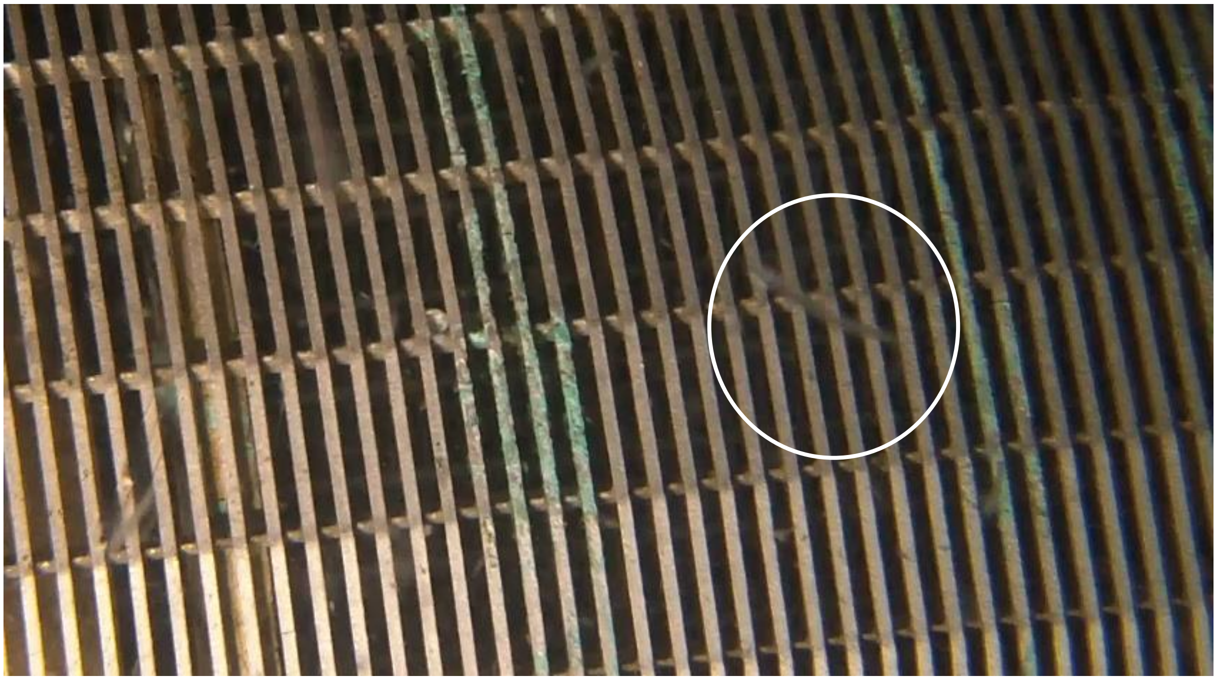


Figure 6-3. Video frame grab of the 2 mm screen taken in January 2012 during wedgewire screen efficiency study for the West Basin Water District with the pump operating (Tenera 2014b). Frame shows the early post-larval fish swimming along horizontal to the screen.

6.2 Conclusions

The results of the ETM assessment indicate an average loss of 0.118% of the source water population due to entrainment and a highest loss by taxa of less than 0.4% (**Table 5-9**). This is the ETM estimate of P_M, which represents the loss caused by entrainment to the population subject to entrainment. The average loss is similar to the results for the taxa analyzed in the Initial ETM Assessment using the same source water model used for the ETM analyses in this report. Those estimates of P_M varied from 0.062% to 0.104% depending on the periods of larval exposure to entrainment used in the calculations (**Table 3-1**). The comparison of the results verifies the usefulness of the volumetric ETM model in initial permitting efforts. With natural variation in the abundance of larval fish populations in the nearshore waters off California among years of up to four orders of magnitude (McClatchie et al. 2018), an additional source of mortality due to entrainment by the two Humboldt Bay intakes that averages only 0.118% would not be expected to have any effect on the health of the fish populations in the bay.

It is important to remember that this estimated level of mortality is extremely conservative because it does not consider the design of the intake system with WWS modules with 0.04 in. (1.0 mm) slot openings. The small slot opening excludes larger fish larvae and invertebrate larvae such as crab megalops. The WWS modules are also designed to maintain a through-slot velocity at the intake surface of 0.2 fps (6 cm/s), which is NMFS criteria for protection of salmonids (NMFS 2011). Tenera has conducted studies that show that many larger fish larvae are able to swim against such currents as shown in **Figure 6-3**. Also, research by Coutant (2020) discusses the design of cylindrical intake screen systems and the features that help reduce entrainment for cylindrical WWS modules beyond the features of the slot opening and low velocity. These features include the cylindrical shape of the intakes and their alignment relative to existing tidal or river currents that creates a bow wave and resulting flow dynamics that help move larvae and other objects away from the screen surface where they may be subject to entrainment. Coutant concludes that the increased turbulence decreases the likelihood that larvae would be oriented exactly parallel to the screen slots where they could be more easily entrained. The design of the intakes, under normal operations, also eliminates any effects of impingement, and effects on fishes (e.g., sharks and perches) and other organisms that do not have life stages subject to entrainment.

The factors discussed by Coutant (2000) are not considered in the calculation of the potential effectiveness of WWS modules with 0.04 in. (1.0 mm) slot openings at reducing entrainment discussed in earlier in this section. This analysis was limited by the size range of the larvae collected during the study, but even with those limitations, the average reduction in mortality resulting from the addition of the WWS technology was as high as 72% for Pacific Staghorn Sculpin and 48% for Pacific Herring across the size range of larvae subject to entrainment for the seven taxa analyzed (**Table 6-1**). It is also important to recognize that these probabilities are based on the conservative assumption that larvae near the screen would be orientated such that the only factor limiting entrainment is the head capsule dimension. The average reduction in entrainment mortality just due to the WWS was 38%, which would reduce the average ETM estimate of P_M of 0.118% in **Table 5-9** to 0.073%. The bow wave created by the WWS module and the low approach velocity that allows many larvae to avoid the screen are not considered in these ETM estimates.

All of these factors indicate that the effects of the ETM assessment indicating an average entrainment loss of only 0.118% (**Table 5-9**) for the seven taxa is conservative since the model assumes that the estimated concentration of larvae at the station are entrained. None of the other factors discussed above that would result in further reductions in entrainment have been included in the calculations of estimated entrainment mortality presented here. The factors contributing to the conservative nature of the average ETM estimate of P_M of 0.118% (**Table 5-9**) include the following:

- The effectiveness of the WWS modules with 0.04 in. (1.0 mm) slot openings at reducing entrainment, which is estimated to average 38% for the seven taxa analyzed;
- The estimated effectiveness is based on the head capsule dimensions of the larvae which assumes that larvae near the screen would be orientated such that the only factor limiting entrainment are the head capsule dimensions;
- The effect of a reduction in entrainment would reduce the maximum length of the larvae entrained and would reduce the larval durations for the taxa used in the calculation of the ETM estimate of P_M for each taxon; and
- The effectiveness of the design of the shape and orientation of the WWS screen modules at reducing entrainment described by Coutant (2020). These design features have the potential to greatly reduce entrainment especially during periods with strong flood and ebb tidal currents.

The APF estimate to compensate for the entrainment losses is estimated at 17.9 acres (7.2 hectares) (**Table 5-9**). The conservative assumptions used in the ETM estimates listed above indicate that the APF estimate based on the average ETM estimate of P_M of 0.118% is also conservative and should fully compensate for the small estimated losses to source water populations. As described in Appendix E of the Final Substitute Documentation for the 2015 California Desalination Amendment to the Ocean Plan,[16] the average ETM and APF estimates from a study can be used to estimate not only the effects of entrainment on the taxa analyzed, but also all of the planktonic organisms subject to entrainment in the source water. Most of these other organisms would likely be more uniformly distributed throughout the source water, because unlike many fishes, there are no specific habitats associated with the reproduction of phytoplankton and most zooplankton. Therefore, the volumetric model would be appropriate for estimating impacts to these components of the plankton community. The fact that the average estimated entrainment mortality is slightly higher than the estimated volumetric loss provides some assurance that the APF estimate of 17.9 acres (7.2 hectares) would fully compensate for not only the estimated losses to the seven taxa, but all entrained organisms and any effects on salmonids and other species of concern due to reductions in prey.

An initial estimate of APF was provided for the District in Appendix N of the Draft EIR[17] for the project that was based on the results of the Initial ETM Assessment prepared by Tenera (2021) (Appendix P of the Draft EIR). The APF estimate of 10.4 acres (4.2 hectares) in Appendix N was based on a source water area of 10,000 acres (4,047 hectares) and was intended to be used as an example of how APF was calculated. The source water area based on the data in Swanson (2015) that was used in the APF calculations in the Initial ETM Assessment and in this report was 15,104 acres (6,112 hectares). Therefore, the corrected APF from the Initial ETM Assessment would be 15.7 acres (6.3 hectares), which, as expected, is very close to the APF estimate of 17.9 acres (7.2 hectares) in this report. Using the same 4:1 ratio proposed in Appendix N, an area of piling removal equivalent to 4.5 acres (1.8 hectares) would fully compensate for the losses to marine resources resulting from entrainment at the two intakes.

An implicit assumption in the application of APF as a form of compensatory mitigation is that the entrainment losses calculated by an ETM (i.e. P_M) directly relate to population losses. This assumption may be invalid, because density-dependent factors are almost certain to affect, and may entirely decouple, the relationship between larval population size in Humboldt Bay and subsequent adult spawning stock size. Density-dependent processes are factors that determine population size that are correlated with the 'density' of the population. A classic example is habitat availability; for example, if a species of fish requires kelp habitat as an adult and there is relatively small amounts of kelp habitat and many larval rockfish ready to develop into the adult

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

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

stage, the number of adult rockfish the following year will be limited by the availability of kelp habitat, not the number of larval rockfish. Therefore, if some proportion of those larval rockfish are entrained into an intake before they can develop into adults and inhabit a local kelp forest, the entrainment proportion will have no bearing on the number of adults that occur in the kelp forest. However, it is state policy that the estimate of proportional mortality from an ETM be used to estimate an APF acreage prior to permit issuance. This calculation of APF ignores any consideration of density-dependent processes. On this basis, ETM and APF are highly conservative entrainment impact assessment approaches.

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Appendix A

Sample Data and Information

This appendix presents tables of the numbers and taxonomic identification of all the organisms collected during the sampling for the Humboldt Bay Intake Assessment study conducted from January through December 2022. Information on each sample includes the sample date of each survey, the sample number, sample volume in m^3, and the split multiplier that identifies what fraction of the original sample the count recorded for each taxa represent. The adjusted count in the table is the estimated count for the entire sample volume after adjusting for the sample split. The concentration in numbers per 1,000 m^3 for the entire sample volume is also presented.

Survey: HuB001 **Start Date: 01/11/2022**

Cycle: 1	Sample: 1	Station: SW1		
Split Multiplier: 1	Volume: 81.92			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Leptocottus armatus	Pacific staghorn sculpin	3	3	36.62
Lepidogobius lepidus	bay goby	1	1	12.21
Spirinchus thaleichthys	longfin smelt	1	1	12.21
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	12	12	146.52

Cycle: 1	Sample: 2	Station: SW2		
Split Multiplier: 1	Volume: 128.87			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Leptocottus armatus	Pacific staghorn sculpin	6	6	46.56
Allosmerus elongatus	whitebait smelt	2	2	15.52
Lepidogobius lepidus	bay goby	1	1	7.76
Oligocottus/Clinocottus spp.	sculpins	1	1	7.76
Fish Fragments				
Leptocottus armatus	Pacific staghorn sculpin	1	1	7.76
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	9	9	69.84

Cycle: 1	Sample: 3	Station: E2		
Split Multiplier: 1	Volume: 104.52			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Leptocottus armatus	Pacific staghorn sculpin	5	5	47.84
Sebastes spp. V_	KGB rockfish larval complex	2	2	19.13
Allosmerus elongatus	whitebait smelt	1	1	9.57
Lepidogobius lepidus	bay goby	1	1	9.57
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	6	6	57.40

Cycle: 1	Sample: 4	Station: E1		
Split Multiplier: 1	Volume: 80.03			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Leptocottus armatus	Pacific staghorn sculpin	2	2	24.99
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	9	9	112.45

(continued)

Survey: HuB001 (continued) **Start Date: 01/11/2022**

Cycle: 1	Sample: 5	Station: SW3		
Split Multiplier: 1	Volume: 81.68			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Leptocottus armatus	Pacific staghorn sculpin	2	2	24.48
Microgadus proximus	Pacific tomcod	2	2	24.48
Allosmerus elongatus	whitebait smelt	1	1	12.24
Lepidogobius lepidus	bay goby	1	1	12.24
Spirinchus thaleichthys	longfin smelt	1	1	12.24
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	6	6	73.45

Cycle: 1	Sample: 6	Station: SW5		
Split Multiplier: 1	Volume: 82.54			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	13	13	157.51
Allosmerus elongatus	whitebait smelt	4	4	48.46
Leptocottus armatus	Pacific staghorn sculpin	2	2	24.23
Microgadus proximus	Pacific tomcod	1	1	12.12
Spirinchus thaleichthys	longfin smelt	1	1	12.12
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	2	2	24.23

Cycle: 1	Sample: 7	Station: SW4		
Split Multiplier: 1	Volume: 80.61			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	7	7	86.83
Leptocottus armatus	Pacific staghorn sculpin	2	2	24.81
Microgadus proximus	Pacific tomcod	2	2	24.81
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	9	9	111.64

Cycle: 1	Sample: 8	Station: SW6		
Split Multiplier: 1	Volume: 83.91			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	1	1	11.92
Leptocottus armatus	Pacific staghorn sculpin	1	1	11.92
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	2	2	23.83

(continued)

Survey: HuB001 (continued) **Start Date: 01/11/2022**

Cycle: 2	**Sample: 9**	**Station: SW1**		
Split Multiplier: 1	**Volume: 79.61**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Leptocottus armatus	Pacific staghorn sculpin	5	5	62.80
Artedius spp.	sculpins	2	2	25.12
larvae, yolksac	yolksac larvae	1	1	12.56
Liparis spp.	snailfishes	1	1	12.56
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	7	7	87.92

Cycle: 2	**Sample: 10**	**Station: SW2**		
Split Multiplier: 1	**Volume: 93.89**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Leptocottus armatus	Pacific staghorn sculpin	2	2	21.30
Allosmerus elongatus	whitebait smelt	1	1	10.65
Sebastes spp. V_	KGB rockfish larval complex	1	1	10.65
Spirinchus thaleichthys	longfin smelt	1	1	10.65
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	5	5	53.25

Cycle: 2	**Sample: 11**	**Station: E2**		
Split Multiplier: 1	**Volume: 156.01**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Leptocottus armatus	Pacific staghorn sculpin	7	7	44.87
Lepidogobius lepidus	bay goby	3	3	19.23
Allosmerus elongatus	whitebait smelt	2	2	12.82
Microgadus proximus	Pacific tomcod	1	1	6.41
Sebastes spp. V_	KGB rockfish larval complex	1	1	6.41
Spirinchus thaleichthys	longfin smelt	1	1	6.41
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	16	16	102.56

(continued)

Survey: HuB001 (continued) **Start Date: 01/11/2022**

Cycle: 2	Sample: 12	Station: E1		
Split Multiplier: 1	Volume: 118.68			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Microgadus proximus	Pacific tomcod	23	23	193.80
Leptocottus armatus	Pacific staghorn sculpin	10	10	84.26
Allosmerus elongatus	whitebait smelt	9	9	75.83
Spirinchus thaleichthys	longfin smelt	5	5	42.13
Lepidogobius lepidus	bay goby	3	3	25.28
Osmeridae	smelts	1	1	8.43
Fish Fragments				
larval fish fragment	larval fish fragments	1	1	8.43
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	6	6	50.56

Cycle: 2	Sample: 13	Station: SW3		
Split Multiplier: 1	Volume: 95.92			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Microgadus proximus	Pacific tomcod	39	39	406.57
Allosmerus elongatus	whitebait smelt	6	6	62.55
Lepidogobius lepidus	bay goby	5	5	52.12
Leptocottus armatus	Pacific staghorn sculpin	3	3	31.27
larvae, yolksac	yolksac larvae	2	2	20.85
Bathymasteridae	ronquils	1	1	10.42
Oligocottus/Clinocottus spp.	sculpins	1	1	10.42
Fish Fragments				
larval fish fragment	larval fish fragments	1	1	10.42
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	5	5	52.12

Survey: HuB002 **Start Date: 02/10/2022**

Cycle: 1	Sample: 1	Station: SW1		
Split Multiplier: 1	Volume: 107.88			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clupea pallasii	Pacific herring	6	6	55.62
Ammodytes hexapterus	Pacific sand lance	2	2	18.54
Leptocottus armatus	Pacific staghorn sculpin	1	1	9.27
Oligocottus/Clinocottus spp.	sculpins	1	1	9.27
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	27	27	250.27

Cycle: 1	Sample: 2	Station: SW2		
Split Multiplier: 1	Volume: 105.54			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Leptocottus armatus	Pacific staghorn sculpin	6	6	56.85
Lepidogobius lepidus	bay goby	2	2	18.95
Ammodytes hexapterus	Pacific sand lance	1	1	9.47
Clupea pallasii	Pacific herring	1	1	9.47
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	76	76	720.09

Cycle: 1	Sample: 3	Station: E2		
Split Multiplier: 1	Volume: 118.12			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Ammodytes hexapterus	Pacific sand lance	4	4	33.86
Leptocottus armatus	Pacific staghorn sculpin	2	2	16.93
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	24	24	203.18

Cycle: 1	Sample: 4	Station: E1		
Split Multiplier: 1	Volume: 80.61			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Ammodytes hexapterus	Pacific sand lance	3	3	37.22
Leptocottus armatus	Pacific staghorn sculpin	3	3	37.22
Clupea pallasii	Pacific herring	2	2	24.81
Oligocottus/Clinocottus spp.	sculpins	1	1	12.41
Pholidae	gunnels	1	1	12.41
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	14	14	173.68

(continued)

Survey: HuB002 (continued) **Start Date: 02/10/2022**

Cycle: 1	**Sample: 5**	**Station: SW3**		
Split Multiplier: 1	**Volume: 102.33**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Ammodytes hexapterus	Pacific sand lance	3	3	29.32
Lepidogobius lepidus	bay goby	2	2	19.55
Oligocottus/Clinocottus spp.	sculpins	2	2	19.55
Allosmerus elongatus	whitebait smelt	1	1	9.77
Clupea pallasii	Pacific herring	1	1	9.77
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	33	33	322.50

Cycle: 1	**Sample: 6**	**Station: SW4**		
Split Multiplier: 1	**Volume: 81.46**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Ammodytes hexapterus	Pacific sand lance	9	9	110.48
Allosmerus elongatus	whitebait smelt	5	5	61.38
Leptocottus armatus	Pacific staghorn sculpin	2	2	24.55
Artedius spp.	sculpins	1	1	12.28
larvae, yolksac	yolksac larvae	1	1	12.28
Sebastes spp. V	blue rockfish larval complex	1	1	12.28
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	16	16	196.40

Cycle: 1	**Sample: 7**	**Station: SW5**		
Split Multiplier: 1	**Volume: 94.08**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Leptocottus armatus	Pacific staghorn sculpin	3	3	31.89
Ammodytes hexapterus	Pacific sand lance	1	1	10.63
Artedius spp.	sculpins	1	1	10.63
Lepidogobius lepidus	bay goby	1	1	10.63
Parophrys vetulus	English sole	1	1	10.63
Pholidae	gunnels	1	1	10.63
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	30	30	318.87

(continued)

Survey: HuB002 (continued) **Start Date: 02/10/2022**

Cycle: 1	Sample: 8	Station: SW6		
Split Multiplier: 1	**Volume: 82.05**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Leptocottus armatus	Pacific staghorn sculpin	6	6	73.13
Clupea pallasii	Pacific herring	4	4	48.75
Allosmerus elongatus	whitebait smelt	1	1	12.19
Clevelandia ios	arrow goby	1	1	12.19
larvae, yolksac	yolksac larvae	1	1	12.19
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	6	6	73.13

Cycle: 2	Sample: 9	Station: SW1		
Split Multiplier: 1	**Volume: 125.69**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Clupea pallasii	Pacific herring	10	10	79.56
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	12	12	95.47

Cycle: 2	Sample: 10	Station: SW2		
Split Multiplier: 1	**Volume: 119.45**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Clupea pallasii	Pacific herring	25	25	209.29
Allosmerus elongatus	whitebait smelt	1	1	8.37
Ammodytes hexapterus	Pacific sand lance	1	1	8.37
Leptocottus armatus	Pacific staghorn sculpin	1	1	8.37
Oligocottus/Clinocottus spp.	sculpins	1	1	8.37
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	8	8	66.97

(continued)

Survey: HuB002 (continued) **Start Date: 02/10/2022**

Cycle: 2	Sample: 11	Station: E2		
Split Multiplier: 1	Volume: 98.40			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clupea pallasii	Pacific herring	8	8	81.30
Leptocottus armatus	Pacific staghorn sculpin	3	3	30.49
Oligocottus/Clinocottus spp.	sculpins	3	3	30.49
Ammodytes hexapterus	Pacific sand lance	2	2	20.33
Allosmerus elongatus	whitebait smelt	1	1	10.16
Artedius spp.	sculpins	1	1	10.16
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	4	4	40.65

Cycle: 2	Sample: 12	Station: E1		
Split Multiplier: 1	Volume: 97.74			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Ammodytes hexapterus	Pacific sand lance	7	7	71.62
Clupea pallasii	Pacific herring	3	3	30.70
Microgadus proximus	Pacific tomcod	3	3	30.70
Parophrys vetulus	English sole	2	2	20.46
Allosmerus elongatus	whitebait smelt	1	1	10.23
larvae, yolksac	yolksac larvae	1	1	10.23
Liparis spp.	snailfishes	1	1	10.23
Oligocottus/Clinocottus spp.	sculpins	1	1	10.23
Spirinchus thaleichthys	longfin smelt	1	1	10.23
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	8	8	81.85

Cycle: 2	Sample: 13	Station: SW3		
Split Multiplier: 1	Volume: 132.22			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Ammodytes hexapterus	Pacific sand lance	9	9	68.07
Leptocottus armatus	Pacific staghorn sculpin	6	6	45.38
Microgadus proximus	Pacific tomcod	3	3	22.69
Artedius spp.	sculpins	1	1	7.56
Citharichthys stigmaeus	speckled sanddab	1	1	7.56
Clupea pallasii	Pacific herring	1	1	7.56
larval fish - damaged	damaged larval fishes	1	1	7.56
Parophrys vetulus	English sole	1	1	7.56
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	7	7	52.94

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Survey: HuB002 (continued) **Start Date: 02/10/2022**

Cycle: 2	Sample: 14	Station: SW4		
Split Multiplier: 1	Volume: 103.85			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Atherinops affinis	topsmelt	10	10	96.29
Microgadus proximus	Pacific tomcod	6	6	57.77
Ammodytes hexapterus	Pacific sand lance	1	1	9.63
Artedius spp.	sculpins	1	1	9.63
Lipolagus ochotensis	popeye blacksmelt	1	1	9.63
Tarletonbeania crenularis	blue lanternfish	1	1	9.63
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	7	7	67.40

Cycle: 2	Sample: 15	Station: SW5		
Split Multiplier: 1	Volume: 87.71			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	5	5	57.00
Ammodytes hexapterus	Pacific sand lance	4	4	45.60
Leptocottus armatus	Pacific staghorn sculpin	3	3	34.20
Lipolagus ochotensis	popeye blacksmelt	3	3	34.20
Liparis spp.	snailfishes	2	2	22.80
Actinopterygii	ray-finned fishes	1	1	11.40
Citharichthys stigmaeus	speckled sanddab	1	1	11.40
larvae, yolksac	yolksac larvae	1	1	11.40
Oligocottus/Clinocottus spp.	sculpins	1	1	11.40
Ruscarius creaseri	roughcheek sculpin	1	1	11.40
Scorpaenichthys marmoratus	cabezon	1	1	11.40
Spirinchus starksi	night smelt	1	1	11.40
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	8	8	91.21

Cycle: 2	Sample: 16	Station: SW6		
Split Multiplier: 1	Volume: 110.01			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	2	2	18.18
Leptocottus armatus	Pacific staghorn sculpin	2	2	18.18
Actinopterygii	ray-finned fishes	1	1	9.09
Ammodytes hexapterus	Pacific sand lance	1	1	9.09
Clupea pallasii	Pacific herring	1	1	9.09
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	10	10	90.90

Survey: HuB003 **Start Date: 03/17/2022**

Cycle: 1	Sample: 1	Station: SW1		
Split Multiplier: 1	Volume: 117.54			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clupea pallasii	Pacific herring	6	6	51.05
Clevelandia ios	arrow goby	4	4	34.03
Ammodytes hexapterus	Pacific sand lance	2	2	17.02
Fish Fragments				
larval fish fragment	larval fish fragments	3	3	25.52
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	23	23	195.68

Cycle: 1	Sample: 2	Station: SW2		
Split Multiplier: 1	Volume: 100.11			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clupea pallasii	Pacific herring	17	17	169.81
Clevelandia ios	arrow goby	6	6	59.93
Ammodytes hexapterus	Pacific sand lance	3	3	29.97
Allosmerus elongatus	whitebait smelt	2	2	19.98
Oligocottus/Clinocottus spp.	sculpins	2	2	19.98
Sebastes spp. V	blue rockfish larval complex	2	2	19.98
Bathymasteridae	ronquils	1	1	9.99
Gillichthys mirabilis	longjaw mudsucker	1	1	9.99
Leptocottus armatus	Pacific staghorn sculpin	1	1	9.99
Liparis spp.	snailfishes	1	1	9.99
Fish Fragments				
larval fish fragment	larval fish fragments	10	10	99.89
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	14	14	139.84

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Survey: HuB003 (continued) **Start Date: 03/17/2022**

Cycle: 1	Sample: 3	Station: E2		
Split Multiplier: 1	**Volume: 114.44**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Clupea pallasii	Pacific herring	12	12	104.86
Oligocottus/Clinocottus spp.	sculpins	4	4	34.95
Sebastes spp. V_	KGB rockfish larval complex	3	3	26.22
Liparis spp.	snailfishes	2	2	17.48
Ammodytes hexapterus	Pacific sand lance	1	1	8.74
larvae, yolksac	yolksac larvae	1	1	8.74
Leptocottus armatus	Pacific staghorn sculpin	1	1	8.74
Microgadus proximus	Pacific tomcod	1	1	8.74
Stenobrachius leucopsarus	northern lampfish	1	1	8.74
Stichaeidae	pricklebacks	1	1	8.74
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	27	27	235.94

Cycle: 1	Sample: 4	Station: E1		
Split Multiplier: 1	**Volume: 100.72**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Sebastes spp. V	blue rockfish larval complex	2	2	19.86
Bathymasteridae	ronquils	1	1	9.93
Clupea pallasii	Pacific herring	1	1	9.93
Liparis spp.	snailfishes	1	1	9.93
Stenobrachius leucopsarus	northern lampfish	1	1	9.93
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	19	19	188.64

Cycle: 1	Sample: 5	Station: SW3		
Split Multiplier: 1	**Volume: 98.51**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Artedius spp.	sculpins	2	2	20.30
Sebastes spp. V	blue rockfish larval complex	2	2	20.30
Stenobrachius leucopsarus	northern lampfish	2	2	20.30
Clupea pallasii	Pacific herring	1	1	10.15
larvae, yolksac	yolksac larvae	1	1	10.15
Lyopsetta exilis	slender sole	1	1	10.15
Microgadus proximus	Pacific tomcod	1	1	10.15
Scorpaenichthys marmoratus	cabezon	1	1	10.15
Tarletonbeania crenularis	blue lanternfish	1	1	10.15
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	6	6	60.91

(continued)

Survey: HuB003 (continued) **Start Date: 03/17/2022**

Cycle: 1	Sample: 6	Station: SW4		
Split Multiplier: 1	Volume: 102.72			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
larvae, yolksac	yolksac larvae	3	3	29.20
Artedius spp.	sculpins	2	2	19.47
Clupea pallasii	Pacific herring	2	2	19.47
Leptocottus armatus	Pacific staghorn sculpin	1	1	9.73
Microgadus proximus	Pacific tomcod	1	1	9.73
Sebastes spp. V	blue rockfish larval complex	1	1	9.73
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	22	22	214.17

Cycle: 1	Sample: 7	Station: SW5		
Split Multiplier: 1	Volume: 84.24			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clupea pallasii	Pacific herring	23	23	273.04
Allosmerus elongatus	whitebait smelt	2	2	23.74
Cottus asper	prickly sculpin	2	2	23.74
Leptocottus armatus	Pacific staghorn sculpin	2	2	23.74
Microgadus proximus	Pacific tomcod	2	2	23.74
Sebastes spp. V	blue rockfish larval complex	1	1	11.87
Spirinchus starksi	night smelt	1	1	11.87
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	13	13	154.33
Targeted Invertebrates				
Romal. anten./Metacar. grac. (megalops)	cancer crabs	1	1	11.87

Cycle: 1	Sample: 8	Station: SW6		
Split Multiplier: 1	Volume: 114.43			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clupea pallasii	Pacific herring	3	3	26.22
Leptocottus armatus	Pacific staghorn sculpin	2	2	17.48
Sebastes spp. V_	KGB rockfish larval complex	2	2	17.48
Allosmerus elongatus	whitebait smelt	1	1	8.74
Clevelandia ios	arrow goby	1	1	8.74
larval fish - damaged	damaged larval fishes	1	1	8.74
Oligocottus/Clinocottus spp.	sculpins	1	1	8.74
Fish Fragments				
larval fish fragment	larval fish fragments	1	1	8.74
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	10	10	87.39

(continued)

Survey: HuB003 (continued) **Start Date: 03/17/2022**

Cycle: 2	Sample: 9	Station: SW5		
Split Multiplier: 1	**Volume: 102.21**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Clupea pallasii	Pacific herring	174	174	1,702.37
Clevelandia ios	arrow goby	3	3	29.35
Leptocottus armatus	Pacific staghorn sculpin	3	3	29.35
Spirinchus starksi	night smelt	3	3	29.35
Allosmerus elongatus	whitebait smelt	2	2	19.57
Artedius spp.	sculpins	1	1	9.78
Oligocottus snyderi	fluffy sculpin	1	1	9.78
Oligocottus/Clinocottus spp.	sculpins	1	1	9.78
Parophrys vetulus	English sole	1	1	9.78
Sebastes spp. V	blue rockfish larval complex	1	1	9.78
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	9	9	88.05

Cycle: 2	Sample: 10	Station: SW4		
Split Multiplier: 1	**Volume: 106.94**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Clupea pallasii	Pacific herring	137	137	1,281.12
Allosmerus elongatus	whitebait smelt	11	11	102.86
larvae, yolksac	yolksac larvae	5	5	46.76
Leptocottus armatus	Pacific staghorn sculpin	4	4	37.40
Liparis spp.	snailfishes	3	3	28.05
Oligocottus/Clinocottus spp.	sculpins	2	2	18.70
Cottus asper	prickly sculpin	1	1	9.35
Lyopsetta exilis	slender sole	1	1	9.35
Spirinchus starksi	night smelt	1	1	9.35
Fish Fragments				
larval fish fragment	larval fish fragments	13	13	121.57
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	20	20	187.02

(continued)

Survey: HuB003 (continued) **Start Date: 03/17/2022**

Cycle: 2	Sample: 11	Station: SW3		
Split Multiplier: 1	Volume: 158.82			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clupea pallasii	Pacific herring	60	60	377.78
Clevelandia ios	arrow goby	8	8	50.37
Allosmerus elongatus	whitebait smelt	3	3	18.89
Artedius spp.	sculpins	3	3	18.89
Leptocottus armatus	Pacific staghorn sculpin	3	3	18.89
Liparis spp.	snailfishes	1	1	6.30
Oligocottus/Clinocottus spp.	sculpins	1	1	6.30
Ruscarius meanyi	Puget Sound sculpin	1	1	6.30
Sebastes spp. V_	KGB rockfish larval complex	1	1	6.30
Fish Fragments				
larval fish fragment	larval fish fragments	6	6	37.78
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	17	17	107.04

Cycle: 2	Sample: 12	Station: E1		
Split Multiplier: 1	Volume: 101.99			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clupea pallasii	Pacific herring	30	30	294.14
Clevelandia ios	arrow goby	10	10	98.05
Allosmerus elongatus	whitebait smelt	3	3	29.41
Leptocottus armatus	Pacific staghorn sculpin	2	2	19.61
Liparis spp.	snailfishes	2	2	19.61
Stenobrachius leucopsarus	northern lampfish	1	1	9.80
Fish Fragments				
larval fish fragment	larval fish fragments	2	2	19.61
Non-Entrainable Fishes				
Ammodytes hexapterus	Pacific sand lance	1	1	9.80
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	12	12	117.66
Targeted Invertebrates				
Romal. anten./Metacar. grac. (megalops)	cancer crabs	1	1	9.80

(continued)

Survey: HuB003 (continued) **Start Date: 03/17/2022**

Cycle: 2	Sample: 13	Station: E2		
Split Multiplier: 1	Volume: 93.70			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	14	14	149.41
Clupea pallasii	Pacific herring	9	9	96.05
Oligocottus/Clinocottus spp.	sculpins	5	5	53.36
Allosmerus elongatus	whitebait smelt	1	1	10.67
Bathymasteridae	ronquils	1	1	10.67
Cottus asper	prickly sculpin	1	1	10.67
Sebastes spp. V_	KGB rockfish larval complex	1	1	10.67
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	3	3	32.02

Cycle: 2	Sample: 14	Station: SW2		
Split Multiplier: 1	Volume: 105.42			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
larval fish - damaged	damaged larval fishes	11	11	104.34
Clevelandia ios	arrow goby	9	9	85.37
Clupea pallasii	Pacific herring	3	3	28.46
Ammodytes hexapterus	Pacific sand lance	1	1	9.49
Bathylagidae	blacksmelts	1	1	9.49
Leptocottus armatus	Pacific staghorn sculpin	1	1	9.49
Fish Fragments				
larval fish fragment	larval fish fragments	5	5	47.43
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	5	5	47.43

Cycle: 2	Sample: 15	Station: SW1		
Split Multiplier: 1	Volume: 114.46			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clupea pallasii	Pacific herring	83	83	725.13
Clevelandia ios	arrow goby	39	39	340.72
larval fish - damaged	damaged larval fishes	2	2	17.47
Leptocottus armatus	Pacific staghorn sculpin	2	2	17.47
Cottus asper	prickly sculpin	1	1	8.74
Liparis spp.	snailfishes	1	1	8.74
Parophrys vetulus	English sole	1	1	8.74
Fish Fragments				
larval fish fragment	larval fish fragments	3	3	26.21
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	19	19	165.99

(continued)

Survey: HuB003 (continued) **Start Date: 03/17/2022**

Cycle: 2	Sample: 16	Station: SW6		
Split Multiplier: 1	Volume: 100.59			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clupea pallasii	Pacific herring	8	8	79.53
Cottus asper	prickly sculpin	2	2	19.88
Allosmerus elongatus	whitebait smelt	1	1	9.94
Clevelandia ios	arrow goby	1	1	9.94
Leptocottus armatus	Pacific staghorn sculpin	1	1	9.94
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	7	7	69.59

Survey: HuB004 **Start Date: 04/26/2022**

Cycle: 1	Sample: 1	Station: SW1		
Split Multiplier: 1	**Volume: 110.73**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	2	2	18.06
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	2	2	18.06

Cycle: 1	Sample: 2	Station: SW2		
Split Multiplier: 1	**Volume: 153.39**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	7	7	45.64
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	3	3	19.56

Cycle: 1	Sample: 3	Station: E2		
Split Multiplier: 1	**Volume: 105.50**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	6	6	56.87
Microgadus proximus	Pacific tomcod	4	4	37.91
Clevelandia ios	arrow goby	3	3	28.44
Liparis spp.	snailfishes	1	1	9.48
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	8	8	75.83

Cycle: 1	Sample: 4	Station: E1		
Split Multiplier: 1	**Volume: 92.63**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Microgadus proximus	Pacific tomcod	6	6	64.78
Lepidogobius lepidus	bay goby	4	4	43.18
Artedius spp.	sculpins	2	2	21.59
Oligocottus/Clinocottus spp.	sculpins	2	2	21.59
Allosmerus elongatus	whitebait smelt	1	1	10.80
Oligocottus snyderi	fluffy sculpin	1	1	10.80
Sebastes spp. V_	KGB rockfish larval complex	1	1	10.80
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	24	24	259.11

(continued)

Survey: HuB004 (continued) **Start Date: 04/26/2022**

Cycle: 1	Sample: 5	Station: SW3		
Split Multiplier: 1	**Volume: 116.58**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	7	7	60.04
Microgadus proximus	Pacific tomcod	6	6	51.47
Lepidogobius lepidus	bay goby	4	4	34.31
Spirinchus starksi	night smelt	3	3	25.73
Clevelandia ios	arrow goby	2	2	17.16
Liparis spp.	snailfishes	1	1	8.58
Oligocottus snyderi	fluffy sculpin	1	1	8.58
Sebastes spp. V_	KGB rockfish larval complex	1	1	8.58
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	28	28	240.17

Cycle: 1	Sample: 6	Station: SW4		
Split Multiplier: 1	**Volume: 82.58**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Spirinchus starksi	night smelt	7	7	84.76
Allosmerus elongatus	whitebait smelt	6	6	72.65
Cottus asper	prickly sculpin	3	3	36.33
Microgadus proximus	Pacific tomcod	3	3	36.33
larval fish – damaged	damaged larval fishes	1	1	12.11
Liparis spp.	snailfishes	1	1	12.11
Non-Entrainable Fishes				
Pholidae	gunnels	1	1	12.11
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	9	9	108.98

Cycle: 1	Sample: 7	Station: SW5		
Split Multiplier: 1	**Volume: 80.12**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	2	2	24.96
Artedius spp.	sculpins	2	2	24.96
Cebidichthys violaceus	monkeyface prickleback	1	1	12.48
Lepidogobius lepidus	bay goby	1	1	12.48
Stichaeidae	pricklebacks	1	1	12.48
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	19	19	237.15

(continued)

Survey: HuB004 (continued) **Start Date: 04/26/2022**

Cycle: 1	Sample: 8	Station: SW6		
Split Multiplier: 1	Volume: 114.46			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	56	56	489.24
Liparis spp.	snailfishes	2	2	17.47
Artedius spp.	sculpins	1	1	8.74
Microgadus proximus	Pacific tomcod	1	1	8.74
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	7	7	61.16

Cycle: 2	Sample: 9	Station: SW5		
Split Multiplier: 1	Volume: 113.95			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	12	12	105.31
Spirinchus starksi	night smelt	10	10	87.75
Microgadus proximus	Pacific tomcod	6	6	52.65
Cottus asper	prickly sculpin	1	1	8.78
Leptocottus armatus	Pacific staghorn sculpin	1	1	8.78
Liparis spp.	snailfishes	1	1	8.78
Oligocottus snyderi	fluffy sculpin	1	1	8.78
Oligocottus/Clinocottus spp.	sculpins	1	1	8.78
Non-Entrainable Fishes				
Pholidae	gunnels	1	1	8.78
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	14	14	122.86
Targeted Invertebrates				
Cancer productus/Romal. spp. (megalops)	rock crab megalops	6	6	52.65
Metacarcinus magister (megalops)	Dungeness crab megalops	5	5	43.88
Romal. anten./Metacar. grac. (megalops)	cancer crabs	2	2	17.55

(continued)

Survey: HuB004 (continued) **Start Date: 04/26/2022**

Cycle: 2	Sample: 10	Station: SW4		
Split Multiplier: 1	Volume: 74.98			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Microgadus proximus	Pacific tomcod	10	10	133.37
Allosmerus elongatus	whitebait smelt	6	6	80.02
Spirinchus starksi	night smelt	6	6	80.02
Leptocottus armatus	Pacific staghorn sculpin	5	5	66.68
Artedius harringtoni	scalyhead sculpin	1	1	13.34
Artedius spp.	sculpins	1	1	13.34
Cottus asper	prickly sculpin	1	1	13.34
Isopsetta isolepis	butter sole	1	1	13.34
Parophrys vetulus	English sole	1	1	13.34
Non-Entrainable Fishes				
Pholidae	gunnels	1	1	13.34
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	13	13	173.38
Targeted Invertebrates				
Cancer productus/Romal. spp. (megalops)	rock crab megalops	5	5	66.68
Metacarcinus magister (megalops)	Dungeness crab megalops	2	2	26.67

Cycle: 2	Sample: 11	Station: SW3		
Split Multiplier: 1	Volume: 102.69			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	13	13	126.60
Spirinchus starksi	night smelt	7	7	68.17
Microgadus proximus	Pacific tomcod	6	6	58.43
Cottidae	sculpins	2	2	19.48
Liparis spp.	snailfishes	2	2	19.48
Artedius spp.	sculpins	1	1	9.74
Clevelandia ios	arrow goby	1	1	9.74
Leptocottus armatus	Pacific staghorn sculpin	1	1	9.74
Oligocottus snyderi	fluffy sculpin	1	1	9.74
Pholidae	gunnels	1	1	9.74
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	21	21	204.50
Targeted Invertebrates				
Cancer productus/Romal. spp. (megalops)	rock crab megalops	3	3	29.21

(continued)

Survey: HuB004 (continued) **Start Date: 04/26/2022**

Cycle: 2	Sample: 12	Station: E1		
Split Multiplier: 1	Volume: 101.29			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	30	30	296.19
Spirinchus starksi	night smelt	15	15	148.09
Microgadus proximus	Pacific tomcod	13	13	128.35
Lepidogobius lepidus	bay goby	5	5	49.36
Clevelandia ios	arrow goby	4	4	39.49
Cottus asper	prickly sculpin	4	4	39.49
Isopsetta isolepis	butter sole	2	2	19.75
Oligocottus/Clinocottus spp.	sculpins	2	2	19.75
Artedius spp.	sculpins	1	1	9.87
Clinocottus embryum	calico sculpin	1	1	9.87
Liparis spp.	snailfishes	1	1	9.87
Ruscarius creaseri	roughcheek sculpin	1	1	9.87
Sebastes spp. V_	KGB rockfish larval complex	1	1	9.87
Stichaeidae	pricklebacks	1	1	9.87
Fish Fragments				
larval fish fragment	larval fish fragments	3	3	29.62
Non-Entrainable Fishes				
Pholidae	gunnels	2	2	19.75
Isopsetta isolepis	butter sole	1	1	9.87
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	13	13	128.35
Targeted Invertebrates				
Cancer productus/Romal. spp. (megalops)	rock crab megalops	2	2	19.75
Metacarcinus magister (megalops)	Dungeness crab megalops	2	2	19.75
Romal. anten./Metacar. grac. (megalops)	cancer crabs	2	2	19.75

(continued)

Survey: HuB004 (continued) **Start Date: 04/26/2022**

Cycle: 2	Sample: 13	Station: E2		
Split Multiplier: 1	Volume: 100.28			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	25	25	249.31
Lepidogobius lepidus	bay goby	8	8	79.78
Microgadus proximus	Pacific tomcod	7	7	69.81
Cottus asper	prickly sculpin	4	4	39.89
Liparis spp.	snailfishes	4	4	39.89
Spirinchus starksi	night smelt	4	4	39.89
Clevelandia ios	arrow goby	2	2	19.94
Artedius spp.	sculpins	1	1	9.97
Clupea pallasii	Pacific herring	1	1	9.97
Isopsetta isolepis	butter sole	1	1	9.97
Fish Fragments				
larval fish fragment	larval fish fragments	5	5	49.86
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	20	20	199.45
Targeted Invertebrates				
Metacarcinus magister (megalops)	Dungeness crab megalops	2	2	19.94
Cancer productus/Romal. spp. (megalops)	rock crab megalops	1	1	9.97

Cycle: 2	Sample: 14	Station: SW2		
Split Multiplier: 1	Volume: 79.62			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	42	42	527.49
Allosmerus elongatus	whitebait smelt	3	3	37.68
Isopsetta isolepis	butter sole	2	2	25.12
Lepidogobius lepidus	bay goby	2	2	25.12
Liparis spp.	snailfishes	2	2	25.12
Microgadus proximus	Pacific tomcod	2	2	25.12
Oligocottus/Clinocottus spp.	sculpins	2	2	25.12
Clupea pallasii	Pacific herring	1	1	12.56
Spirinchus starksi	night smelt	1	1	12.56
Fish Fragments				
larval fish fragment	larval fish fragments	8	8	100.47
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	18	18	226.07
Targeted Invertebrates				
Metacarcinus magister (megalops)	Dungeness crab megalops	1	1	12.56

(continued)

Survey: HuB004 (continued) **Start Date: 04/26/2022**

Cycle: 2	Sample: 15	Station: SW1		
Split Multiplier: 1	Volume: 74.77			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	7	7	93.62
Clevelandia ios	arrow goby	5	5	66.87
Microgadus proximus	Pacific tomcod	4	4	53.50
Liparis spp.	snailfishes	2	2	26.75
Cottus asper	prickly sculpin	1	1	13.37
Lepidogobius lepidus	bay goby	1	1	13.37
Leptocottus armatus	Pacific staghorn sculpin	1	1	13.37
Sebastes spp. V_	KGB rockfish larval complex	1	1	13.37
Spirinchus starksi	night smelt	1	1	13.37
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	97	97	1,297.26

Cycle: 2	Sample: 16	Station: SW6		
Split Multiplier: 1	Volume: 87.31			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	5	5	57.26
Clevelandia ios	arrow goby	3	3	34.36
Lepidogobius lepidus	bay goby	2	2	22.91
Microgadus proximus	Pacific tomcod	2	2	22.91
Oligocottus/Clinocottus spp.	sculpins	2	2	22.91
Spirinchus starksi	night smelt	2	2	22.91
Artedius spp.	sculpins	1	1	11.45
Gillichthys mirabilis	longjaw mudsucker	1	1	11.45
Leptocottus armatus	Pacific staghorn sculpin	1	1	11.45
Parophrys vetulus	English sole	1	1	11.45
Sebastes spp. V_	KGB rockfish larval complex	1	1	11.45
Non-Entrainable Fishes				
Clevelandia ios	arrow goby	1	1	11.45
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	19	19	217.61

Survey: HuB005 **Start Date: 05/26/2022**

Cycle: 1	Sample: 1	Station: SW1		
Split Multiplier: 2	**Volume: 161.37**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	92	184	1,140.21
Lepidogobius lepidus	bay goby	1	2	12.39
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	38	76	470.96

Cycle: 1	Sample: 2	Station: SW2		
Split Multiplier: 4	**Volume: 129.70**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	248	992	7,648.54
Acanthogobius flavimanus	yellowfin goby	1	4	30.84
Bathymasteridae	ronquils	1	4	30.84
Gillichthys mirabilis	longjaw mudsucker	1	4	30.84
Platichthys stellatus	starry flounder	1	4	30.84
Rhinogobiops nicholsii	blackeye goby	1	4	30.84
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	23	92	709.34

Cycle: 1	Sample: 3	Station: E2		
Split Multiplier: 1	**Volume: 129.34**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	12	12	92.78
Liparis spp.	snailfishes	1	1	7.73
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	68	68	525.73

(continued)

Survey: HuB005 (continued) **Start Date: 05/26/2022**

Cycle: 1	Sample: 4	Station: E1		
Split Multiplier: 1	Volume: 85.73			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Citharichthys sordidus	Pacific sanddab	7	7	81.65
Lepidogobius lepidus	bay goby	5	5	58.32
Clevelandia ios	arrow goby	4	4	46.66
Clupea pallasii	Pacific herring	1	1	11.66
Pleuronectidae	righteye flounders	1	1	11.66
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	80	80	933.19
Targeted Invertebrates				
Metacarcinus magister (megalops)	Dungeness crab megalops	1	1	11.66

Cycle: 1	Sample: 5	Station: SW3		
Split Multiplier: 1	Volume: 120.19			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Citharichthys sordidus	Pacific sanddab	31	31	257.93
Hippoglossoides elassodon	flathead sole	3	3	24.96
Clevelandia ios	arrow goby	1	1	8.32
Cottus asper	prickly sculpin	1	1	8.32
larval fish - damaged	damaged larval fishes	1	1	8.32
Oligocottus/Clinocottus spp.	sculpins	1	1	8.32
Rhinogobiops nicholsii	blackeye goby	1	1	8.32
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	49	49	407.70
Targeted Invertebrates				
Metacarcinus magister (megalops)	Dungeness crab megalops	2	2	16.64

(continued)

Survey: HuB005 (continued) **Start Date: 05/26/2022**

Cycle: 1	Sample: 6	Station: SW4		
Split Multiplier: 2	Volume: 96.85			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Citharichthys sordidus	Pacific sanddab	12	24	247.80
Allosmerus elongatus	whitebait smelt	7	14	144.55
Hippoglossoides elassodon	flathead sole	3	6	61.95
Clevelandia ios	arrow goby	1	2	20.65
Oligocottus/Clinocottus spp.	sculpins	1	2	20.65
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	18	36	371.69
Targeted Invertebrates				
Cancer productus/Romal. spp. (megalops)	rock crab megalops	3	6	61.95
Metacarcinus magister (megalops)	Dungeness crab megalops	2	4	41.30

Cycle: 1	Sample: 7	Station: SW5		
Split Multiplier: 1	Volume: 101.54			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Citharichthys sordidus	Pacific sanddab	22	22	216.67
Hippoglossoides elassodon	flathead sole	6	6	59.09
Pleuronectoidei	flatfishes	4	4	39.39
Lepidogobius lepidus	bay goby	2	2	19.70
Oligocottus/Clinocottus spp.	sculpins	1	1	9.85
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	74	74	728.81
Targeted Invertebrates				
Metacarcinus magister (megalops)	Dungeness crab megalops	1	1	9.85

(continued)

Survey: HuB005 (continued) **Start Date: 05/26/2022**

Cycle: 1	Sample: 8	Station: SW6		
Split Multiplier: 1	**Volume: 107.97**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	14	14	129.67
Lepidogobius lepidus	bay goby	2	2	18.52
Acanthogobius flavimanus	yellowfin goby	1	1	9.26
Allosmerus elongatus	whitebait smelt	1	1	9.26
Gillichthys mirabilis	longjaw mudsucker	1	1	9.26
Rhinogobiops nicholsii	blackeye goby	1	1	9.26
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	182	182	1,685.70

Cycle: 2	Sample: 9	Station: SW5		
Split Multiplier: 1	**Volume: 95.99**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Citharichthys sordidus	Pacific sanddab	26	26	270.87
Pleuronectoidei	flatfishes	15	15	156.27
Hippoglossoides elassodon	flathead sole	10	10	104.18
Lepidogobius lepidus	bay goby	2	2	20.84
Allosmerus elongatus	whitebait smelt	1	1	10.42
Clevelandia ios	arrow goby	1	1	10.42
Oligocottus/Clinocottus spp.	sculpins	1	1	10.42
Spirinchus starksi	night smelt	1	1	10.42
Tarletonbeania crenularis	blue lanternfish	1	1	10.42
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	58	58	604.24

Cycle: 2	Sample: 10	Station: SW4		
Split Multiplier: 2	**Volume: 88.83**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	21	42	472.80
Citharichthys sordidus	Pacific sanddab	10	20	225.14
Spirinchus starksi	night smelt	9	18	202.63
Hippoglossoides elassodon	flathead sole	8	16	180.11
Chitonotus pugetensis	roughback sculpin	1	2	22.51
Pleuronectoidei	flatfishes	1	2	22.51
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	22	44	495.31
Targeted Invertebrates				
Metacarcinus magister (megalops)	Dungeness crab megalops	1	2	22.51

(continued)

Survey: HuB005 (continued) **Start Date: 05/26/2022**

Cycle: 2	Sample: 11	Station: SW3		
Split Multiplier: 1	Volume: 123.18			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	40	40	324.72
Citharichthys sordidus	Pacific sanddab	16	16	129.89
Spirinchus starksi	night smelt	13	13	105.53
Hippoglossoides elassodon	flathead sole	7	7	56.83
Pleuronectoidei	flatfishes	6	6	48.71
Cottus asper	prickly sculpin	1	1	8.12
Fish Fragments				
larval fish fragment	larval fish fragments	8	8	64.94
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	76	76	616.97
Targeted Invertebrates				
Metacarcinus magister (megalops)	Dungeness crab megalops	177	177	1,436.89
Cancer productus/Romal. spp. (megalops)	rock crab megalops	2	2	16.24

Cycle: 2	Sample: 12	Station: E1		
Split Multiplier: 1	Volume: 102.14			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	51	51	499.30
Spirinchus starksi	night smelt	18	18	176.22
Citharichthys sordidus	Pacific sanddab	5	5	48.95
Hippoglossoides elassodon	flathead sole	5	5	48.95
Artedius spp.	sculpins	3	3	29.37
Hypomesus pretiosus	surf smelt	1	1	9.79
Lepidogobius lepidus	bay goby	1	1	9.79
Rhinogobiops nicholsii	blackeye goby	1	1	9.79
Fish Fragments				
larval fish fragment	larval fish fragments	4	4	39.16
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	52	52	509.09
Targeted Invertebrates				
Metacarcinus magister (megalops)	Dungeness crab megalops	90	90	881.11
Cancer productus/Romal. spp. (megalops)	rock crab megalops	2	2	19.58
Romal. anten./Metacar. grac. (megalops)	cancer crabs	1	1	9.79

(continued)

Survey: HuB005 (continued) **Start Date: 05/26/2022**

Cycle: 2	Sample: 13	Station: E2		
Split Multiplier: 1	Volume: 94.60			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	9	9	95.14
Citharichthys sordidus	Pacific sanddab	3	3	31.71
Clevelandia ios	arrow goby	2	2	21.14
Spirinchus starksi	night smelt	2	2	21.14
Hippoglossoides elassodon	flathead sole	1	1	10.57
Rhinogobiops nicholsii	blackeye goby	1	1	10.57
Fish Fragments				
larval fish fragment	larval fish fragments	2	2	21.14
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	38	38	401.68
Targeted Invertebrates				
Metacarcinus magister (megalops)	Dungeness crab megalops	10	10	105.71
Cancer productus/Romal. spp. (megalops)	rock crab megalops	4	4	42.28

Cycle: 2	Sample: 14	Station: SW2		
Split Multiplier: 1	Volume: 95.17			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	11	11	115.58
Clevelandia ios	arrow goby	10	10	105.07
Allosmerus elongatus	whitebait smelt	2	2	21.01
Citharichthys sordidus	Pacific sanddab	2	2	21.01
Gillichthys mirabilis	longjaw mudsucker	1	1	10.51
Hippoglossoides elassodon	flathead sole	1	1	10.51
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	30	30	315.21
Targeted Invertebrates				
Metacarcinus magister (megalops)	Dungeness crab megalops	3	3	31.52

(continued)

Survey: HuB005 (continued) **Start Date: 05/26/2022**

Cycle: 2	**Sample: 15**	**Station: SW1**		
Split Multiplier: 4	**Volume: 85.39**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	13	52	609.00
Citharichthys sordidus	Pacific sanddab	1	4	46.85
Pleuronectoidei	flatfishes	1	4	46.85
Rhinogobiops nicholsii	blackeye goby	1	4	46.85
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	15	60	702.70
Targeted Invertebrates				
Metacarcinus magister (megalops)	Dungeness crab megalops	4	16	187.39

Cycle: 2	**Sample: 16**	**Station: SW6**		
Split Multiplier: 1	**Volume: 112.01**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	12	12	107.13
Atherinops affinis	topsmelt	1	1	8.93
Pleuronectoidei	flatfishes	1	1	8.93
Rhinogobiops nicholsii	blackeye goby	1	1	8.93
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	44	44	392.82
Targeted Invertebrates				
Cancer productus/Romal. spp. (megalops)	rock crab megalops	1	1	8.93

Survey: HuB006 **Start Date: 06/28/2022**

Cycle: 1	Sample: 1	Station: SW1		
Split Multiplier: 1	Volume: 117.95			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	24	24	203.48
Lepidogobius lepidus	bay goby	1	1	8.48
Rhinogobiops nicholsii	blackeye goby	1	1	8.48
Syngnathidae	pipefishes	1	1	8.48
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	11	11	93.26
Engraulidae (eggs)	anchovy eggs	10	10	84.78

Cycle: 1	Sample: 2	Station: SW2		
Split Multiplier: 4	Volume: 116.98			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	55	220	1,880.67
Engraulis mordax	northern anchovy	1	4	34.19
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	3	12	102.58

Cycle: 1	Sample: 3	Station: E2		
Split Multiplier: 4	Volume: 90.11			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	88	352	3,906.16
Allosmerus elongatus	whitebait smelt	1	4	44.39
Atherinopsis californiensis	jacksmelt	1	4	44.39
Fish Fragments				
larval fish fragment	larval fish fragments	2	8	88.78
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	13	52	577.05
Engraulidae (eggs)	anchovy eggs	9	36	399.49

(continued)

Survey: HuB006 (continued) **Start Date: 06/28/2022**

Cycle: 1	Sample: 4	Station: E1		
Split Multiplier: 8	Volume: 97.07			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	259	2,072	21,346.19
Cottus asper	prickly sculpin	1	8	82.42
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	34	272	2,802.20
Engraulidae (eggs)	anchovy eggs	1	8	82.42

Cycle: 1	Sample: 5	Station: SW3		
Split Multiplier: 8	Volume: 104.14			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	18	144	1,382.69
Allosmerus elongatus	whitebait smelt	1	8	76.82
Artedius spp.	sculpins	1	8	76.82
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	74	592	5,684.40
Engraulidae (eggs)	anchovy eggs	1	8	76.82

Cycle: 1	Sample: 6	Station: SW4		
Split Multiplier: 4	Volume: 77.61			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	3	12	154.63
Hypomesus pretiosus	surf smelt	2	8	103.08
Clevelandia ios	arrow goby	1	4	51.54
Spirinchus starksi	night smelt	1	4	51.54
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	14	56	721.59
Targeted Invertebrates				
Cancer productus/Romal. spp. (megalops)	rock crab megalops	1	4	51.54

(continued)

Survey: HuB006 (continued) **Start Date: 06/28/2022**

Cycle: 1	Sample: 7	Station: SW5		
Split Multiplier: 4	Volume: 87.13			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Hippoglossoides elassodon	flathead sole	1	4	45.91
Hypomesus pretiosus	surf smelt	1	4	45.91
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	83	332	3,810.39
Engraulidae (eggs)	anchovy eggs	1	4	45.91

Cycle: 1	Sample: 8	Station: SW6		
Split Multiplier: 1	Volume: 92.15			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	188	188	2,040.14
Lepidogobius lepidus	bay goby	6	6	65.11
Allosmerus elongatus	whitebait smelt	3	3	32.56
Spirinchus starksi	night smelt	1	1	10.85
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	158	158	1,714.59
Engraulidae (eggs)	anchovy eggs	2	2	21.70

Cycle: 2	Sample: 9	Station: SW5		
Split Multiplier: 4	Volume: 99.99			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Hypomesus pretiosus	surf smelt	3	12	120.01
Allosmerus elongatus	whitebait smelt	2	8	80.00
Pleuronectoidei	flatfishes	2	8	80.00
Clevelandia ios	arrow goby	1	4	40.00
Hippoglossoides elassodon	flathead sole	1	4	40.00
Lepidogobius lepidus	bay goby	1	4	40.00
Ruscarius meanyi	Puget Sound sculpin	1	4	40.00
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	53	212	2,120.12

(continued)

Survey: HuB006 (continued) **Start Date: 06/28/2022**

Cycle: 2	Sample: 10	Station: SW4		
Split Multiplier: 8	Volume: 86.60			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	36	288	3,325.63
Hypomesus pretiosus	surf smelt	3	24	277.14
Artedius spp.	sculpins	1	8	92.38
Lepidogobius lepidus	bay goby	1	8	92.38
Fish Fragments				
larval fish fragment	larval fish fragments	4	32	369.51
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	35	280	3,233.25

Cycle: 2	Sample: 11	Station: SW3		
Split Multiplier: 2	Volume: 114.62			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	25	50	436.23
Hypomesus pretiosus	surf smelt	1	2	17.45
Lepidogobius lepidus	bay goby	1	2	17.45
Pleuronectoidei	flatfishes	1	2	17.45
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	51	102	889.90

Cycle: 2	Sample: 12	Station: E1		
Split Multiplier: 8	Volume: 100.55			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	9	72	716.07
Hypomesus pretiosus	surf smelt	3	24	238.69
Liparis spp.	snailfishes	1	8	79.56
Microgadus proximus	Pacific tomcod	1	8	79.56
Sebastes spp. V_	KGB rockfish larval complex	1	8	79.56
Fish Fragments				
larval fish fragment	larval fish fragments	1	8	79.56
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	51	408	4,057.72
Targeted Invertebrates				
Cancer productus/Romal. spp. (megalops)	rock crab megalops	1	8	79.56

(continued)

Survey: HuB006 (continued) **Start Date: 06/28/2022**

Cycle: 2	Sample: 13	Station: E2		
Split Multiplier: 4	Volume: 80.68			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	19	76	941.99
Clevelandia ios	arrow goby	5	20	247.89
Hypomesus pretiosus	surf smelt	4	16	198.31
Lepidogobius lepidus	bay goby	2	8	99.16
Liparis spp.	snailfishes	2	8	99.16
Artedius spp.	sculpins	1	4	49.58
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	42	168	2,082.30

Cycle: 2	Sample: 14	Station: SW2		
Split Multiplier: 4	Volume: 100.77			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	48	192	1,905.30
Allosmerus elongatus	whitebait smelt	6	24	238.16
Artedius spp.	sculpins	1	4	39.69
larvae, yolksac	yolksac larvae	1	4	39.69
Lepidogobius lepidus	bay goby	1	4	39.69
Rhinogobiops nicholsii	blackeye goby	1	4	39.69
Fish Fragments				
larval fish fragment	larval fish fragments	1	4	39.69
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	47	188	1,865.61
Engraulidae (eggs)	anchovy eggs	6	24	238.16

Cycle: 2	Sample: 15	Station: SW1		
Split Multiplier: 4	Volume: 89.75			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	14	56	623.95
Clevelandia ios	arrow goby	13	52	579.38
Spirinchus starksi	night smelt	5	20	222.84
Allosmerus elongatus	whitebait smelt	3	12	133.70
Engraulis mordax	northern anchovy	1	4	44.57
Hypomesus pretiosus	surf smelt	1	4	44.57
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	68	272	3,030.60

(continued)

Survey: HuB006 (continued) **Start Date: 06/28/2022**

Cycle: 2	Sample: 16	Station: SW6		
Split Multiplier: 1	**Volume: 86.07**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	16	16	185.89
Hypomesus pretiosus	surf smelt	7	7	81.33
Lepidogobius lepidus	bay goby	2	2	23.24
Cebidichthys violaceus	monkeyface prickleback	1	1	11.62
Clevelandia ios	arrow goby	1	1	11.62
Radulinus spp.	sculpins	1	1	11.62
Stellerina xyosterna	pricklebreast poacher	1	1	11.62
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	223	223	2,590.85
Targeted Invertebrates				
Cancer productus/Romal. spp. (megalops)	rock crab megalops	1	1	11.62

Survey: HuB007 **Start Date: 07/29/2022**

Cycle: 1	Sample: 1	Station: SW1		
Split Multiplier: 1	Volume: 112.04			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	70	70	624.78
Gillichthys mirabilis	longjaw mudsucker	1	1	8.93
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	7	7	62.48

Cycle: 1	Sample: 2	Station: SW2		
Split Multiplier: 1	Volume: 90.26			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	19	19	210.51
Gillichthys mirabilis	longjaw mudsucker	2	2	22.16
Lepidogobius lepidus	bay goby	1	1	11.08
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	8	8	88.63
Engraulidae (eggs)	anchovy eggs	1	1	11.08

Cycle: 1	Sample: 3	Station: E2		
Split Multiplier: 1	Volume: 85.07			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	10	10	117.55
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	17	17	199.84
Engraulidae (eggs)	anchovy eggs	5	5	58.78

Cycle: 1	Sample: 4	Station: E1		
Split Multiplier: 1	Volume: 116.70			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	211	211	1,808.06
Lepidogobius lepidus	bay goby	19	19	162.81
Citharichthys sordidus	Pacific sanddab	1	1	8.57
Gillichthys mirabilis	longjaw mudsucker	1	1	8.57
Hippoglossoides elassodon	flathead sole	1	1	8.57
larvae, yolksac	yolksac larvae	1	1	8.57
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	89	89	762.64
Engraulidae (eggs)	anchovy eggs	1	1	8.57

(continued)

Survey: HuB007 (continued) **Start Date: 07/29/2022**

Cycle: 1	**Sample: 5**	**Station: SW3**		
Split Multiplier: 1	**Volume: 94.02**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	61	61	648.78
Lepidogobius lepidus	bay goby	4	4	42.54
Rhinogobiops nicholsii	blackeye goby	1	1	10.64
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	127	127	1,350.75

Cycle: 1	**Sample: 6**	**Station: SW4**		
Split Multiplier: 1	**Volume: 46.21**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	4	4	86.56
Lepidogobius lepidus	bay goby	2	2	43.28
Clevelandia ios	arrow goby	1	1	21.64
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	63	63	1,363.25

Cycle: 1	**Sample: 7**	**Station: SW5**		
Split Multiplier: 1	**Volume: 78.97**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Ammodytes hexapterus	Pacific sand lance	5	5	63.32
larvae, yolksac	yolksac larvae	1	1	12.66
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	213	213	2,697.32

Cycle: 1	**Sample: 8**	**Station: SW6**		
Split Multiplier: 2	**Volume: 90.24**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	12	24	265.94
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	66	132	1,462.69
Engraulidae (eggs)	anchovy eggs	4	8	88.65

(continued)

Survey: HuB007 (continued) **Start Date: 07/29/2022**

Cycle: 2	Sample: 9	Station: SW5		
Split Multiplier: 1	Volume: 97.12			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	5	5	51.48
Lepidogobius lepidus	bay goby	2	2	20.59
Citharichthys sordidus	Pacific sanddab	1	1	10.30
Hypomesus pretiosus	surf smelt	1	1	10.30
larvae, yolksac	yolksac larvae	1	1	10.30
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	197	197	2,028.40

Cycle: 2	Sample: 10	Station: SW4		
Split Multiplier: 1	Volume: 77.74			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	11	11	141.50
Lepidogobius lepidus	bay goby	5	5	64.32
Clevelandia ios	arrow goby	2	2	25.73
Fish Fragments				
larval fish fragment	larval fish fragments	2	2	25.73
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	171	171	2,199.74

Cycle: 2	Sample: 11	Station: SW3		
Split Multiplier: 2	Volume: 105.08			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	5	10	95.17
Lepidogobius lepidus	bay goby	3	6	57.10
Hypomesus pretiosus	surf smelt	1	2	19.03
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	112	224	2,131.72

(continued)

Survey: HuB007 (continued) **Start Date: 07/29/2022**

Cycle: 2	Sample: 12	Station: E1		
Split Multiplier: 1	Volume: 95.89			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Allosmerus elongatus	whitebait smelt	5	5	52.14
Clevelandia ios	arrow goby	1	1	10.43
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	167	167	1,741.63

Cycle: 2	Sample: 13	Station: E2		
Split Multiplier: 1	Volume: 86.55			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	7	7	80.88
Allosmerus elongatus	whitebait smelt	1	1	11.55
Citharichthys sordidus	Pacific sanddab	1	1	11.55
Clevelandia ios	arrow goby	1	1	11.55
Hypomesus pretiosus	surf smelt	1	1	11.55
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	125	125	1,444.32

Cycle: 2	Sample: 14	Station: SW2		
Split Multiplier: 1	Volume: 105.56			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	49	49	464.21
Lepidogobius lepidus	bay goby	4	4	37.89
Allosmerus elongatus	whitebait smelt	1	1	9.47
Engraulis mordax	northern anchovy	1	1	9.47
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	100	100	947.36

(continued)

Survey: HuB007 (continued) **Start Date: 07/29/2022**

Cycle: 2	Sample: 15	Station: SW1		
Split Multiplier: 1	Volume: 97.81			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	3	3	30.67
Allosmerus elongatus	whitebait smelt	1	1	10.22
Clevelandia ios	arrow goby	1	1	10.22
Non-Entrainable Fishes				
Pholis ornata	saddleback gunnel	1	1	10.22
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	153	153	1,564.33

Cycle: 2	Sample: 16	Station: SW6		
Split Multiplier: 1	Volume: 113.83			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	4	4	35.14
Allosmerus elongatus	whitebait smelt	3	3	26.36
Lepidogobius lepidus	bay goby	3	3	26.36
Hypomesus pretiosus	surf smelt	2	2	17.57
larvae, yolksac	yolksac larvae	1	1	8.79
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	149	149	1,309.03

Survey: HuB008 **Start Date: 08/18/2022**

Cycle: 1	Sample: 1	Station: SW1		
Split Multiplier: 1	Volume: 99.07			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	10	10	100.93
Lepidogobius lepidus	bay goby	3	3	30.28
Gillichthys mirabilis	longjaw mudsucker	1	1	10.09
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	65	65	656.07

Cycle: 1	Sample: 2	Station: SW2		
Split Multiplier: 1	Volume: 109.46			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	126	126	1,151.07
Lepidogobius lepidus	bay goby	10	10	91.35
Gillichthys mirabilis	longjaw mudsucker	1	1	9.14
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	211	211	1,927.59
Engraulidae (eggs)	anchovy eggs	2	2	18.27

Cycle: 1	Sample: 3	Station: E2		
Split Multiplier: 1	Volume: 103.09			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	36	36	349.21
Lepidogobius lepidus	bay goby	7	7	67.90
Genyonemus lineatus	white croaker	1	1	9.70
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	784	784	7,605.05

Cycle: 1	Sample: 4	Station: E1		
Split Multiplier: 1	Volume: 99.37			
Egg Jar Volume: 30	Egg Total Volume: 300			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	106	106	1,066.69
Lepidogobius lepidus	bay goby	12	12	120.76
Allosmerus elongatus	whitebait smelt	1	1	10.06
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	80	800	8,050.45

(continued)

Survey: HuB008 (continued) **Start Date: 08/18/2022**

Cycle: 1	**Sample: 5**	**Station: SW3**		
Split Multiplier: 1	**Volume: 107.90**			
Egg Jar Volume: 30	**Egg Total Volume: 300**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	47	47	435.60
Clevelandia ios	arrow goby	29	29	268.77
Allosmerus elongatus	whitebait smelt	3	3	27.80
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	97	970	8,990.04

Cycle: 1	**Sample: 6**	**Station: SW4**		
Split Multiplier: 1	**Volume: 80.98**			
Egg Jar Volume: 30	**Egg Total Volume: 300**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	18	18	222.28
Artedius spp.	sculpins	1	1	12.35
Pleuronectoidei	flatfishes	1	1	12.35
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	40	400	4,939.63
Targeted Invertebrates				
Cancridae (megalops)	cancer crabs megalops	1	1	12.35

Cycle: 1	**Sample: 7**	**Station: SW5**		
Split Multiplier: 1	**Volume: 96.40**			
Egg Jar Volume: 30	**Egg Total Volume: 300**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	10	10	103.74
larvae, yolksac	yolksac larvae	1	1	10.37
Fish Fragments				
larval fish - damaged	damaged larval fishes	1	1	10.37
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	58	580	6,016.86

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Survey: HuB008 (continued) **Start Date: 08/18/2022**

Cycle: 1	**Sample: 8**	**Station: SW6**		
Split Multiplier: 1	**Volume: 91.75**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	38	38	414.15
Lepidogobius lepidus	bay goby	2	2	21.80
Rhinogobiops nicholsii	blackeye goby	1	1	10.90
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	158	158	1,721.99
Engraulidae (eggs)	anchovy eggs	2	2	21.80

Cycle: 2	**Sample: 9**	**Station: SW5**		
Split Multiplier: 1	**Volume: 128.26**			
Egg Jar Volume: 30	**Egg Total Volume: 300**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	130	130	1,013.53
Allosmerus elongatus	whitebait smelt	1	1	7.80
Clevelandia ios	arrow goby	1	1	7.80
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	54	540	4,210.06
Engraulidae (eggs)	anchovy eggs	1	10	77.96

Cycle: 2	**Sample: 10**	**Station: SW4**		
Split Multiplier: 4	**Volume: 136.88**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	9	36	263.00
Allosmerus elongatus	whitebait smelt	2	8	58.44
Fish Fragments				
larval fish fragment	larval fish fragments	1	4	29.22
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	210	840	6,136.58
Engraulidae (eggs)	anchovy eggs	1	4	29.22

(continued)

Survey: HuB008 (continued) **Start Date: 08/18/2022**

Cycle: 2	Sample: 11	Station: SW3		
Split Multiplier: 1	Volume: 110.18			
Egg Jar Volume: 30	Egg Total Volume: 300			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	44	44	399.36
Allosmerus elongatus	whitebait smelt	2	2	18.15
Clevelandia ios	arrow goby	1	1	9.08
Rhinogobiops nicholsii	blackeye goby	1	1	9.08
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	77	770	6,988.82

Cycle: 2	Sample: 12	Station: E1		
Split Multiplier: 2	Volume: 128.54			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	55	110	855.74
Clevelandia ios	arrow goby	8	16	124.47
Syngnathidae	pipefishes	1	2	15.56
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	404	808	6,285.81
Engraulidae (eggs)	anchovy eggs	2	4	31.12

Cycle: 2	Sample: 13	Station: E2		
Split Multiplier: 2	Volume: 109.14			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	169	338	3,096.93
Lepidogobius lepidus	bay goby	21	42	384.83
Gillichthys mirabilis	longjaw mudsucker	1	2	18.33
Fish Fragments				
larval fish fragment	larval fish fragments	4	8	73.30
Non-Entrainable Fishes				
Hypomesus pretiosus	surf smelt	2	4	36.65
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	206	412	3,774.95

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Survey: HuB008 (continued) **Start Date: 08/18/2022**

Cycle: 2	**Sample: 14**	**Station: SW2**		
Split Multiplier: 4	**Volume: 131.29**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	227	908	6,916.08
Lepidogobius lepidus	bay goby	3	12	91.40
Hypomesus pretiosus	surf smelt	2	8	60.93
Engraulis mordax	northern anchovy	1	4	30.47
Fish Fragments				
larval fish fragment	larval fish fragments	4	16	121.87
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	55	220	1,675.70

Cycle: 2	**Sample: 15**	**Station: SW1**		
Split Multiplier: 1	**Volume: 109.39**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	77	77	703.92
Lepidogobius lepidus	bay goby	3	3	27.43
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	34	34	310.82

Cycle: 2	**Sample: 16**	**Station: SW6**		
Split Multiplier: 2	**Volume: 104.17**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	370	740	7,103.58
Gillichthys mirabilis	longjaw mudsucker	3	6	57.60
Lepidogobius lepidus	bay goby	2	4	38.40
Porichthys notatus	plainfin midshipman	2	4	38.40
Hypomesus pretiosus	surf smelt	1	2	19.20
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	25	50	479.97

Survey: HuB009 **Start Date: 09/22/2022**

Cycle: 1	Sample: 1	Station: SW1		
Split Multiplier: 1	Volume: 108.41			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	9	9	83.01
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	27	27	249.04

Cycle: 1	Sample: 2	Station: SW2		
Split Multiplier: 2	Volume: 97.39			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	18	36	369.66
Lepidogobius lepidus	bay goby	2	4	41.07
larvae, yolksac	yolksac larvae	1	2	20.54
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	6	12	123.22

Cycle: 1	Sample: 3	Station: E2		
Split Multiplier: 1	Volume: 97.15			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	14	14	144.10
Hypomesus pretiosus	surf smelt	1	1	10.29
larval fish - damaged	damaged larval fishes	1	1	10.29
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	148	148	1,523.35

Cycle: 1	Sample: 4	Station: E1		
Split Multiplier: 1	Volume: 93.68			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	12	12	128.10
Hypomesus pretiosus	surf smelt	1	1	10.67
Icichthys lockingtoni	medusa fish	1	1	10.67
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	367	367	3,917.63
Engraulidae (eggs)	anchovy eggs	16	16	170.80

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Survey: HuB009 (continued) **Start Date: 09/22/2022**

Cycle: 1	**Sample: 5**	**Station: SW3**		
Split Multiplier: 1	**Volume: 97.53**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	1	1	10.25
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	349	349	3,578.52
Engraulidae (eggs)	anchovy eggs	14	14	143.55

Cycle: 1	**Sample: 6**	**Station: SW4**		
Split Multiplier: 1	**Volume: 106.75**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	11	11	103.05
Nannobrachium regalis	pinpoint lanternfish	1	1	9.37
Tarletonbeania crenularis	blue lanternfish	1	1	9.37
Trachipterus altivelis	king-of-the-salmon	1	1	9.37
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	394	394	3,690.99
Engraulidae (eggs)	anchovy eggs	36	36	337.25

Cycle: 1	**Sample: 7**	**Station: SW5**		
Split Multiplier: 1	**Volume: 110.92**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	1	1	9.02
Fish Fragments				
larval fish fragment	larval fish fragments	1	1	9.02
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	394	394	3,552.14
Engraulidae (eggs)	anchovy eggs	35	35	315.55

Cycle: 1	**Sample: 8**	**Station: SW6**		
Split Multiplier: 1	**Volume: 81.17**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	5	5	61.60
Lepidogobius lepidus	bay goby	2	2	24.64
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	130	130	1,601.66
Engraulidae (eggs)	anchovy eggs	1	1	12.32

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Survey: HuB009 (continued) **Start Date: 09/22/2022**

Cycle: 2	**Sample: 9**	**Station: SW5**		
Split Multiplier: 1	**Volume: 125.44**			
Egg Jar Volume: 30	**Egg Total Volume: 300**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Citharichthys stigmaeus	speckled sanddab	1	1	7.97
Nannobrachium spp.	lanternfishes	1	1	7.97
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	57	570	4,543.94
Engraulidae (eggs)	anchovy eggs	3	30	239.15

Cycle: 2	**Sample: 10**	**Station: SW4**		
Split Multiplier: 1	**Volume: 93.34**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	474	474	5,078.14
Engraulidae (eggs)	anchovy eggs	29	29	310.69

Cycle: 2	**Sample: 11**	**Station: SW3**		
Split Multiplier: 1	**Volume: 90.22**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	3	3	33.25
Rhinogobiops nicholsii	blackeye goby	1	1	11.08
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	240	240	2,660.20
Engraulidae (eggs)	anchovy eggs	10	10	110.84

Cycle: 2	**Sample: 12**	**Station: E1**		
Split Multiplier: 1	**Volume: 122.51**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	22	22	179.57
Leptocottus armatus	Pacific staghorn sculpin	1	1	8.16
Rhinogobiops nicholsii	blackeye goby	1	1	8.16
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	274	274	2,236.49
Engraulidae (eggs)	anchovy eggs	5	5	40.81

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Survey: HuB009 (continued) **Start Date: 09/22/2022**

Cycle: 2	Sample: 13	Station: E2		
Split Multiplier: 1	Volume: 105.96			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	49	49	462.44
Clevelandia ios	arrow goby	3	3	28.31
Allosmerus elongatus	whitebait smelt	1	1	9.44
Nannobrachium regalis	pinpoint lanternfish	1	1	9.44
Rhinogobiops nicholsii	blackeye goby	1	1	9.44
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	185	185	1,745.96
Engraulidae (eggs)	anchovy eggs	4	4	37.75

Cycle: 2	Sample: 14	Station: SW2		
Split Multiplier: 1	Volume: 90.30			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	23	23	254.72
Clevelandia ios	arrow goby	13	13	143.97
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	74	74	819.53
Engraulidae (eggs)	anchovy eggs	1	1	11.07

Cycle: 2	Sample: 15	Station: SW1		
Split Multiplier: 1	Volume: 92.85			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Hypomesus pretiosus	surf smelt	1	1	10.77
Lepidogobius lepidus	bay goby	1	1	10.77
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	316	316	3,403.23
Engraulidae (eggs)	anchovy eggs	2	2	21.54
Targeted Invertebrates				
Romal. anten./Metacar. grac. (megalops)	cancer crabs	1	1	10.77

(continued)

Survey: HuB009 (continued) **Start Date: 09/22/2022**

Cycle: 2	Sample: 16	Station: SW6		
Split Multiplier: 1	Volume: 84.70			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	53	53	625.71
Trachipterus altivelis	king-of-the-salmon	1	1	11.81
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	410	410	4,840.40
Engraulidae (eggs)	anchovy eggs	2	2	23.61

Survey: HuB010 **Start Date: 10/11/2022**

Cycle: 1	Sample: 1	Station: SW1		
Split Multiplier: 1	**Volume: 91.49**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	1	1	10.93
Lepidogobius lepidus	bay goby	1	1	10.93
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	12	12	131.17

Cycle: 1	Sample: 2	Station: SW2		
Split Multiplier: 1	**Volume: 110.66**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	6	6	54.22
Lepidogobius lepidus	bay goby	4	4	36.15
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	20	20	180.73

Cycle: 1	Sample: 3	Station: E2		
Split Multiplier: 1	**Volume: 88.50**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	6	6	67.80
Clevelandia ios	arrow goby	2	2	22.60
Icichthys lockingtoni	medusa fish	1	1	11.30
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	263	263	2,971.82

Cycle: 1	Sample: 4	Station: E1		
Split Multiplier: 1	**Volume: 85.00**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	36	36	423.53
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	246	246	2,894.09

(continued)

Survey: HuB010 (continued) **Start Date: 10/11/2022**

Cycle: 1	Sample: 5	Station: SW3		
Split Multiplier: 1	Volume: 91.12			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	16	16	175.59
Clevelandia ios	arrow goby	1	1	10.97
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	227	227	2,491.24

Cycle: 1	Sample: 6	Station: SW4		
Split Multiplier: 1	Volume: 92.86			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	2	2	21.54
Engraulis mordax	northern anchovy	1	1	10.77
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	29	29	312.29

Cycle: 1	Sample: 7	Station: SW5		
Split Multiplier: 1	Volume: 87.18			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	12	12	137.64
Tarletonbeania crenularis	blue lanternfish	2	2	22.94
Psettichthys melanostictus	sand sole	1	1	11.47
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	50	50	573.51
Engraulidae (eggs)	anchovy eggs	2	2	22.94

Cycle: 1	Sample: 8	Station: SW6		
Split Multiplier: 1	Volume: 106.50			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	3	3	28.17
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	238	238	2,234.84

(continued)

Survey: HuB010 (continued) **Start Date: 10/11/2022**

Cycle: 2	Sample: 9	Station: SW5		
Split Multiplier: 1	**Volume: 91.57**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	2	2	21.84
Clevelandia ios	arrow goby	1	1	10.92
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	58	58	633.38

Cycle: 2	Sample: 10	Station: SW4		
Split Multiplier: 1	**Volume: 99.13**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	12	12	121.05
Rhinogobiops nicholsii	blackeye goby	1	1	10.09
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	52	52	524.55

Cycle: 2	Sample: 11	Station: SW3		
Split Multiplier: 1	**Volume: 97.34**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	4	4	41.09
Gillichthys mirabilis	longjaw mudsucker	1	1	10.27
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	28	28	287.64

Cycle: 2	Sample: 12	Station: E1		
Split Multiplier: 1	**Volume: 96.30**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	4	4	41.54
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	23	23	238.84

(continued)

Survey: HuB010 (continued) **Start Date: 10/11/2022**

Cycle: 2	Sample: 13	Station: E2		
Split Multiplier: 1	Volume: 98.29			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	3	3	30.52
Gillichthys mirabilis	longjaw mudsucker	1	1	10.17
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	14	14	142.43

Cycle: 2	Sample: 14	Station: SW2		
Split Multiplier: 1	Volume: 96.10			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	13	13	135.27
Gillichthys mirabilis	longjaw mudsucker	1	1	10.41
Non-Entrainable Fishes				
Hypomesus pretiosus	surf smelt	1	1	10.41
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	1	1	10.41

Cycle: 2	Sample: 15	Station: SW1		
Split Multiplier: 1	Volume: 109.19			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	6	6	54.95
Clevelandia ios	arrow goby	1	1	9.16
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	1	1	9.16

Cycle: 2	Sample: 16	Station: SW6		
Split Multiplier: 1	Volume: 95.44			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	5	5	52.39
Clevelandia ios	arrow goby	3	3	31.43
Engraulis mordax	northern anchovy	1	1	10.48
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	13	13	136.21

Survey: HuB011 **Start Date: 11/07/2022**

Cycle: 1	Sample: 1	Station: SW1		
Split Multiplier: 1	Volume: 86.83			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	2	2	23.03
Engraulis mordax	northern anchovy	1	1	11.52
Genyonemus lineatus	white croaker	1	1	11.52
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	44	44	506.72

Cycle: 1	Sample: 2	Station: SW2		
Split Multiplier: 1	Volume: 100.57			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	9	9	89.49
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	52	52	517.05

Cycle: 1	Sample: 3	Station: E2		
Split Multiplier: 1	Volume: 99.68			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	52	52	521.68
Hypomesus pretiosus	surf smelt	5	5	50.16
Leptocottus armatus	Pacific staghorn sculpin	2	2	20.06
Engraulis mordax	northern anchovy	1	1	10.03
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	60	60	601.94

(continued)

Survey: HuB011 (continued) **Start Date: 11/07/2022**

Cycle: 1	Sample: 4	Station: E1		
Split Multiplier: 1	**Volume: 89.40**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Engraulis mordax	northern anchovy	3	3	33.56
Hypomesus pretiosus	surf smelt	2	2	22.37
Fish Fragments				
larval fish fragment	larval fish fragments	11	11	123.05
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	8	8	89.49
Targeted Invertebrates				
Cancer productus/Romal. spp. (megalops)	rock crab megalops	1	1	11.19

Cycle: 1	Sample: 5	Station: SW3		
Split Multiplier: 1	**Volume: 91.89**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Engraulis mordax	northern anchovy	3	3	32.65
Leptocottus armatus	Pacific staghorn sculpin	1	1	10.88
Fish Fragments				
larval fish fragment	larval fish fragments	3	3	32.65
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	4	4	43.53

Cycle: 1	Sample: 6	Station: SW4		
Split Multiplier: 1	**Volume: 100.55**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Hypomesus pretiosus	surf smelt	3	3	29.84
Genyonemus lineatus	white croaker	2	2	19.89
Engraulis mordax	northern anchovy	1	1	9.95
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	4	4	39.78

(continued)

Survey: HuB011 (continued) **Start Date: 11/07/2022**

Cycle: 1	**Sample: 7**	**Station: SW5**		
Split Multiplier: 1	**Volume: 86.80**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	18	18	207.36
Engraulis mordax	northern anchovy	5	5	57.60
Genyonemus lineatus	white croaker	2	2	23.04
Hexagrammos decagrammus	kelp greenling	1	1	11.52
Hypomesus pretiosus	surf smelt	1	1	11.52
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	19	19	218.88

Cycle: 1	**Sample: 8**	**Station: SW6**		
Split Multiplier: 1	**Volume: 110.91**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	14	14	126.23
Engraulis mordax	northern anchovy	1	1	9.02
Hypomesus pretiosus	surf smelt	1	1	9.02
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	56	56	504.92

Cycle: 2	**Sample: 9**	**Station: SW5**		
Split Multiplier: 1	**Volume: 109.80**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	6	6	54.65
Leptocottus armatus	Pacific staghorn sculpin	2	2	18.22
Clevelandia ios	arrow goby	1	1	9.11
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	10	10	91.08

(continued)

Survey: HuB011 (continued) **Start Date: 11/07/2022**

Cycle: 2	Sample: 10	Station: SW4		
Split Multiplier: 1	Volume: 126.32			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	4	4	31.66
Gillichthys mirabilis	longjaw mudsucker	1	1	7.92
Hypomesus pretiosus	surf smelt	1	1	7.92
Non-Entrainable Fishes				
Hypomesus pretiosus	surf smelt	6	6	47.50
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	22	22	174.16

Cycle: 2	Sample: 11	Station: SW3		
Split Multiplier: 1	Volume: 87.40			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Engraulis mordax	northern anchovy	4	4	45.77
Lepidogobius lepidus	bay goby	2	2	22.88
Leptocottus armatus	Pacific staghorn sculpin	2	2	22.88
Clevelandia ios	arrow goby	1	1	11.44
Gillichthys mirabilis	longjaw mudsucker	1	1	11.44
Non-Entrainable Fishes				
Hypomesus pretiosus	surf smelt	1	1	11.44
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	11	11	125.86

Cycle: 2	Sample: 12	Station: E1		
Split Multiplier: 1	Volume: 83.99			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	1	1	11.91
Non-Entrainable Fishes				
Hypomesus pretiosus	surf smelt	4	4	47.63
Sardinops sagax	Pacific sardine	2	2	23.81
Engraulis mordax	northern anchovy	1	1	11.91
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	8	8	95.26

(continued)

Survey: HuB011 (continued) **Start Date: 11/07/2022**

Cycle: 2	Sample: 13	Station: E2		
Split Multiplier: 1	Volume: 104.83			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	6	6	57.24
Lepidogobius lepidus	bay goby	3	3	28.62
Engraulis mordax	northern anchovy	1	1	9.54
Leptocottus armatus	Pacific staghorn sculpin	1	1	9.54
Non-Entrainable Fishes				
Clupea pallasii	Pacific herring	1	1	9.54
Hypomesus pretiosus	surf smelt	1	1	9.54
Porichthys notatus	plainfin midshipman	1	1	9.54
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	6	6	57.24
Targeted Invertebrates				
Cancer productus/Romal. spp. (megalops)	rock crab megalops	1	1	9.54

Cycle: 2	Sample: 14	Station: SW2		
Split Multiplier: 1	Volume: 87.49			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Gillichthys mirabilis	longjaw mudsucker	3	3	34.29
Clevelandia ios	arrow goby	2	2	22.86
Leptocottus armatus	Pacific staghorn sculpin	1	1	11.43

(continued)

Survey: HuB011 (continued) **Start Date: 11/07/2022**

Cycle: 2	Sample: 15	Station: SW1		
Split Multiplier: 1	Volume: 103.58			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Clevelandia ios	arrow goby	2	2	19.31
Engraulis mordax	northern anchovy	1	1	9.65
Leptocottus armatus	Pacific staghorn sculpin	1	1	9.65
Non-Entrainable Fishes				
Hypomesus pretiosus	surf smelt	1	1	9.65
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	6	6	57.92
Targeted Invertebrates				
Cancer productus/Romal. spp. (megalops)	rock crab megalops	1	1	9.65

Cycle: 2	Sample: 16	Station: SW6		
Split Multiplier: 1	Volume: 88.47			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Non-Entrainable Larval Fishes				
Engraulis mordax	northern anchovy	1	1	11.30
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	8	8	90.43

Survey: HuB012 **Start Date: 12/06/2022**

Cycle: 1	Sample: 1	Station: SW1		
Split Multiplier: 1	Volume: 104.96			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	10	10	95.28
Leptocottus armatus	Pacific staghorn sculpin	1	1	9.53
Sebastes spp. V	blue rockfish larval complex	1	1	9.53
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	11	11	104.80

Cycle: 1	Sample: 2	Station: SW2		
Split Multiplier: 1	Volume: 110.02			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	27	27	245.40
Clevelandia ios	arrow goby	1	1	9.09
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	20	20	181.78

Cycle: 1	Sample: 3	Station: E2		
Split Multiplier: 1	Volume: 98.69			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	7	7	70.93
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	10	10	101.33

Cycle: 1	Sample: 4	Station: E1		
Split Multiplier: 1	Volume: 121.94			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	19	19	155.82
Leptocottus armatus	Pacific staghorn sculpin	3	3	24.60
Fish Fragments				
larval fish fragment	larval fish fragments	1	1	8.20
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	9	9	73.81

(continued)

Survey: HuB012 (continued) **Start Date: 12/06/2022**

Cycle: 1	Sample: 5	Station: SW3		
Split Multiplier: 1	**Volume: 118.79**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	12	12	101.02
Leptocottus armatus	Pacific staghorn sculpin	3	3	25.26
Hypomesus pretiosus	surf smelt	1	1	8.42
Liparis spp.	snailfishes	1	1	8.42
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	8	8	67.35

Cycle: 1	Sample: 6	Station: SW4		
Split Multiplier: 1	**Volume: 88.41**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Tarletonbeania crenularis	blue lanternfish	1	1	11.31
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	2	2	22.62

Cycle: 1	Sample: 7	Station: SW5		
Split Multiplier: 1	**Volume: 110.20**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	5	5	45.37
Leptocottus armatus	Pacific staghorn sculpin	2	2	18.15
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	8	8	72.59

Cycle: 1	Sample: 8	Station: SW6		
Split Multiplier: 1	**Volume: 119.50**			
Taxon	**Common Name**	**Count**	**Adjusted Count**	**Concentration (#/1000m3)**
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	7	7	58.58
Leptocottus armatus	Pacific staghorn sculpin	3	3	25.10
Fish Fragments				
larval fish fragment	larval fish fragments	1	1	8.37
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	18	18	150.62

(continued)

Survey: HuB012 (continued) **Start Date: 12/06/2022**

Cycle: 2	Sample: 9	Station: SW5		
Split Multiplier: 1	Volume: 103.53			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	16	16	154.54
Clevelandia ios	arrow goby	1	1	9.66
Hypomesus pretiosus	surf smelt	1	1	9.66
Leptocottus armatus	Pacific staghorn sculpin	1	1	9.66
Fish Fragments				
larval fish fragment	larval fish fragments	5	5	48.29
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	4	4	38.64

Cycle: 2	Sample: 10	Station: SW4		
Split Multiplier: 1	Volume: 122.08			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	11	11	90.10
Hypomesus pretiosus	surf smelt	4	4	32.77
Leptocottus armatus	Pacific staghorn sculpin	2	2	16.38
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	18	18	147.44

Cycle: 2	Sample: 11	Station: SW3		
Split Multiplier: 1	Volume: 101.55			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	8	8	78.78
Hypomesus pretiosus	surf smelt	5	5	49.23
Engraulis mordax	northern anchovy	1	1	9.85
Leptocottus armatus	Pacific staghorn sculpin	1	1	9.85
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	14	14	137.86

(continued)

Survey: HuB012 (continued) **Start Date: 12/06/2022**

Cycle: 2	Sample: 12	Station: E1		
Split Multiplier: 1	Volume: 101.77			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	15	15	147.39
Engraulis mordax	northern anchovy	2	2	19.65
Hypomesus pretiosus	surf smelt	2	2	19.65
Clevelandia ios	arrow goby	1	1	9.83
Fish Fragments				
larval fish fragment	larval fish fragments	1	1	9.83
Non-Entrainable Fishes				
Engraulis mordax	northern anchovy	1	1	9.83
Hypomesus pretiosus	surf smelt	1	1	9.83
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	14	14	137.57

Cycle: 2	Sample: 13	Station: E2		
Split Multiplier: 1	Volume: 95.54			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Lepidogobius lepidus	bay goby	7	7	73.27
Non-Entrainable Fishes				
Hypomesus pretiosus	surf smelt	2	2	20.93
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	2	2	20.93

Cycle: 2	Sample: 14	Station: SW2		
Split Multiplier: 1	Volume: 97.90			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Hypomesus pretiosus	surf smelt	3	3	30.64
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	3	3	30.64

(continued)

Survey: HuB012 (continued) **Start Date: 12/06/2022**

Cycle: 2	Sample: 15	Station: SW1		
Split Multiplier: 1	Volume: 94.64			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Hypomesus pretiosus	surf smelt	6	6	63.40
Engraulis mordax	northern anchovy	2	2	21.13
Lepidogobius lepidus	bay goby	2	2	21.13
Clevelandia ios	arrow goby	1	1	10.57
Gillichthys mirabilis	longjaw mudsucker	1	1	10.57
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	4	4	42.27

Cycle: 2	Sample: 16	Station: SW6		
Split Multiplier: 1	Volume: 90.48			
Taxon	Common Name	Count	Adjusted Count	Concentration (#/1000m3)
Entrainable Larval Fishes				
Hypomesus pretiosus	surf smelt	6	6	66.31
Lepidogobius lepidus	bay goby	2	2	22.10
Non-Entrainable Fishes				
Hypomesus pretiosus	surf smelt	1	1	11.05
Fish Eggs				
non-engraulidae eggs	non-engraulidae eggs	6	6	66.31

Appendix B

Sample Information

This appendix presents information on each of samples collected. The data from these samples are presented in Appendix A. The following data are included in this appendix with the column title and definition:

Column Heading	Definition
Date Time	Date and time in PST
Survey	Numeric survey number that corresponds to numeric month of the year
Sample Number	Sample number for survey
Station	Station designation
Cycle	1 = day, 2 = night
Depth (ft)	Depth at location of sampling in feet
Split Multiple	Number of times the sample volume was divided before processing
Sample Volume (m^3)	Volume of seawater filtered for sample in cubic meters (1.0 m^3 = 264.2 gal)
Tide Height (m)	Tide height in m relative to MLLW at time of sampling
Tide Flow	Tidal flow during sampling (E = ebb, F = flood, S = slack)
Tide Change	Location in tide cycle (HH = high high, LH = low high, HL = high low, LL = low low)
Burke-o-lator Temperature (˚C)	Temperature at time of sampling from Burke-o-lator at Hog Island Oyster*
Burke-o-lator Salinity (PSU)	Salinity at time of sampling from Burke-o-lator at Hog Island Oyster*
CTD Salinity (PSU) Top	Salinity at time of sampling from near water surface 0.25m to 0.75m
CTD Salinity (PSU) Middle	Salinity at time of sampling from one meter layer at mid-water of CTD cast
CTD Salinity (PSU) Bottom	Salinity at time of sampling from one meter layer at bottom of CTD cast [1]
CTD Temperature (˚C) Top	Water temperature at time of sampling from near water surface 0.25m to 0.75m
CTD Temperature (˚C) Middle	Water temperature at time of sampling from one meter layer at mid-water of CTD cast
CTD Temperature (˚C) Bottom	Water temperature at time of sampling from one meter layer at bottom of CTD cast

* - data from Burke-o-lator at Hog Island Oyster Company used for Survey 1 due to CTD malfunction. Source: https://data.caloos.org/#metadata/100009/station/data.

1 - salinity data not screened for salinity readings at bottom of cast that may have been affected by sediments suspended from CTD hitting the bottom.

								Tide Information			Data from Burkeolator		Data from CTD Casts					
													Salinity (PSU)			Temperature (C)		
DateTime	Survey	Sample	Station	Cycle	Depth (ft)	Split Multiple	Sample Volume (m^3)	Tide Height (m)	Tide Flow	Tide Change	Temperature (C)	Salinity (PSU)	Top	Middle	Bottom	Top	Middle	Bottom
1/11/2022 9:35	1	1	SW1	1	19	1	81.92	1.51	E	HH-LL	10.45	29.91						
1/11/2022 10:18	1	2	SW2	1	22	1	128.87	1.24	E	HH-LL	10.61	29.52						
1/11/2022 10:45	1	3	EA2	1	19	1	104.52	1.07	E	HH-LL	10.77	29.24						
1/11/2022 11:06	1	4	EA1	1	43	1	80.03	0.94	E	HH-LL	10.73	28.87						
1/11/2022 11:27	1	5	SW3	1	43	1	81.68	0.83	E	HH-LL	10.95	28.61						
1/11/2022 11:54	1	6	SW5	1	44	1	82.54	0.69	E	HH-LL	11.06	28.52						
1/11/2022 12:16	1	7	SW4	1	48	1	80.61	0.59	E	HH-LL	11.05	28.42						
1/11/2022 12:48	1	8	SW6	1	19	1	83.91	0.49	E	HH-LL	11.09	28.29						
1/11/2022 18:25	1	9	SW1	2	20	1	79.61	1.22	F	LL-LH	10.58	28.42						
1/11/2022 19:25	1	10	SW2	2	21	1	93.89	1.34	F	LL-LH	10.69	29.04						
1/11/2022 19:55	1	11	EA2	2	32	1	156.01	1.35	S	LH	10.78	29.40						
1/11/2022 20:25	1	12	EA1	2	46	1	118.68	1.35	E	LH-HL	10.82	29.75						
1/11/2022 20:50	1	13	SW3	2	45	1	95.92	1.33	E	LH-HL	10.80	29.72						
2/10/2022 9:20	2	1	SW1	1	20	1	107.88	1.49	E	HH-LL			32.38	32.67	32.85	10.26	10.13	10.10
2/10/2022 9:59	2	2	SW2	1	22.8	1	105.54	1.27	E	HH-LL			32.34	32.58	32.65	10.37	10.27	10.20
2/10/2022 10:22	2	3	EA2	1	20.1	1	118.12	1.14	E	HH-LL			32.79	32.78	32.81	10.10	10.04	10.05
2/10/2022 10:37	2	4	EA1	1	38.4	1	80.61	1.05	E	HH-LL			32.86	32.86	32.88	10.19	10.11	10.09
2/10/2022 10:55	2	5	SW3	1	43.2	1	102.33	0.95	E	HH-LL			32.88	33.03	33.07	10.17	10.03	10.00
2/10/2022 11:17	2	6	SW4	1	40.3	1	81.46	0.83	E	HH-LL			33.36	33.38	33.40	9.88	9.82	9.81
2/10/2022 11:34	2	7	SW5	1	40.3	1	94.08	0.73	E	HH-LL			33.42	33.46	33.46	10.92	10.12	10.06
2/10/2022 12:24	2	8	SW6	1	20.7	1	82.05	0.50	E	HH-LL			31.41	31.42	31.49	11.19	10.94	10.98
2/10/2022 18:03	2	9	SW1	2	15.8	1	125.69	1.01	F	LL-LH			32.25	32.16	32.16	11.07	11.06	11.03
2/10/2022 18:52	2	10	SW2	2	20.1	1	119.45	1.18	F	LL-LH			32.41	32.41	32.41	10.73	10.75	10.75
2/10/2022 19:25	2	11	EA2	2	19.9	1	98.40	1.27	F	LL-LH			32.50	32.65	32.74	10.67	10.46	10.39
2/10/2022 19:45	2	12	EA1	2	41.3	1	97.74	1.31	F	LL-LH			32.80	33.16	33.21	10.31	10.26	10.25
2/10/2022 20:06	2	13	SW3	2	48.1	1	132.22	1.35	F	LL-LH			33.36	33.41	33.42	10.09	10.02	10.00
2/10/2022 20:40	2	14	SW4	2	46	1	103.85	1.38	F	LL-LH			33.59	33.60	33.60	9.74	9.73	9.74
2/10/2022 21:06	2	15	SW5	2	47.7	1	87.71	1.39	S	LH			33.50	33.56	33.59	10.15	9.71	9.67
2/10/2022 22:05	2	16	SW6	2	22.3	1	110.01	1.37	E	LH-HL			32.44	32.68	32.77	10.49	10.39	10.46

								Tide Information			Data from Burkeolator		Data from CTD Casts					
													Salinity (PSU)			Temperature (C)		
DateTime	Survey	Sample	Station	Cycle	Depth (ft)	Split Multiple	Sample Volume (m^3)	Tide Height (m)	Tide Flow	Tide Change	Temperature (C)	Salinity (PSU)	Top	Middle	Bottom	Top	Middle	Bottom
3/17/2022 8:17	3	1	SW1	1	18	1	117.54	1.44	F	HL-HH			21.44	33.09	33.01	11.84	11.84	11.84
3/17/2022 8:58	3	2	SW2	1	22	1	100.11	1.68	F	HL-HH			33.07	33.10	33.10	11.87	11.89	11.89
3/17/2022 9:29	3	3	EA2	1	26	1	114.44	1.83	F	HL-HH			33.26	33.37	33.38	11.13	10.75	10.69
3/17/2022 10:20	3	4	EA1	1	48	1	100.72	2.01	F	HL-HH			33.43	33.57	33.57	10.54	9.96	9.93
3/17/2022 10:48	3	5	SW3	1	48	1	98.51	2.05	S	HH			33.61	33.62	33.62	9.93	9.79	9.75
3/17/2022 11:19	3	6	SW4	1	52	1	102.72	2.05	E	HH-LL			33.61	33.63	33.63	9.95	9.78	9.73
3/17/2022 12:04	3	7	SW5	1	48	1	84.24	1.92	E	HH-LL			33.56	33.65	33.67	10.34	9.78	9.70
3/17/2022 12:56	3	8	SW6	1	25	1	114.43	1.63	E	HH-LL			33.16	33.21	33.22	12.13	11.94	11.90
3/17/2022 18:50	3	9	SW5	2	41	1	102.21	0.22	F	LL-LH			33.45	33.50	33.54	11.97	11.50	11.18
3/17/2022 19:10	3	10	SW4	2	47	1	106.94	0.34	F	LL-LH			33.40	33.41	33.41	11.26	11.10	11.09
3/17/2022 19:37	3	11	SW3	2	40	1	158.82	0.51	F	LL-LH			33.02	33.14	33.14	12.27	12.33	12.32
3/17/2022 20:00	3	12	EA1	2	42	1	101.99	0.68	F	LL-LH			33.08	33.11	33.12	12.63	12.59	12.55
3/17/2022 20:19	3	13	EA2	2	16	1	93.70	0.82	F	LL-LH			32.94	33.00	31.62	12.97	12.98	12.98
3/17/2022 20:48	3	14	SW2	2	20	1	105.42	1.04	F	LL-LH			32.93	32.94	32.95	13.39	13.41	13.41
3/17/2022 21:30	3	15	SW1	2	20	1	114.46	1.34	F	LL-LH			33.03	33.06	33.06	12.58	12.63	12.64
3/17/2022 21:54	3	16	SW6	2	24	1	100.59	1.50	F	LL-LH			32.96	33.04	33.08	12.44	12.34	12.26
4/26/2022 8:57	4	1	SW1	1	17	1	110.73	1.68	E	LH-LL			9.74	31.57	31.59	11.83	11.77	11.75
4/26/2022 9:45	4	2	SW2	1	19	1	153.39	1.51	E	LH-LL			31.29	31.41	31.39	12.18	12.02	11.91
4/26/2022 10:08	4	3	EA2	1	23	1	105.50	1.40	E	LH-LL			31.10	32.48	31.99	11.10	10.76	10.70
4/26/2022 10:21	4	4	EA1	1	42	1	92.63	1.33	E	LH-LL			32.13	32.63	32.68	11.34	10.61	10.55
4/26/2022 10:39	4	5	SW3	1	47	1	116.58	1.22	E	LH-LL			31.71	32.70	32.87	11.08	10.56	10.33
4/26/2022 11:03	4	6	SW4	1	48	1	82.58	1.07	E	LH-LL			32.96	33.16	33.20	10.42	9.95	9.87
4/26/2022 11:19	4	7	SW5	1	36	1	80.12	0.96	E	LH-LL			32.80	32.89	33.05	10.81	10.54	10.08
4/26/2022 12:08	4	8	SW6	1	25	1	114.46	0.62	E	LH-LL			30.46	30.49	27.50	13.38	13.30	13.27
4/26/2022 20:13	4	9	SW5	2	44	1	113.95	1.75	F	LL-HH			33.01	33.14	33.14	10.39	10.24	10.24
4/26/2022 20:33	4	10	SW4	2	52	1	74.98	1.81	F	LL-HH			32.94	33.23	33.23	10.25	10.28	10.28
4/26/2022 21:07	4	11	SW3	2	42	1	102.69	1.87	S	HH			31.74	32.91	32.95	11.20	10.72	10.47
4/26/2022 21:25	4	12	EA1	2	46	1	101.29	1.87	S	HH			32.62	32.80	32.84	11.13	10.91	10.87
4/26/2022 21:40	4	13	EA2	2	26	1	100.28	1.86	E	HH-HL			30.61	32.63	32.63	11.93	11.18	11.19

								Tide Information			Data from Burkeolator		Data from CTD Casts					
													Salinity (PSU)			Temperature (C)		
DateTime	Survey	Sample	Station	Cycle	Depth (ft)	Split Multiple	Sample Volume (m^3)	Tide Height (m)	Tide Flow	Tide Change	Temperature (C)	Salinity (PSU)	Top	Middle	Bottom	Top	Middle	Bottom
4/26/2022 22:11	4	14	SW2	2	23	1	79.62	1.80	E	HH-HL			31.42	31.89	31.89	12.40	12.04	11.96
4/26/2022 23:05	4	15	SW1	2	22	1	74.77	1.58	E	HH-HL			31.31	32.03	31.65	12.25	11.88	11.79
4/26/2022 23:31	4	16	SW6	2	24	1	87.31	1.44	E	HH-HL			31.43	32.24	29.60	12.06	11.64	11.36
5/26/2022 6:57	5	1	SW1	1	22	2	161.37	1.11	F	LL-LH			32.53	32.58	26.93	15.00	14.73	14.82
5/26/2022 7:47	5	2	SW2	1	21	4	129.70	1.33	F	LL-LH			32.46	32.66	32.51	14.66	14.47	14.43
5/26/2022 8:20	5	3	EA2	1	21.4	1	129.34	1.42	F	LL-LH			32.39	33.20	32.45	13.55	11.93	11.73
5/26/2022 8:37	5	4	EA1	1	43	1	85.73	1.45	F	LL-LH			33.32	33.52	32.50	11.63	10.83	10.80
5/26/2022 8:56	5	5	SW3	1	46.6	1	120.19	1.47	S	LH			33.66	33.71	33.80	10.07	9.66	9.02
5/26/2022 9:28	5	6	SW4	1	48.2	2	96.85	1.47	S	LH			33.98	33.93	33.94	8.24	8.07	8.03
5/26/2022 9:50	5	7	SW5	1	42.8	1	101.54	1.44	E	LH-HL			33.64	33.83	33.79	11.18	8.80	8.73
5/26/2022 10:40	5	8	SW6	1	23.8	1	107.97	1.30	E	LH-HL			31.98	32.99	33.34	13.87	12.98	11.59
5/26/2022 19:43	5	9	SW5	2	50	1	95.99	1.87	F	HL-HH			33.92	33.92	33.92	8.38	8.39	8.37
5/26/2022 20:05	5	10	SW4	2	54	2	88.83	1.95	F	HL-HH			33.88	33.88	33.87	8.71	8.69	8.70
5/26/2022 20:35	5	11	SW3	2	47	1	123.18	2.03	F	HL-HH			33.78	33.84	33.50	9.66	9.04	9.02
5/26/2022 20:54	5	12	EA1	2	47	1	102.14	2.06	F	HL-HH			33.78	33.79	33.81	9.54	9.43	9.34
5/26/2022 21:10	5	13	EA2	2	22	1	94.60	2.06	S	HH			33.40	33.64	30.65	11.47	10.50	9.89
5/26/2022 21:39	5	14	SW2	2	28	1	95.17	2.04	E	HH-LL			33.20	33.46	33.51	12.45	11.37	11.21
5/26/2022 22:26	5	15	SW1	2	21	4	85.39	1.89	E	HH-LL			32.82	33.34	33.51	14.17	12.10	11.31
5/26/2022 22:51	5	16	SW6	2	26	1	112.01	1.77	E	HH-LL			32.99	33.39	33.42	12.10	11.75	11.62
6/28/2022 7:54	6	1	SW1	1	10.4	1	117.95	0.30	F	LL-LH			33.41	33.46	31.55	19.60	19.59	19.57
6/28/2022 8:41	6	2	SW2	1	19.3	4	116.98	0.60	F	LL-LH			33.52	33.55	33.54	18.97	19.03	19.04
6/28/2022 9:12	6	3	EA2	1	17.7	4	90.11	0.80	F	LL-LH			33.48	33.46	32.00	18.42	18.20	17.96
6/28/2022 9:28	6	4	EA1	1	39.7	8	97.07	0.91	F	LL-LH			30.24	31.16	31.25	17.38	16.69	16.52
6/28/2022 9:51	6	5	SW3	1	42.4	8	104.14	1.05	F	LL-LH			31.59	33.36	33.36	14.89	14.57	14.43
6/28/2022 10:25	6	6	SW4	1	51.6	4	77.61	1.24	F	LL-LH			32.33	33.43	33.43	12.00	11.41	11.19
6/28/2022 10:54	6	7	SW5	1	35.2	4	87.13	1.37	F	LL-LH			33.37	33.35	33.34	12.19	11.70	11.68
6/28/2022 11:55	6	8	SW6	1	23.1	1	92.15	1.53	F	LL-LH			30.20	26.86	23.22	16.23	15.17	15.27
6/28/2022 20:02	6	9	SW5	2	30	4	99.99	1.62	F	HL-HH			29.63	33.42	33.41	12.32	11.91	11.94
6/28/2022 20:31	6	10	SW4	2	52.5	8	86.60	1.76	F	HL-HH			33.06	33.53	32.60	11.05	10.90	10.96

								Tide Information			Data from Burkeolator		Data from CTD Casts					
													Salinity (PSU)			Temperature (C)		
DateTime	Survey	Sample	Station	Cycle	Depth (ft)	Split Multiple	Sample Volume (m^3)	Tide Height (m)	Tide Flow	Tide Change	Temperature (C)	Salinity (PSU)	Top	Middle	Bottom	Top	Middle	Bottom
6/28/2022 21:07	6	11	SW3	2	48	2	114.62	1.91	F	HL-HH			33.20	33.41	32.68	12.21	12.14	12.05
6/28/2022 21:31	6	12	EA1	2	48	8	100.55	2.00	F	HL-HH			31.57	33.41	33.41	12.29	12.15	12.15
6/28/2022 21:50	6	13	EA2	2	24	4	80.68	2.05	F	HL-HH			33.32	33.42	33.36	14.13	13.17	12.74
6/28/2022 22:26	6	14	SW2	2	16.4	4	100.77	2.13	F	HL-HH			33.23	33.40	32.05	16.46	15.32	14.93
6/28/2022 23:15	6	15	SW1	2	17.4	4	89.75	2.13	E	HH-LL			33.37	33.40	32.08	14.82	14.77	14.59
6/28/2022 23:42	6	16	SW6	2	28	1	86.07	2.07	E	HH-LL			33.04	33.38	33.38	14.64	13.70	13.26
7/29/2022 7:33	7	1	SW1	1	14	1	112.04	0.00	F	LL-LH			33.39	34.11	33.20	20.08	20.12	20.12
7/29/2022 8:17	7	2	SW2	1	17	1	90.26	0.23	F	LL-LH			30.91	34.08	33.93	19.42	19.75	19.70
7/29/2022 8:48	7	3	EA2	1	17	1	85.07	0.42	F	LL-LH			33.25	33.97	33.51	18.83	18.92	18.87
7/29/2022 9:04	7	4	EA1	1	37	1	116.70	0.53	F	LL-LH			32.35	33.89	33.88	18.17	17.91	17.65
7/29/2022 9:27	7	5	SW3	1	43	1	94.02	0.69	F	LL-LH			33.79	33.81	33.79	17.04	16.66	16.12
7/29/2022 9:58	7	6	SW4	1	51	1	46.21	0.90	F	LL-LH			31.72	33.67	33.67	11.46	11.14	10.90
7/29/2022 10:53	7	7	SW5	1	46	1	78.97	1.24	F	LL-LH			33.64	33.63	33.63	12.68	12.17	12.03
7/29/2022 11:55	7	8	SW6	1	34	2	90.24	1.53	F	LL-LH			31.38	33.70	29.34	17.33	15.74	15.79
7/29/2022 19:52	7	9	SW5	2	43	1	97.12	1.21	F	HL-HH			30.61	33.61	33.61	12.81	12.77	12.65
7/29/2022 20:21	7	10	SW4	2	49	1	77.74	1.35	F	HL-HH			33.63	33.64	33.64	12.18	11.55	11.56
7/29/2022 20:57	7	11	SW3	2	45	2	105.08	1.53	F	HL-HH			33.62	33.67	33.65	13.35	13.12	12.78
7/29/2022 21:19	7	12	EA1	2	44	1	95.89	1.65	F	HL-HH			33.26	33.70	33.69	14.30	13.65	13.42
7/29/2022 21:39	7	13	EA2	2	22	1	86.55	1.74	F	HL-HH			31.87	33.69	30.05	15.66	14.30	14.10
7/29/2022 22:14	7	14	SW2	2	20	1	105.56	1.90	F	HL-HH			32.85	33.80	32.57	16.71	16.47	16.38
7/29/2022 22:59	7	15	SW1	2	15	1	97.81	2.05	F	HL-HH			33.70	33.71	30.51	14.35	14.33	14.34
7/29/2022 23:31	7	16	SW6	2	24	1	113.83	2.10	F	HL-HH			29.42	26.90	25.26	13.28	13.08	13.08
8/18/2022 7:56	8	1	SW1	1	13.7	1	99.07	0.94	E	LH-HL			20.42	31.88	30.79	19.07	19.07	19.06
8/18/2022 8:53	8	2	SW2	1	20	1	109.46	0.79	E	LH-HL			32.42	33.58	33.58	19.09	19.13	19.09
8/18/2022 9:21	8	3	EA2	1	18	1	103.09	0.74	E	LH-HL			33.44	33.46	33.46	18.30	18.20	18.15
8/18/2022 9:36	8	4	EA1	1	41	1	99.37	0.73	E	LH-HL			33.47	33.47	33.47	18.00	17.93	17.89
8/18/2022 9:54	8	5	SW3	1	43	1	107.90	0.73	S	HL			33.15	33.40	33.39	17.27	16.97	16.81
8/18/2022 10:26	8	6	SW4	1	47	1	80.98	0.75	F	HL-HH			32.78	33.29	33.29	14.87	14.55	14.30
8/18/2022 10:48	8	7	SW5	1	44.5	1	96.40	0.79	F	HL-HH			33.27	33.30	33.34	13.98	12.77	12.06

								Tide Information			Data from Burkeolator		Data from CTD Casts					
													Salinity (PSU)			Temperature (C)		
DateTime	Survey	Sample	Station	Cycle	Depth (ft)	Split Multiple	Sample Volume (m^3)	Tide Height (m)	Tide Flow	Tide Change	Temperature (C)	Salinity (PSU)	Top	Middle	Bottom	Top	Middle	Bottom
8/18/2022 11:46	8	8	SW6	1	19.6	1	91.75	0.98	F	HL-HH			33.52	33.54	33.53	18.48	18.47	18.26
8/18/2022 19:33	8	9	SW5	2	46	1	128.26	1.31	E	HH-LL			33.23	33.23	33.23	15.37	15.32	14.80
8/18/2022 19:56	8	10	SW4	2	52	4	136.88	1.17	E	HH-LL			33.28	33.28	33.28	12.94	12.88	12.86
8/18/2022 20:28	8	11	SW3	2	44	1	110.18	0.97	E	HH-LL			33.35	33.36	33.36	16.20	16.08	15.87
8/18/2022 20:48	8	12	EA1	2	42	2	128.54	0.85	E	HH-LL			33.42	33.43	33.42	17.25	17.24	17.23
8/18/2022 21:06	8	13	EA2	2	15	2	109.14	0.75	E	HH-LL			33.43	33.46	33.45	17.83	17.81	17.67
8/18/2022 21:38	8	14	SW2	2	19	4	131.29	0.59	E	HH-LL			33.71	33.72	33.67	19.93	19.79	19.50
8/18/2022 22:21	8	15	SW1	2	13	1	109.39	0.43	E	HH-LL			33.70	33.73	33.72	20.54	20.32	20.25
8/18/2022 22:44	8	16	SW6	2	20	2	104.17	0.38	E	HH-LL			33.67	33.71	33.69	20.69	20.59	20.47
9/22/2022 7:37	9	1	SW1	1	13	1	108.41	1.21	F	LL-LH			32.79	33.36	31.51	17.37	17.45	17.47
9/22/2022 8:33	9	2	SW2	1	23	2	97.39	1.48	F	LL-LH			31.80	33.37	29.72	17.36	17.38	17.44
9/22/2022 9:04	9	3	EA2	1	19	1	97.15	1.58	F	LL-LH			32.02	33.26	31.63	16.80	16.71	16.66
9/22/2022 9:25	9	4	EA1	1	45	1	93.68	1.63	F	LL-LH			32.69	32.71	32.72	14.37	14.38	14.39
9/22/2022 9:52	9	5	SW3	1	45	1	97.53	1.67	F	LL-LH			31.86	32.60	32.61	14.29	14.17	14.16
9/22/2022 10:25	9	6	SW4	1	60	1	106.75	1.67	S	LH			30.90	32.63	32.64	14.33	13.62	13.42
9/22/2022 10:51	9	7	SW5	1	47	1	110.92	1.64	E	LH-HL			32.10	32.62	32.63	14.17	13.84	13.77
9/22/2022 11:54	9	8	SW6	1	26	1	81.17	1.48	E	LH-HL			32.67	33.20	33.18	16.97	16.72	16.62
9/22/2022 18:38	9	9	SW5	2	46	1	125.44	1.44	F	HL-HH			32.63	32.62	32.62	14.68	14.64	14.48
9/22/2022 19:01	9	10	SW4	2	50	1	93.34	1.54	F	HL-HH			32.54	32.62	32.62	14.34	14.33	14.29
9/22/2022 19:28	9	11	SW3	2	46	1	90.22	1.66	F	HL-HH			32.09	32.68	32.68	14.67	14.67	14.67
9/22/2022 19:46	9	12	EA1	2	47	1	122.51	1.73	F	HL-HH			32.73	32.73	32.73	14.82	14.80	14.79
9/22/2022 20:02	9	13	EA2	2	21	1	105.96	1.79	F	HL-HH			31.98	32.98	32.60	15.96	15.84	15.65
9/22/2022 20:28	9	14	SW2	2	15	1	90.30	1.87	F	HL-HH			33.03	33.23	32.22	17.07	17.10	17.05
9/22/2022 21:15	9	15	SW1	2	16	1	92.85	1.93	S	HH			32.35	32.92	31.95	15.64	15.72	15.73
9/22/2022 21:38	9	16	SW6	2	22	1	84.70	1.92	E	HH-LL			32.28	32.86	31.72	15.47	15.53	15.55
10/11/2022 7:36	10	1	SW1	1	12	1	91.49	0.77	F	HL-HH			20.72	32.99	32.69	15.11	15.14	15.13
10/11/2022 8:18	10	2	SW2	1	20	1	110.66	1.04	F	HL-HH			32.98	33.02	32.99	15.21	15.24	15.25
10/11/2022 8:47	10	3	EA2	1	19	1	88.50	1.24	F	HL-HH			32.97	32.98	32.97	14.29	14.29	14.28
10/11/2022 9:03	10	4	EA1	1	45	1	85.00	1.36	F	HL-HH			32.94	32.96	32.96	12.90	12.87	12.88

								Tide Information			Data from Burkeolator		Data from CTD Casts					
													Salinity (PSU)			Temperature (C)		
DateTime	Survey	Sample	Station	Cycle	Depth (ft)	Split Multiple	Sample Volume (m^3)	Tide Height (m)	Tide Flow	Tide Change	Temperature (C)	Salinity (PSU)	Top	Middle	Bottom	Top	Middle	Bottom
10/11/2022 9:24	10	5	SW3	1	46	1	91.12	1.51	F	HL-HH			32.97	32.98	32.98	11.38	11.39	11.43
10/11/2022 9:57	10	6	SW4	1	52	1	92.86	1.73	F	HL-HH			32.97	32.99	33.00	10.56	10.50	10.43
10/11/2022 10:16	10	7	SW5	1	36	1	87.18	1.85	F	HL-HH			33.01	33.05	33.05	10.31	10.22	10.19
10/11/2022 11:03	10	8	SW6	1	25	1	106.50	2.08	F	HL-HH			33.02	32.98	32.88	11.89	11.64	11.63
10/11/2022 18:03	10	9	SW5	2	43	1	91.57	-0.04	E	HH-LL			32.95	32.95	32.96	12.62	12.60	12.60
10/11/2022 18:24	10	10	SW4	2	45	1	99.13	-0.09	E	HH-LL			32.88	32.98	32.98	13.93	13.68	13.55
10/11/2022 18:52	10	11	SW3	2	40	1	97.34	-0.10	S	LL			32.99	33.00	33.00	15.35	15.22	15.20
10/11/2022 19:10	10	12	EA1	2	37	1	96.30	-0.08	F	LL-LH			32.98	33.02	33.02	15.65	15.66	15.64
10/11/2022 19:25	10	13	EA2	2	16	1	98.29	-0.04	F	LL-LH			33.01	33.03	32.99	15.73	15.74	15.71
10/11/2022 19:52	10	14	SW2	2	15	1	96.10	0.06	F	LL-LH			33.04	33.06	33.05	16.14	15.88	15.78
10/11/2022 20:42	10	15	SW1	2	17	1	109.19	0.34	F	LL-LH			32.95	33.01	32.86	15.97	15.99	15.98
10/11/2022 21:12	10	16	SW6	2	20	1	95.44	0.55	F	LL-LH			32.95	32.99	30.45	15.35	15.32	15.32
11/7/2022 8:28	11	1	SW1	1	17	1	86.83	1.88	F	HL-HH			32.27	32.38	32.38	11.07	11.10	11.11
11/7/2022 9:06	11	2	SW2	1	24	1	100.57	2.09	F	HL-HH			32.34	32.43	32.44	11.02	11.00	11.00
11/7/2022 9:30	11	3	EA2	1	21	1	99.68	2.19	F	HL-HH			32.39	32.57	32.09	10.82	10.66	10.59
11/7/2022 9:46	11	4	EA1	1	47	1	89.40	2.24	F	HL-HH			32.77	32.80	32.81	10.48	10.49	10.49
11/7/2022 10:09	11	5	SW3	1	47	1	91.89	2.29	F	HL-HH			32.83	32.83	32.83	10.57	10.57	10.57
11/7/2022 10:42	11	6	SW4	1	51	1	100.55	2.29	E	HH-LL			32.80	32.81	32.81	10.57	10.56	10.54
11/7/2022 11:00	11	7	SW5	1	50	1	86.80	2.26	E	HH-LL			32.85	32.87	32.88	10.59	10.57	10.58
11/7/2022 11:49	11	8	SW6	1	26	1	110.91	2.08	E	HH-LL			32.60	32.66	32.67	10.64	10.54	10.47
11/7/2022 17:27	11	9	SW5	2	43	1	109.80	-0.12	F	LL-LH			32.46	32.48	32.53	10.66	10.67	10.68
11/7/2022 17:44	11	10	SW4	2	43	1	126.32	-0.09	F	LL-LH			32.23	32.27	32.27	11.24	11.29	11.28
11/7/2022 18:09	11	11	SW3	2	39	1	87.40	0.00	F	LL-LH			32.04	32.05	32.06	11.43	11.45	11.45
11/7/2022 18:28	11	12	EA1	2	41	1	83.99	0.09	F	LL-LH			31.83	31.99	32.06	11.42	11.54	11.54
11/7/2022 18:42	11	13	EA2	2	27	1	104.83	0.16	F	LL-LH			31.85	31.84	31.84	11.35	11.36	11.36
11/7/2022 19:06	11	14	SW2	2	20	1	87.49	0.31	F	LL-LH			31.49	31.53	31.55	11.22	11.25	11.26
11/7/2022 19:43	11	15	SW1	2	18	1	103.58	0.57	F	LL-LH			31.38	31.46	31.48	11.31	11.35	11.35
11/7/2022 20:11	11	16	SW6	2	21	1	88.47	0.78	F	LL-LH			30.89	31.93	31.04	11.21	11.41	11.44
12/6/2022 8:38	12	1	SW1	1	18	1	104.96	2.20	F	HL-HH			22.46	31.75	31.75	9.64	9.76	9.76

								Tide Information			Data from Burkeolator		Data from CTD Casts					
													Salinity (PSU)			Temperature (C)		
DateTime	Survey	Sample	Station	Cycle	Depth (ft)	Split Multiple	Sample Volume (m^3)	Tide Height (m)	Tide Flow	Tide Change	Temperature (C)	Salinity (PSU)	Top	Middle	Bottom	Top	Middle	Bottom
12/6/2022 9:41	12	2	SW2	1	25	1	110.02	2.35	S	HH			31.03	31.80	31.84	9.15	9.81	9.85
12/6/2022 10:06	12	3	EA2	1	23	1	98.69	2.35	E	HH-LL			31.90	32.08	32.16	9.92	10.05	10.09
12/6/2022 10:24	12	4	EA1	1	45	1	121.94	2.32	E	HH-LL			31.88	32.11	32.13	10.23	10.21	10.19
12/6/2022 10:44	12	5	SW3	1	48	1	118.79	2.27	E	HH-LL			32.05	32.12	32.17	10.22	10.24	10.24
12/6/2022 11:11	12	6	SW4	1	51	1	88.41	2.16	E	HH-LL			31.96	32.08	32.13	10.24	10.23	10.26
12/6/2022 11:28	12	7	SW5	1	41	1	110.20	2.07	E	HH-LL			32.36	32.38	32.39	10.44	10.43	10.43
12/6/2022 12:17	12	8	SW6	1	25	1	119.50	1.73	E	HH-LL			31.01	31.25	31.26	9.53	9.59	9.61
12/6/2022 16:27	12	9	SW5	2	40	1	103.53	-0.16	E	HH-LL			27.95	31.38	31.82	9.93	10.03	10.14
12/6/2022 17:20	12	10	SW4	2	44	1	122.08	-0.16	F	LL-LH			29.98	30.76	30.81	9.37	9.43	9.45
12/6/2022 17:44	12	11	SW3	2	42	1	101.55	-0.10	F	LL-LH			30.31	30.40	30.45	9.25	9.27	9.27
12/6/2022 18:00	12	12	EA1	2	40	1	101.77	-0.04	F	LL-LH			29.55	30.18	30.42	8.99	9.18	9.24
12/6/2022 18:16	12	13	EA2	2	19	1	95.54	0.03	F	LL-LH			28.66	30.08	30.02	8.88	9.19	9.19
12/6/2022 18:37	12	14	SW2	2	20	1	97.90	0.14	F	LL-LH			26.89	29.55	29.33	8.74	8.96	8.96
12/6/2022 19:14	12	15	SW1	2	16	1	94.64	0.36	F	LL-LH			26.32	29.33	29.27	8.81	9.09	9.09
12/6/2022 19:37	12	16	SW6	2	18	1	90.48	0.52	F	LL-LH			24.44	29.72	26.80	8.81	9.20	9.27

Appendix C

CTD Data Graphs

This appendix presents plots of data collected using an AML Oceanographic AML-3 multiparameter sonde configured to collect conductivity, temperature and depth (pressure) data (CTD). The CTD was configured to collect data at 5 Hz (five samples per second). The CTD instrument was deployed at each of the sampling stations during each sampling event during the study. The CTD was deployed by allowing the instrument to drop through the water column to the bottom and then was pulled back up to the surface. The data from each deployment was filtered to remove data at the surface (measured depths < 0.25m) and also at the deepest 0.15 m depths of the deployment. These data were removed due to potential erroneous salinity readings at the surface when the instrument was potentially out of the water and at the bottom where the salinity probe could be affected by fine sediments suspended at the bottom by the instrument.

There are no plots shown for Survey 1 due to an instrument malfunction.

Survey 2 – 2022-02-10

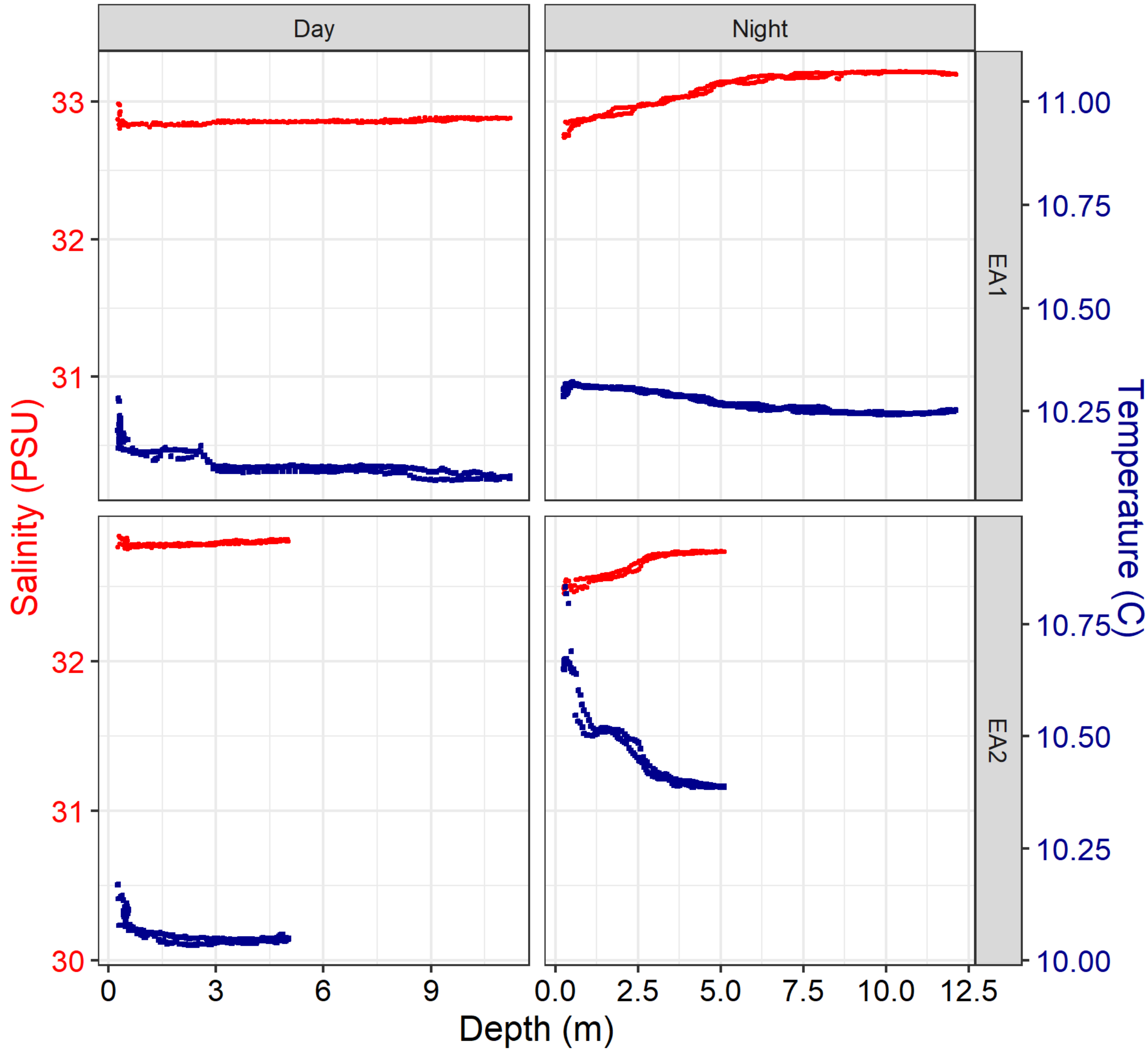

Figure C-1. Plot of Salinity (PSU) and temperature (°C) with depth (m) at entrainment stations EA1 and EA2 during Survey 02 on February 10, 2022 during day and night sampling.

Survey 2 – 2022-02-10

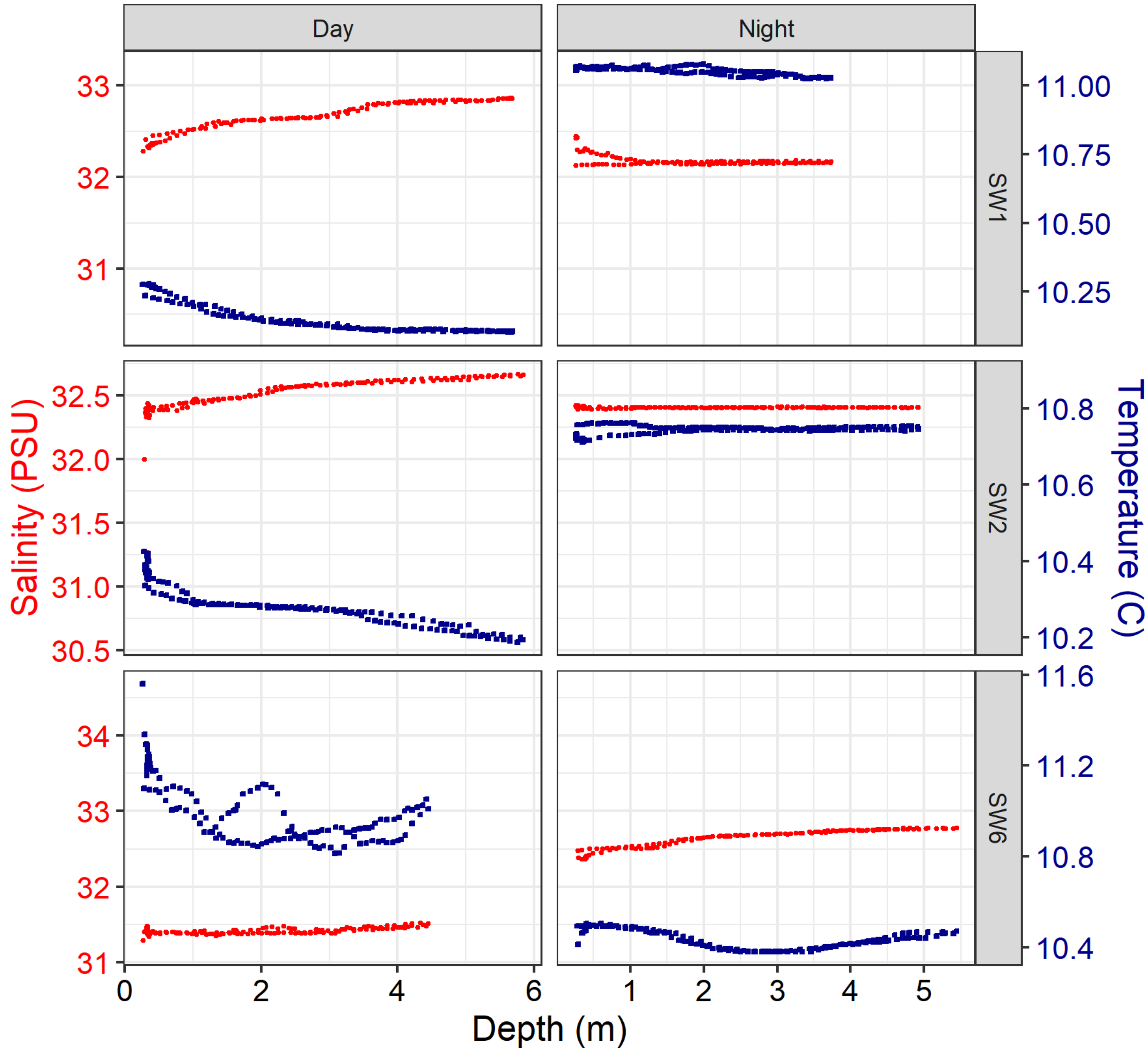

Figure C-2. Plot of Salinity (PSU) and temperature (°C) with depth (m) at source water stations SW1, SW2, and SW6 during Survey 02 on February 10, 2022 during day and night sampling.

Survey 2 – 2022-02-10

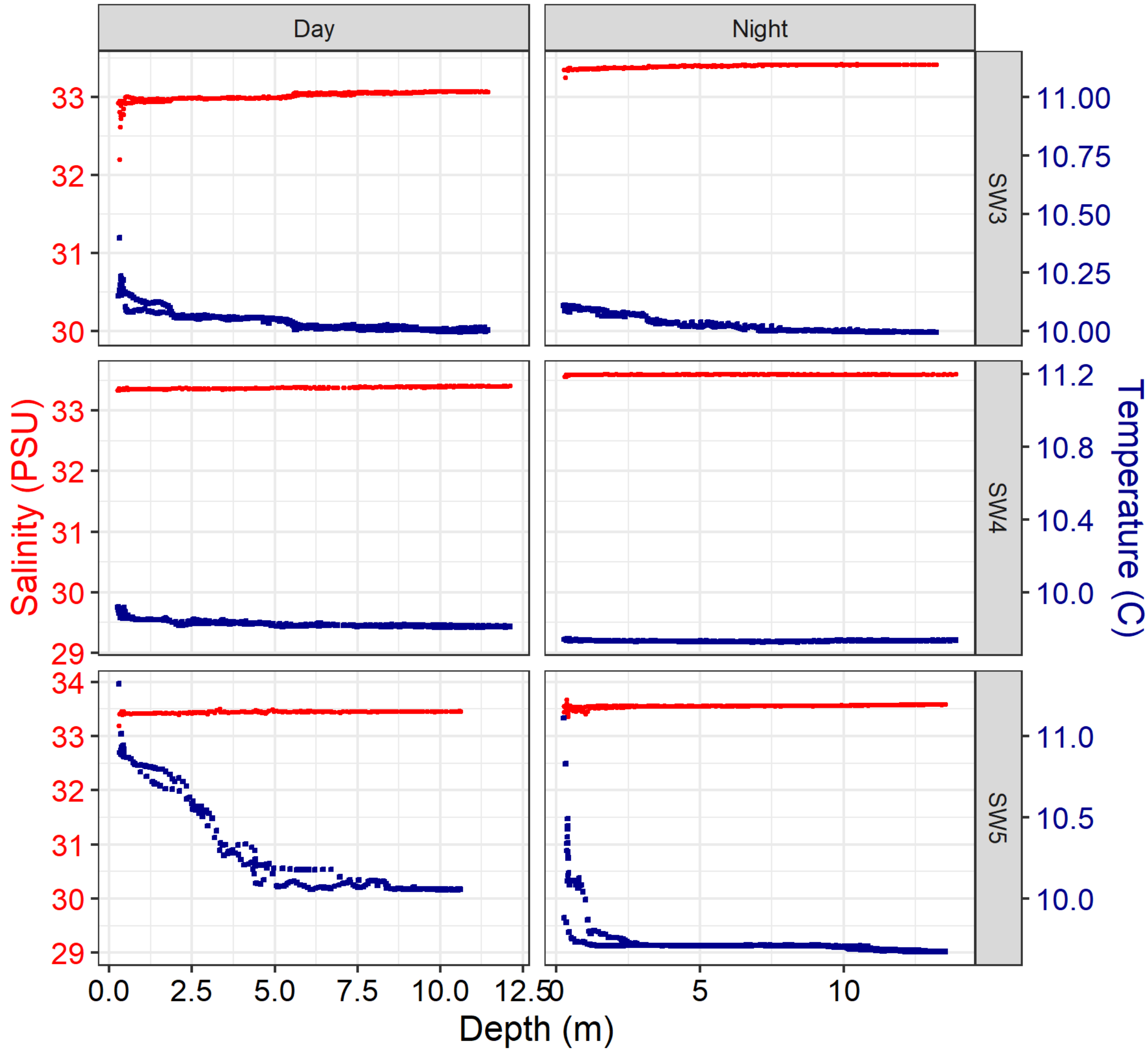

Figure C-3. Plot of Salinity (PSU) and temperature (°C) with depth (m) at source water stations SW3, SW4, and SW5 during Survey 02 on February 10, 2022 during day and night sampling.

Survey 3 – 2022-03-18

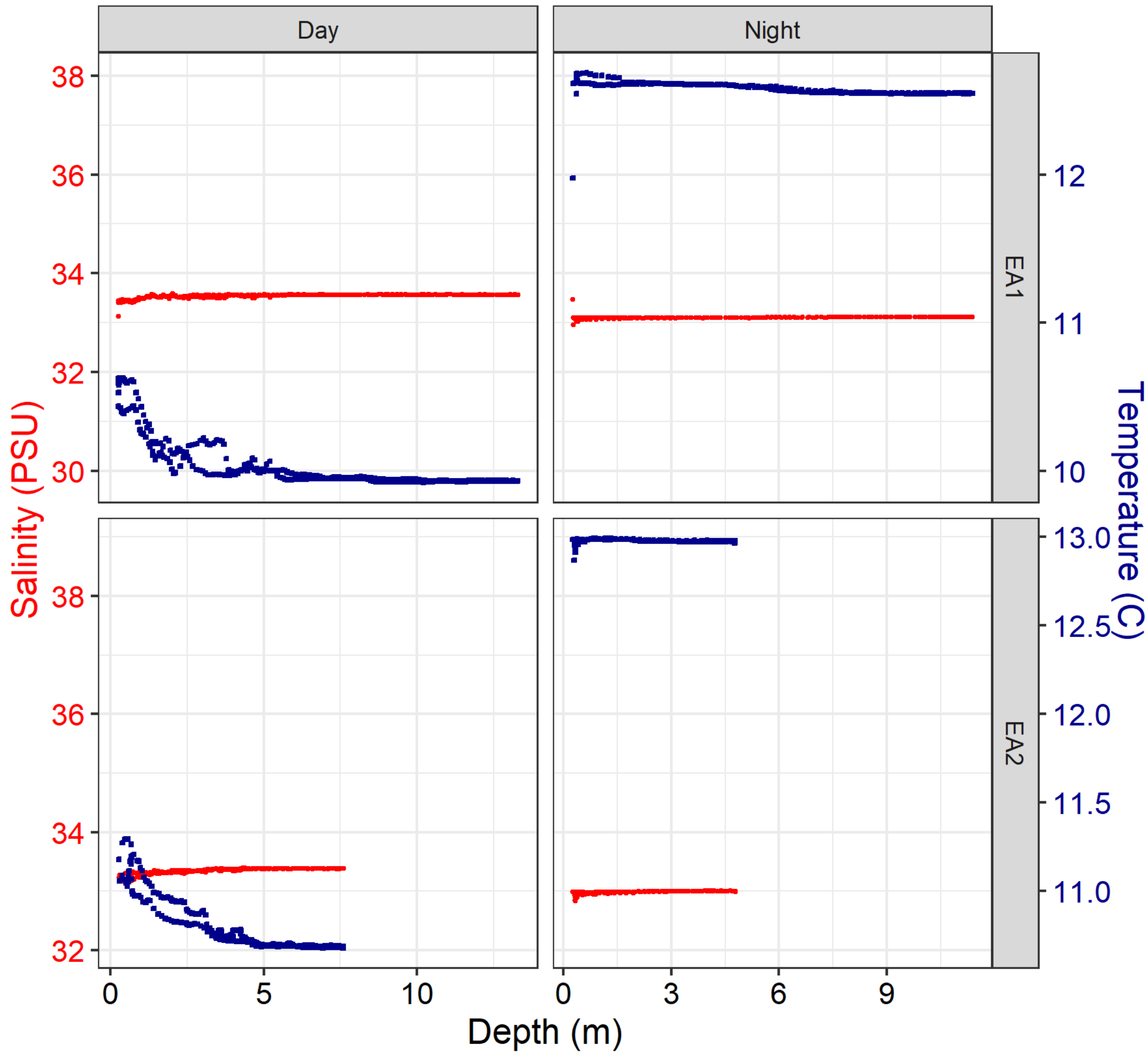

Figure C-4. Plot of Salinity (PSU) and temperature (°C) with depth (m) at entrainment stations EA1 and EA2 during Survey 03 on March 18, 2022 during day and night sampling.

Survey 3 – 2022-03-18

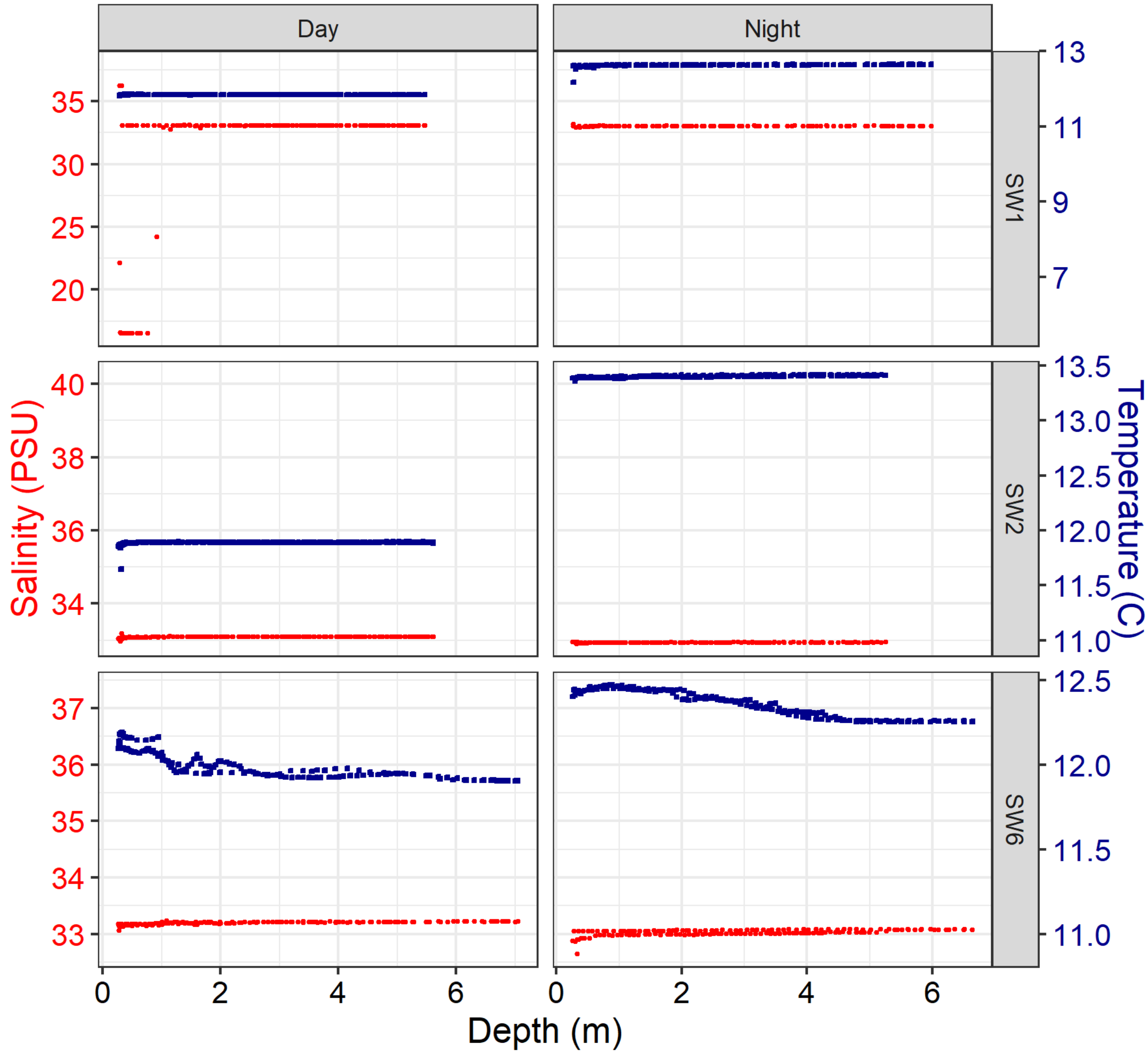

Figure C-5. Plot of Salinity (PSU) and temperature (°C) with depth (m) at source water stations SW1, SW2, and SW6 during Survey 03 on March 18, 2022 during day and night sampling.

Survey 3 – 2022-03-18

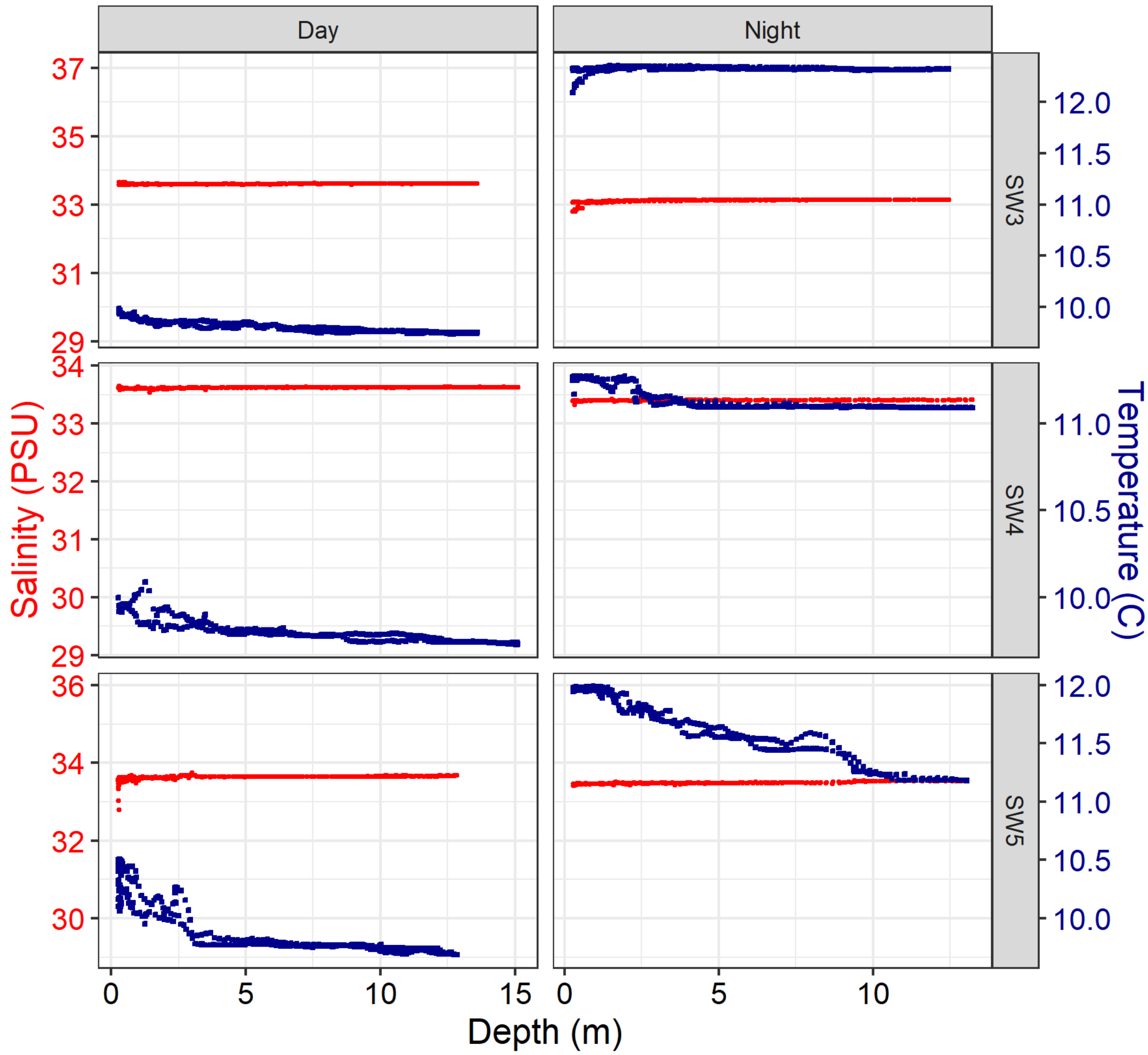

Figure C-6. Plot of Salinity (PSU) and temperature (°C) with depth (m) at source water stations SW3, SW4, and SW5 during Survey 03 on March 18, 2022 during day and night sampling.

Survey 4 – 2022-04-26

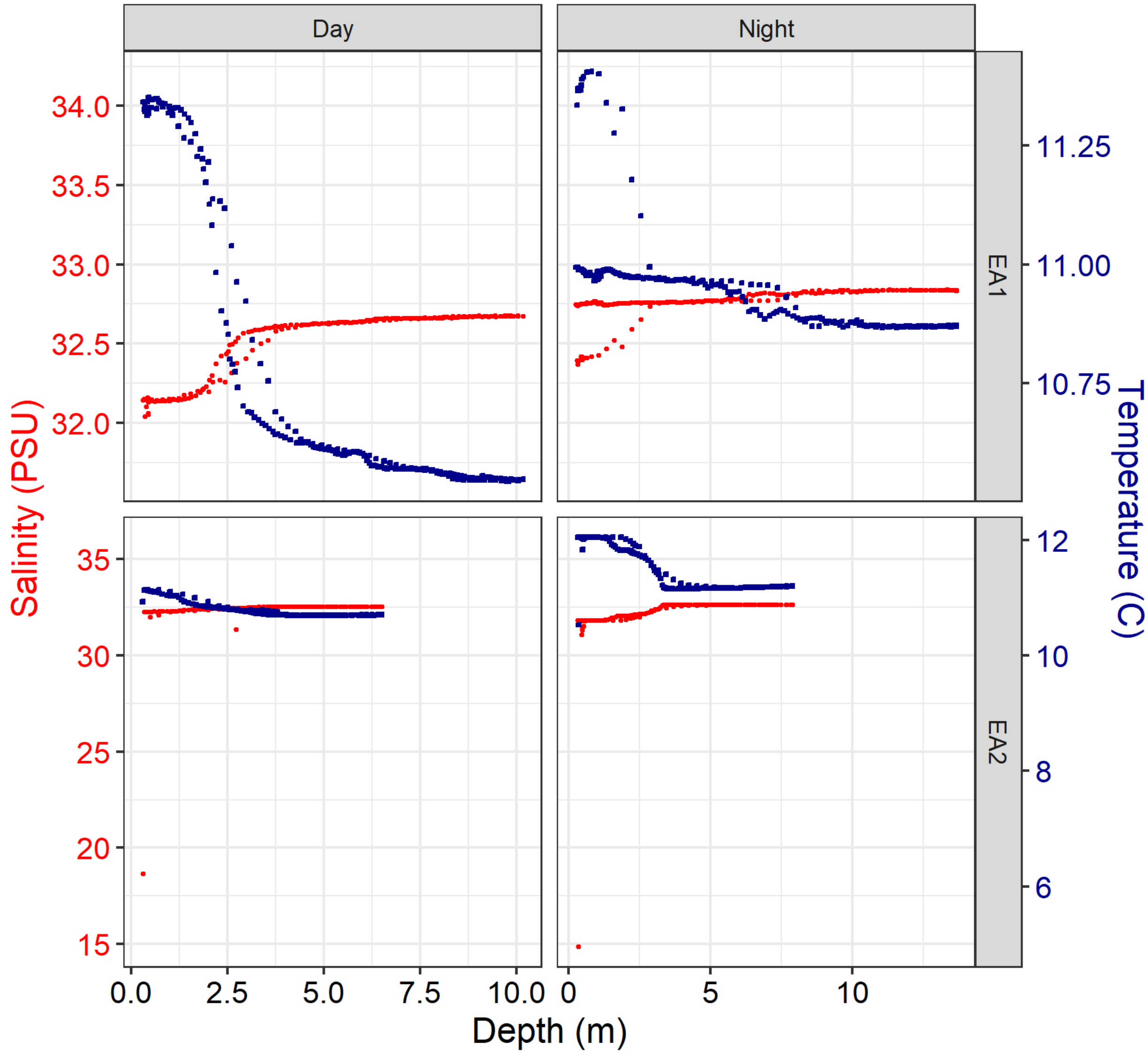

Figure C-7. Plot of Salinity (PSU) and temperature (°C) with depth (m) at entrainment stations EA1 and EA2 during Survey 04 on April 26, 2022 during day and night sampling.

Survey 4 – 2022-04-26

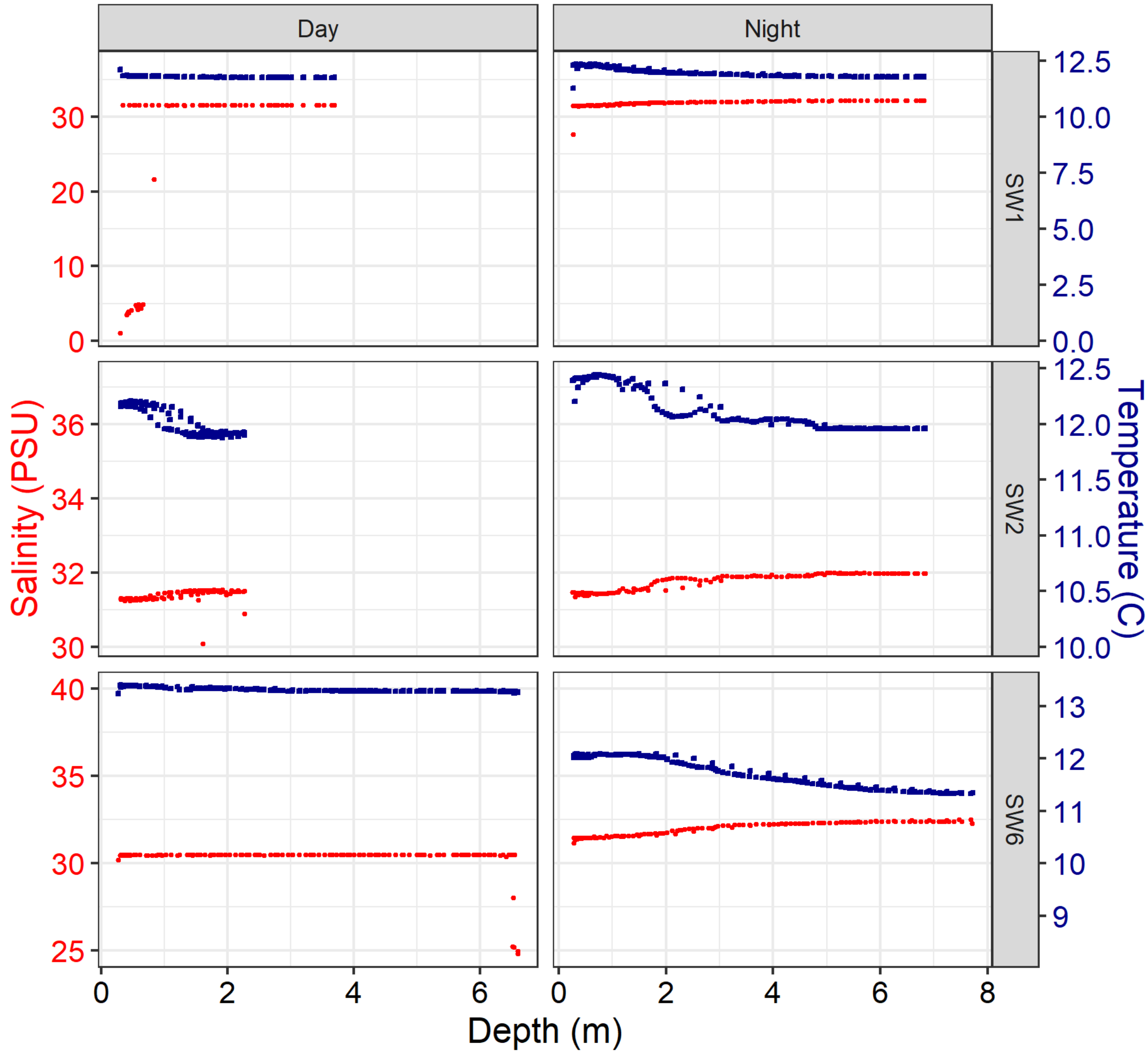

Figure C-8. Plot of Salinity (PSU) and temperature (°C) with depth (m) at source water stations SW1, SW2, and SW6 during Survey 04 on April 26, 2022 during day and night sampling.

Survey 4 – 2022-04-26

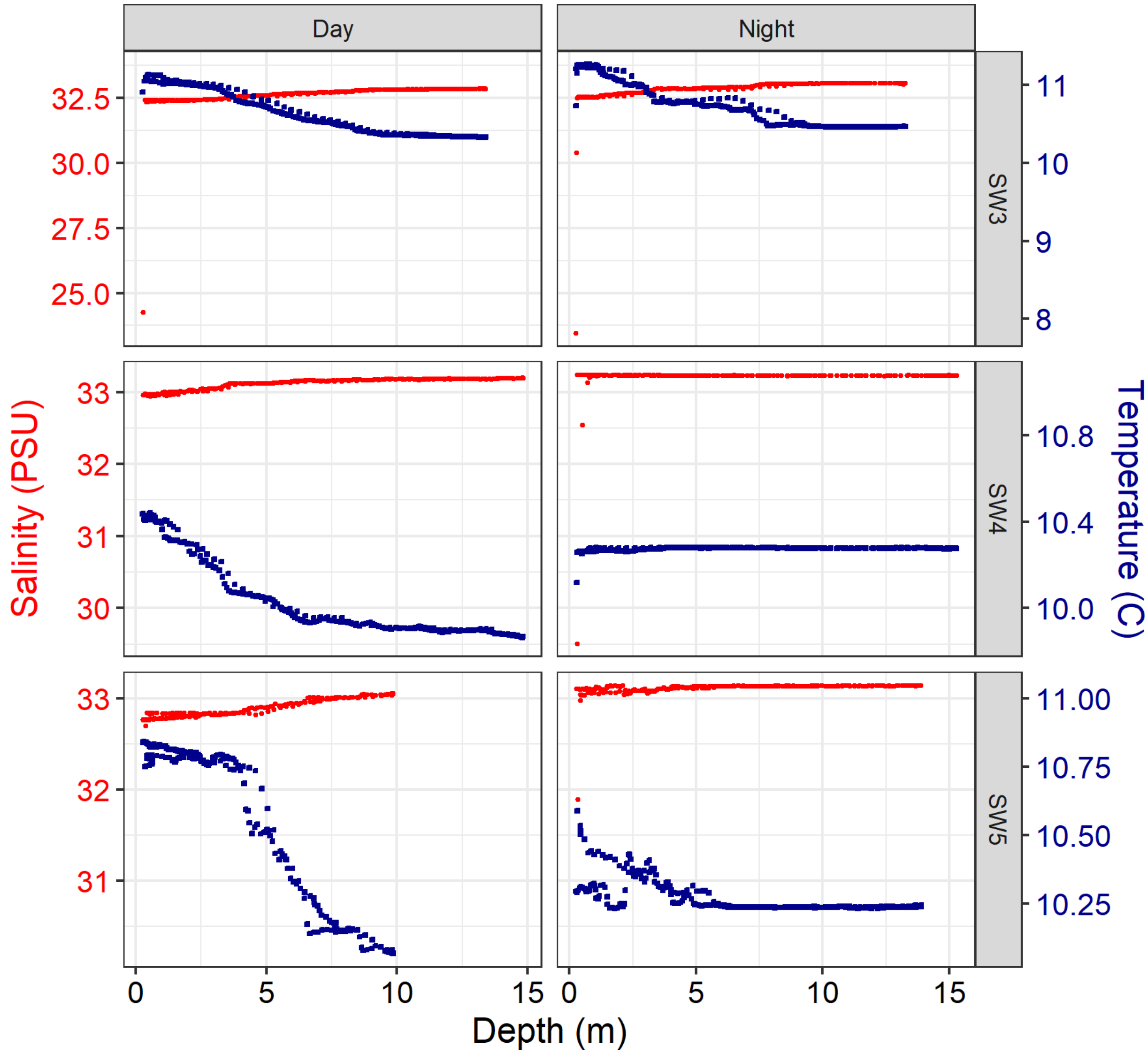

Figure C-9. Plot of Salinity (PSU) and temperature (°C) with depth (m) at source water stations SW3, SW4, and SW5 during Survey 04 on April 26, 2022 during day and night sampling.

Survey 5 – 2022-05-26

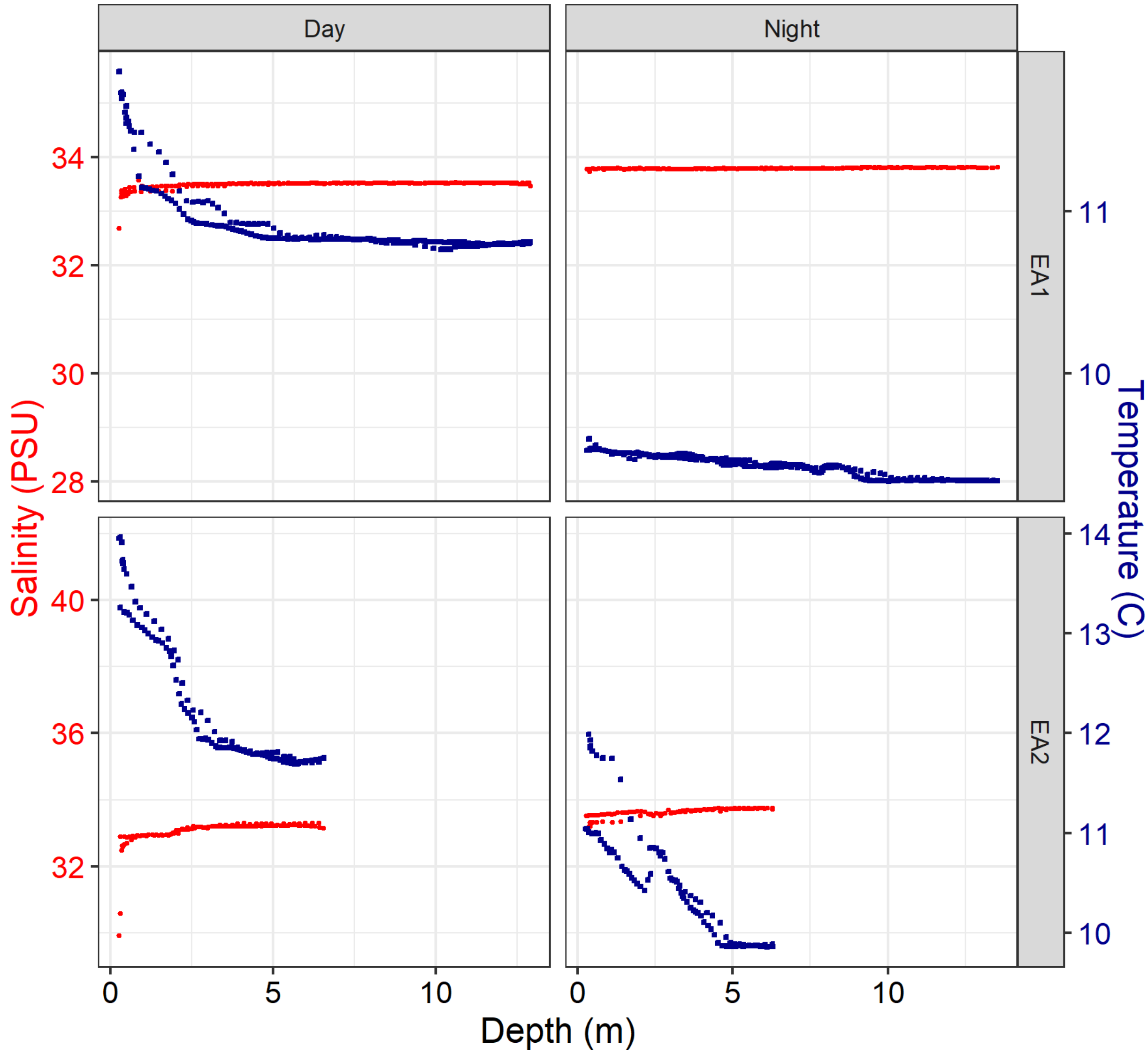

Figure C-10. Plot of Salinity (PSU) and temperature (°C) with depth (m) at entrainment stations EA1 and EA2 during Survey 05 on May 26, 2022 during day and night sampling.

Survey 5 – 2022-05-26

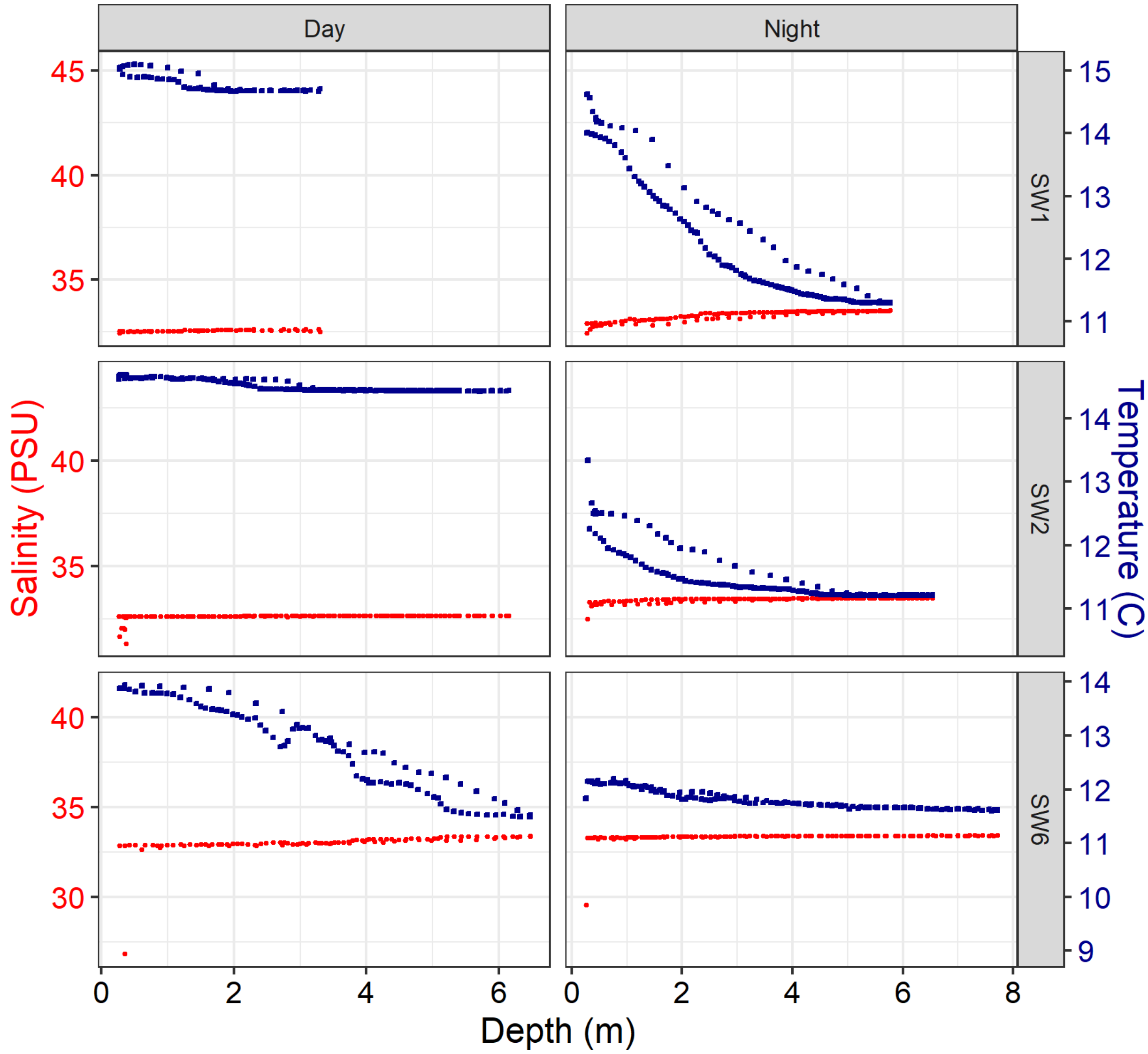

Figure C-11. Plot of Salinity (PSU) and temperature (°C) with depth (m) at source water stations SW1, SW2, and SW6 during Survey 05 on May 26, 2022 during day and night sampling.

Survey 5 – 2022-05-26

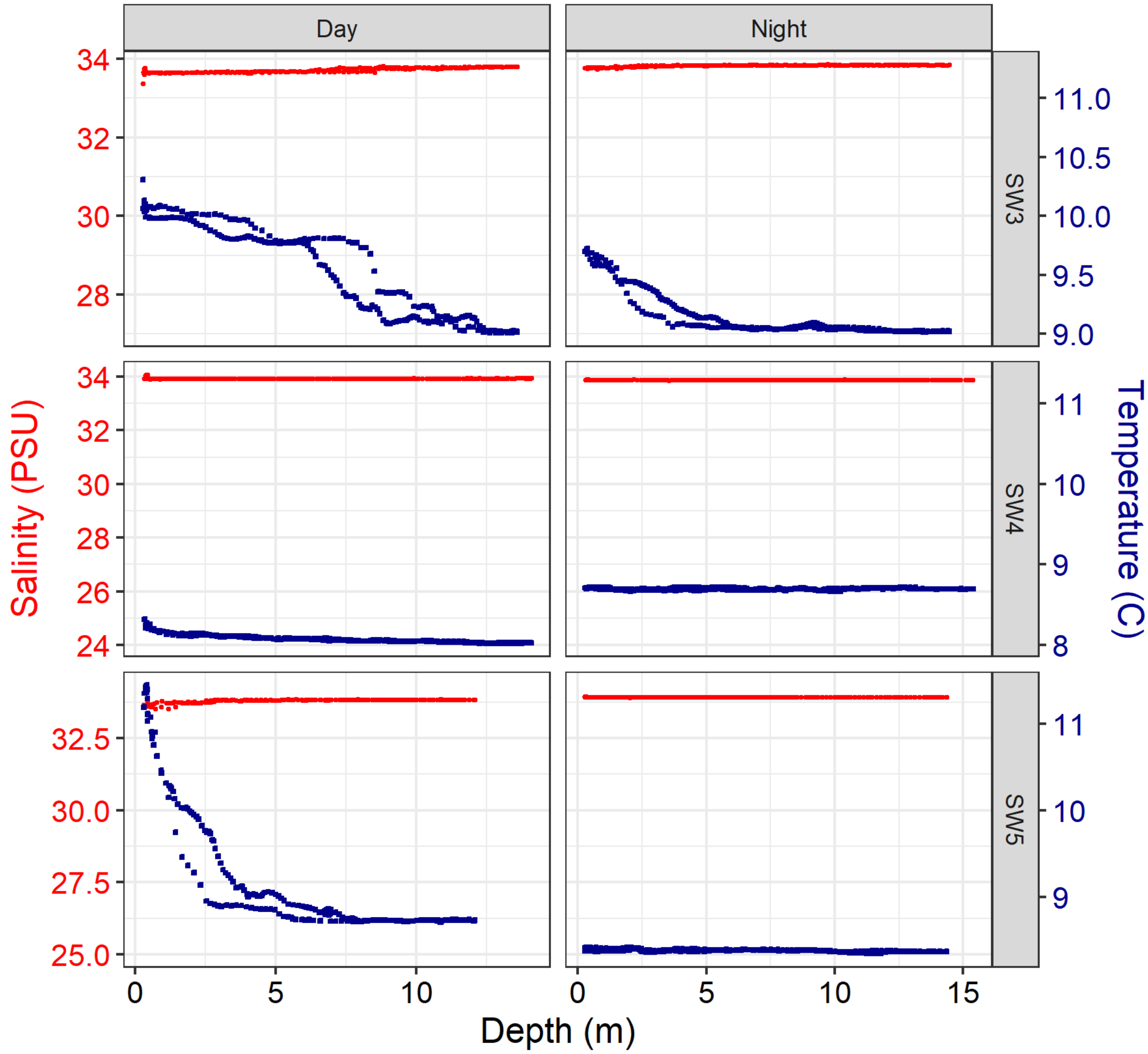

Figure C-12. Plot of Salinity (PSU) and temperature (°C) with depth (m) at source water stations SW3, SW4, and SW5 during Survey 05 on May 26, 2022 during day and night sampling.

Survey 6 – 2022-06-28

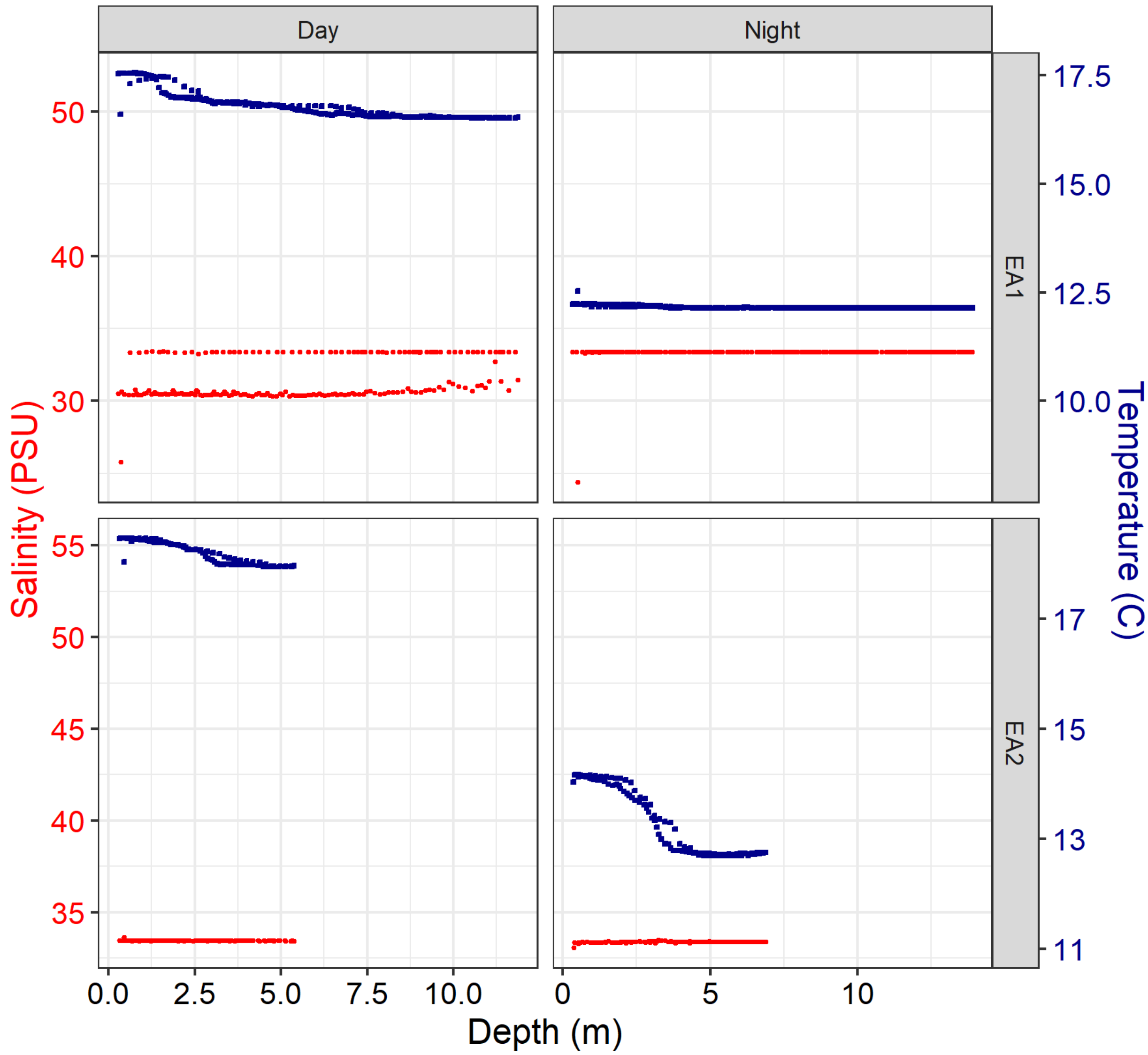

Figure C-13. Plot of Salinity (PSU) and temperature (°C) with depth (m) at entrainment stations EA1 and EA2 during Survey 06 on June 28, 2022 during day and night sampling.

Survey 6 – 2022-06-28

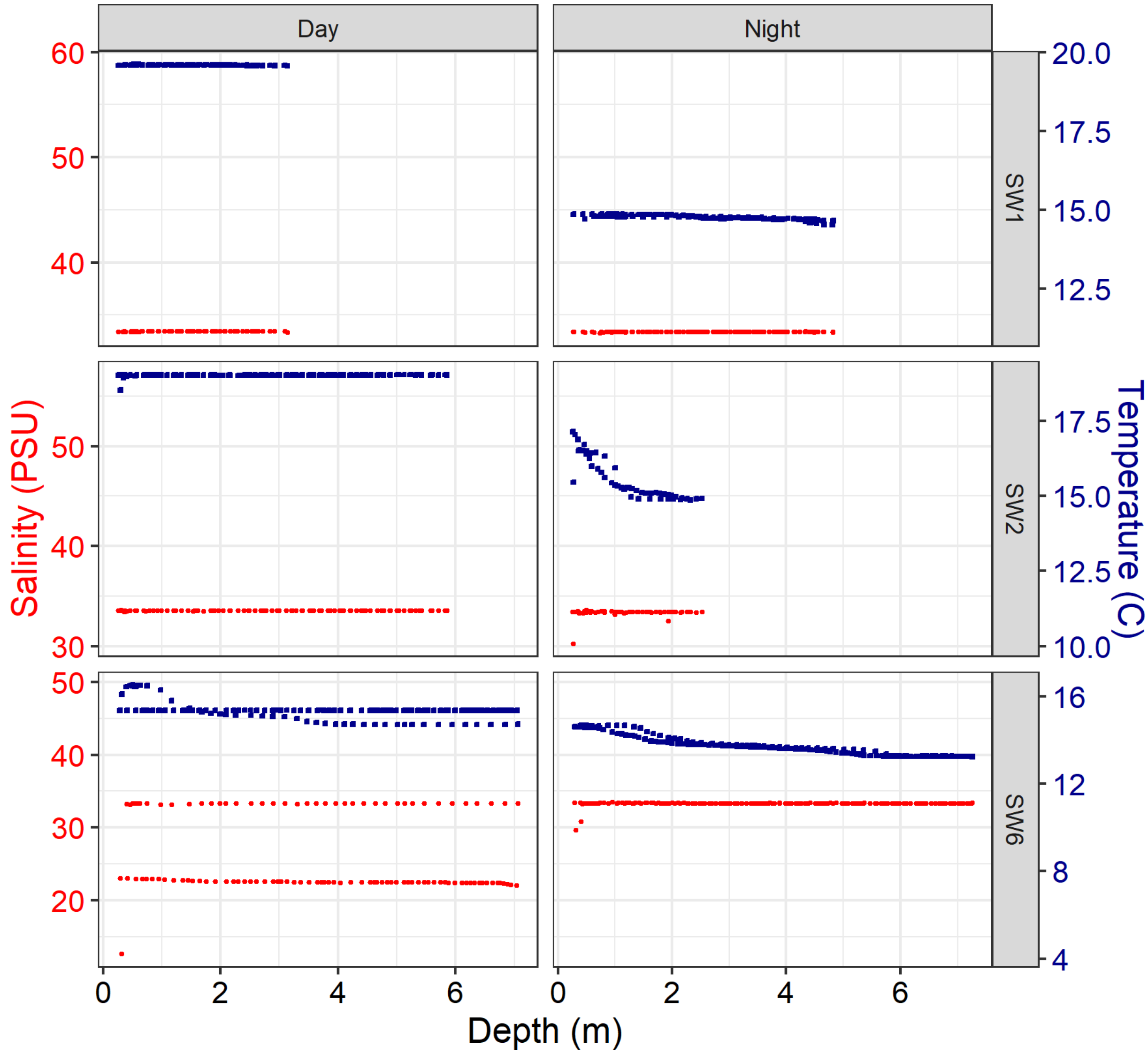

Figure C-14. Plot of Salinity (PSU) and temperature (°C) with depth (m) at source water stations SW1, SW2, and SW6 during Survey 06 on June 28, 2022 during day and night sampling.

Survey 6 – 2022-06-28

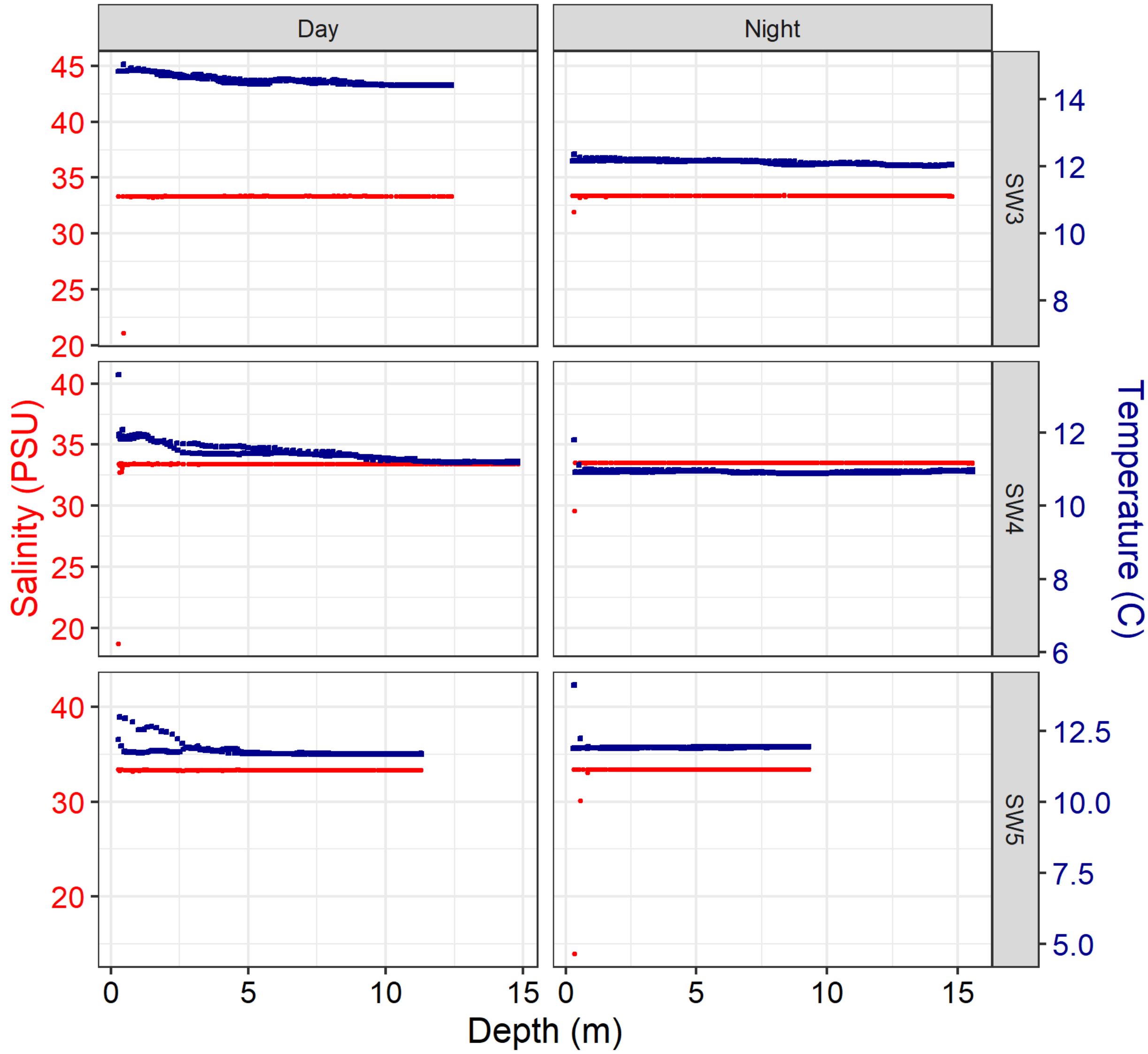

Figure C-15. Plot of Salinity (PSU) and temperature (°C) with depth (m) at source water stations SW3, SW4, and SW5 on Survey 06 on June 28, 2022 during day and night sampling.

Survey 7 – 2022-07-29

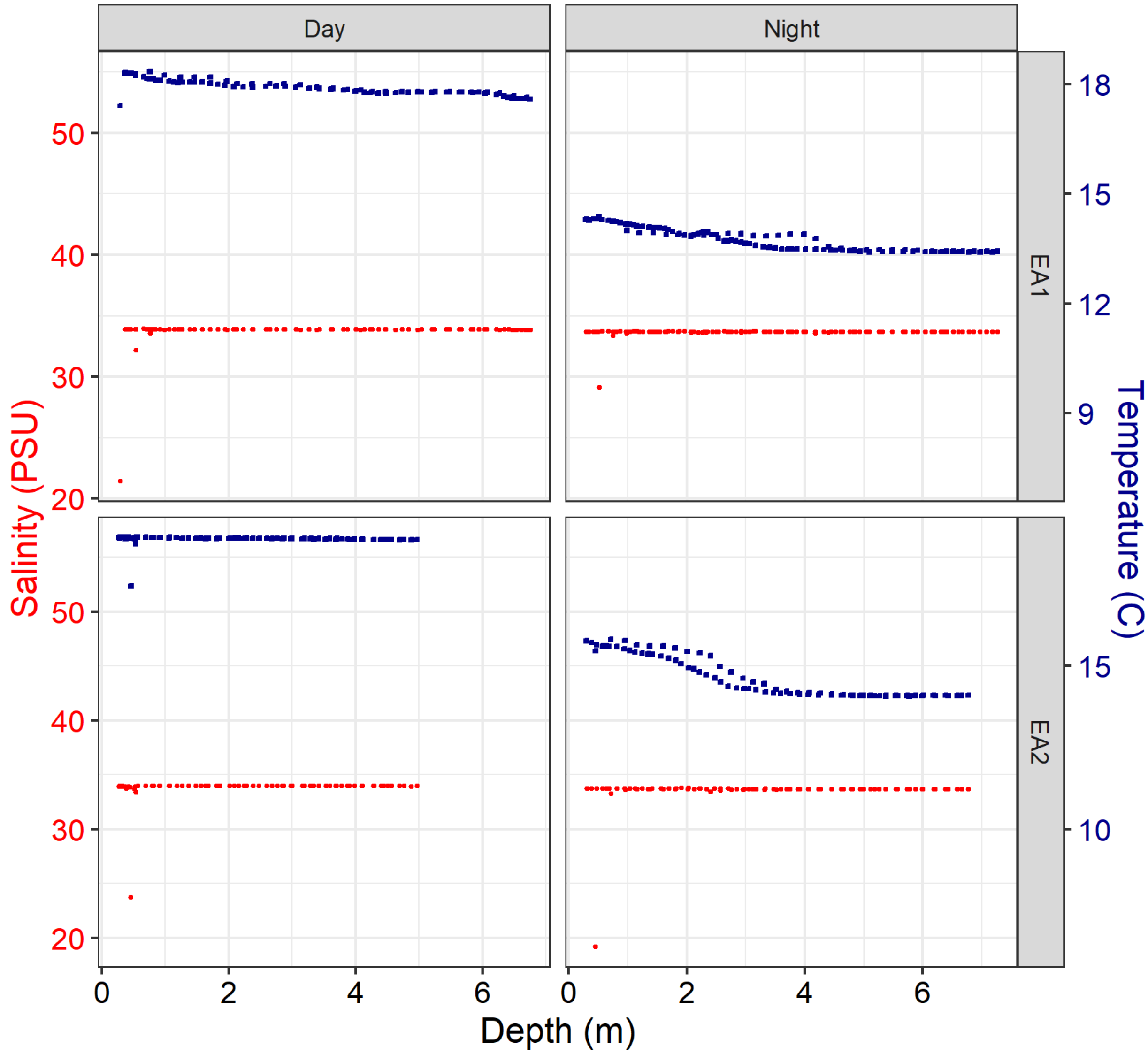

Figure C-16. Plot of Salinity (PSU) and temperature (°C) with depth (m) at entrainment stations EA1 and EA2 during Survey 07 on July 29, 2022 during day and night sampling.

Survey 7 – 2022-07-29

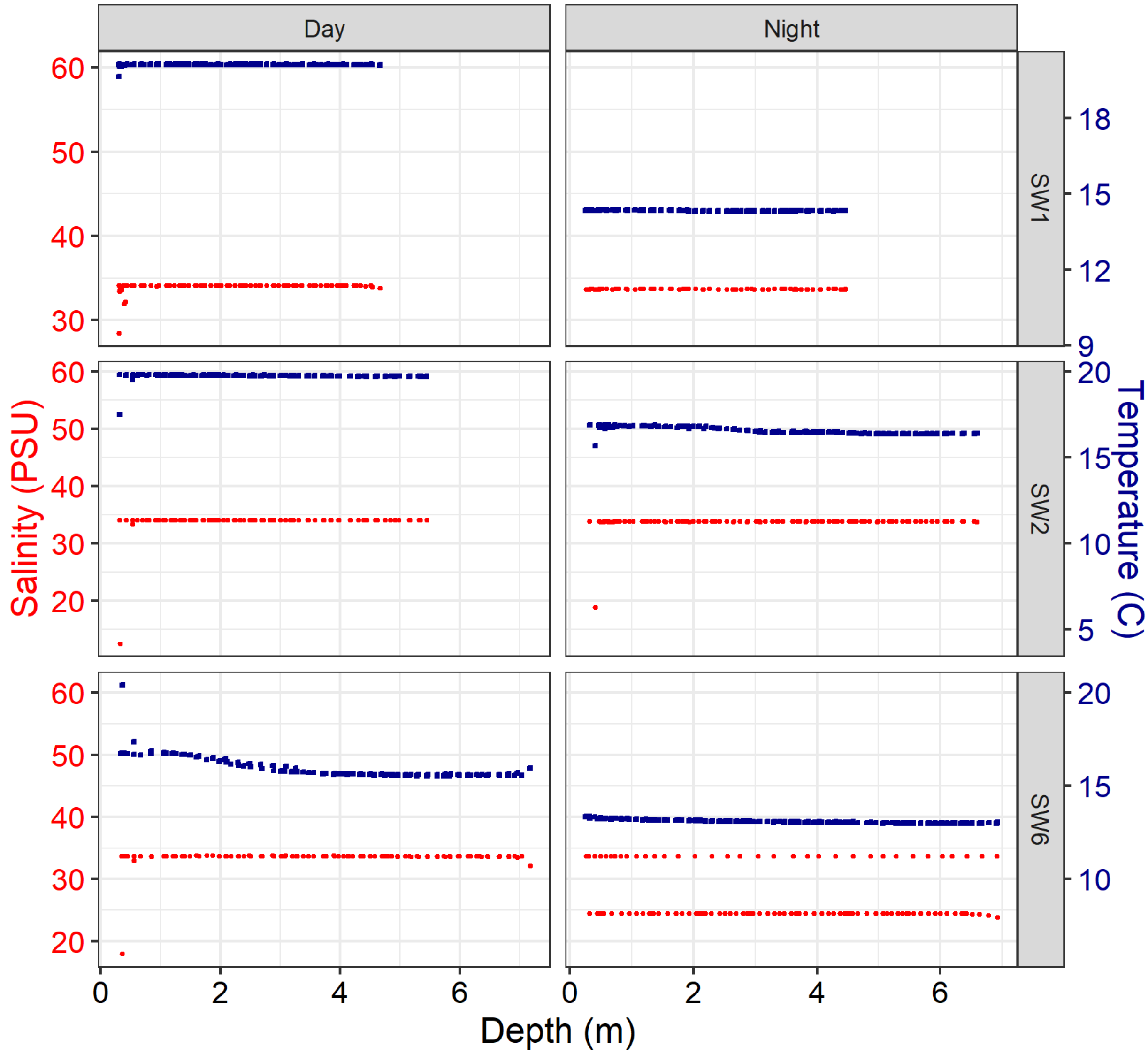

Figure C-17. Plot of Salinity (PSU) and temperature (°C) with depth (m) at source water stations SW1, SW2, and SW6 during Survey 07 on July 29, 2022 during day and night sampling.

Survey 7 – 2022-07-29

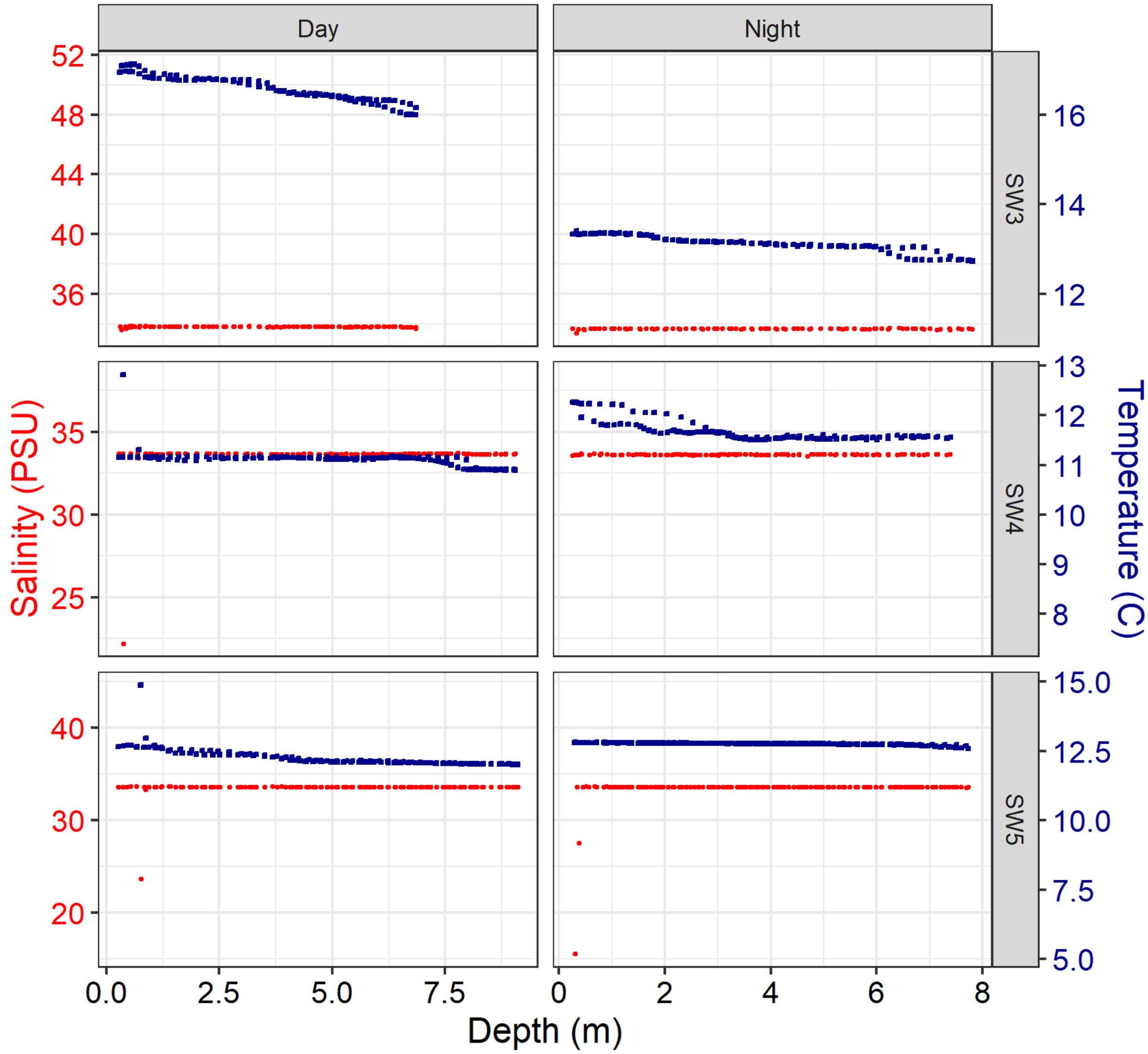

Figure C-18. Plot of Salinity (PSU) and temperature (°C) with depth (m) at source water stations SW3, SW4, and SW5 on Survey 07 on July 29, 2022 during day and night sampling.

Survey 8 – 2022-08-18

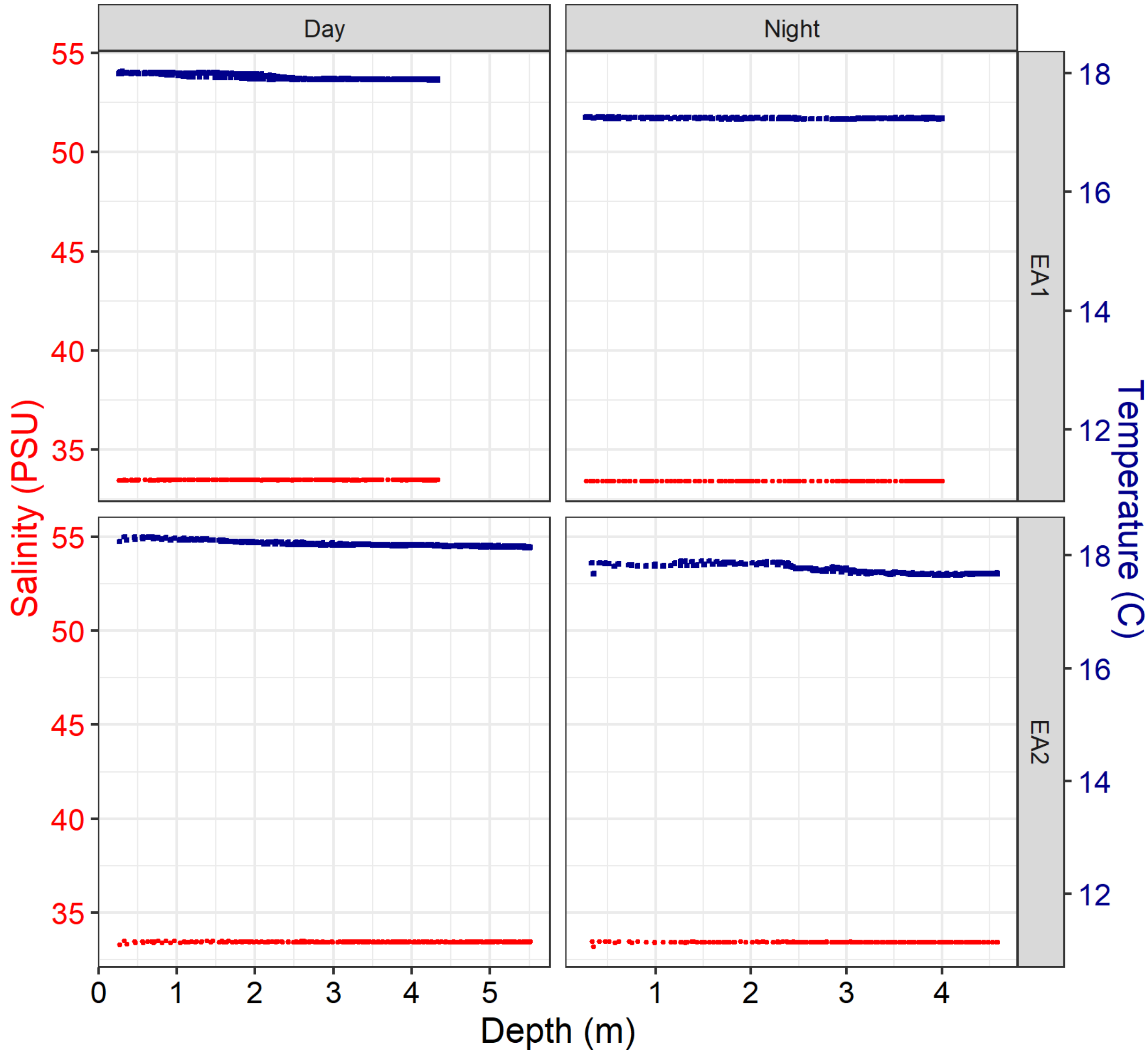

Figure C-19. Plot of Salinity (PSU) and temperature (°C) with depth (m) at entrainment stations EA1 and EA2 during Survey 08 on August 18, 2022 during day and night sampling.

Survey 8 – 2022-08-18

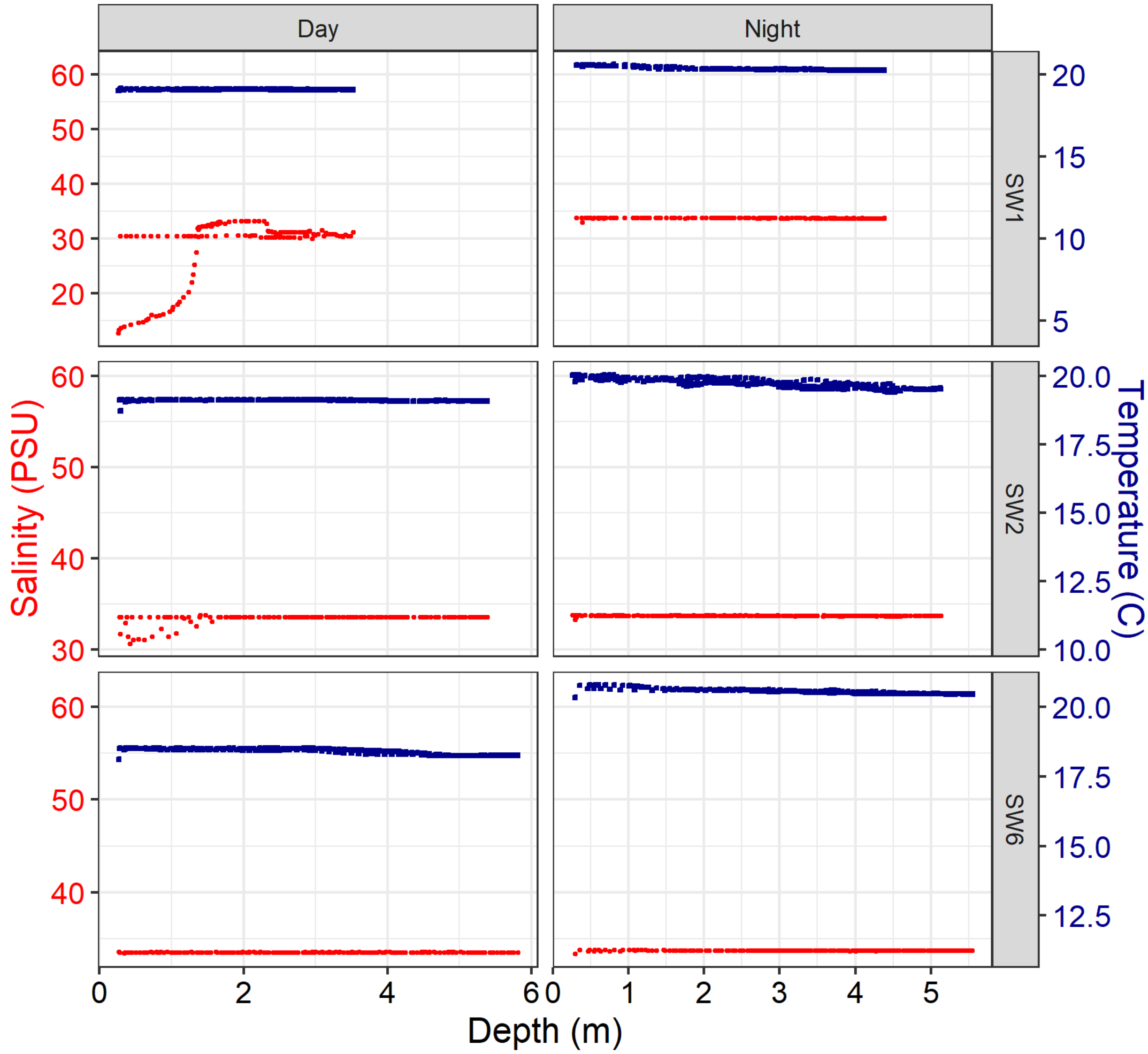

Figure C-20. Plot of Salinity (PSU) and temperature (°C) with depth (m) at source water stations SW1, SW2, and SW6 during Survey 08 on August 18, 2022 during day and night sampling.

Survey 8 – 2022-08-18

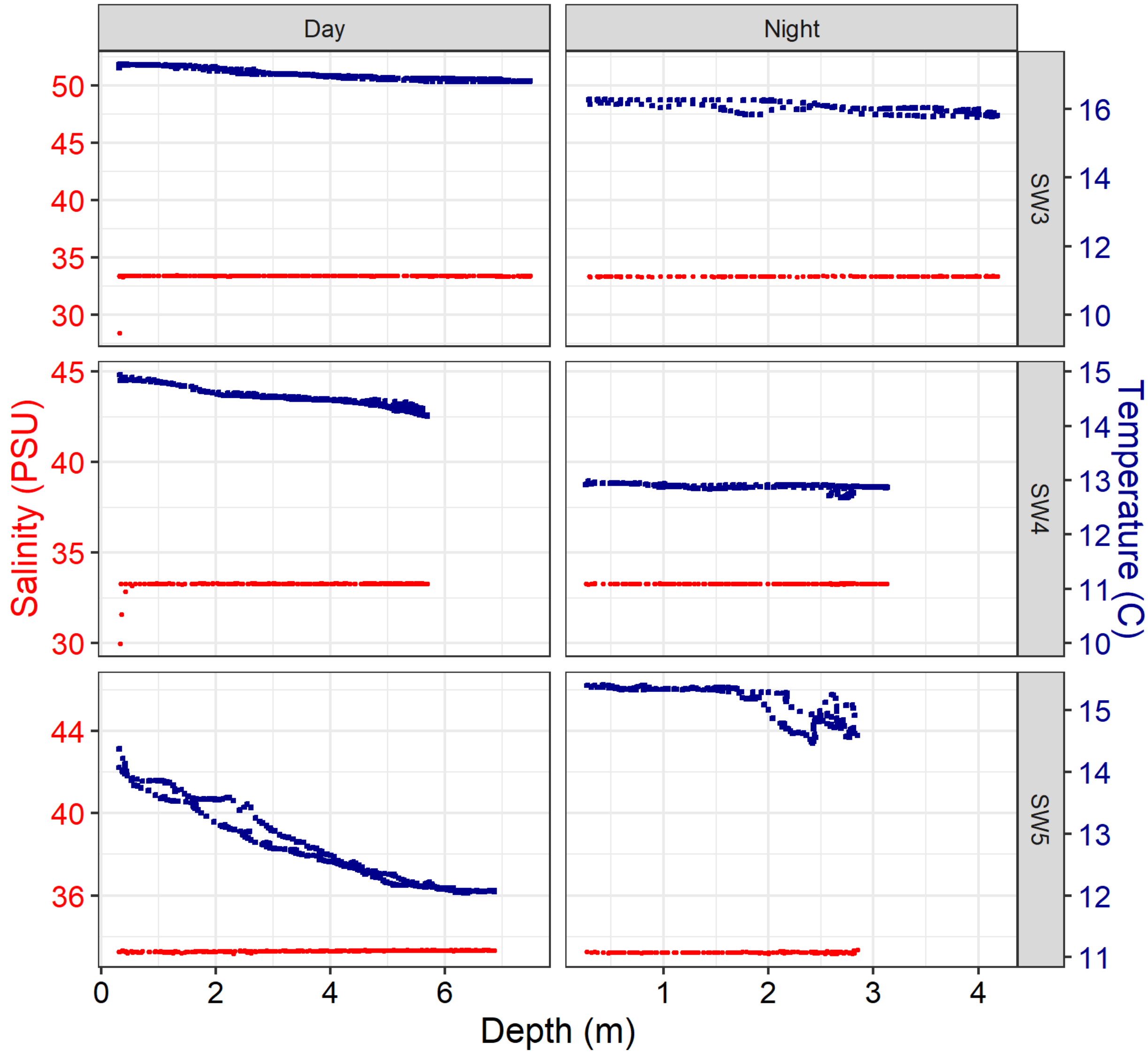

Figure C-21. Plot of Salinity (PSU) and temperature (°C) with depth (m) at source water stations SW3, SW4, and SW5 on Survey 08 on August 18, 2022 during day and night sampling.

Survey 9 – 2022-09-22

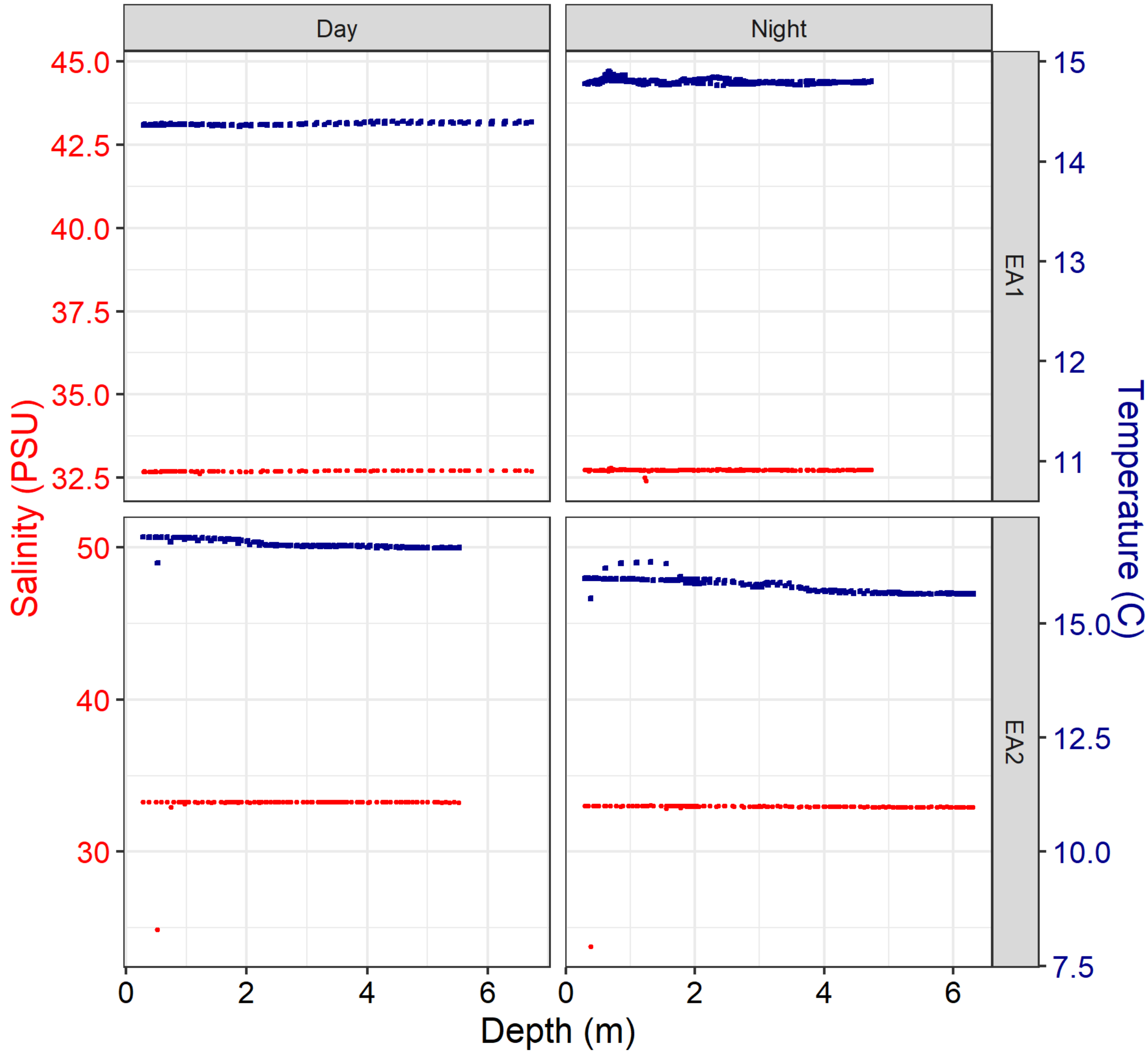

Figure C-22. Plot of Salinity (PSU) and temperature (°C) with depth (m) at entrainment stations EA1 and EA2 during Survey 09 on September 22, 2022 during day and night sampling.

Survey 9 – 2022-09-22

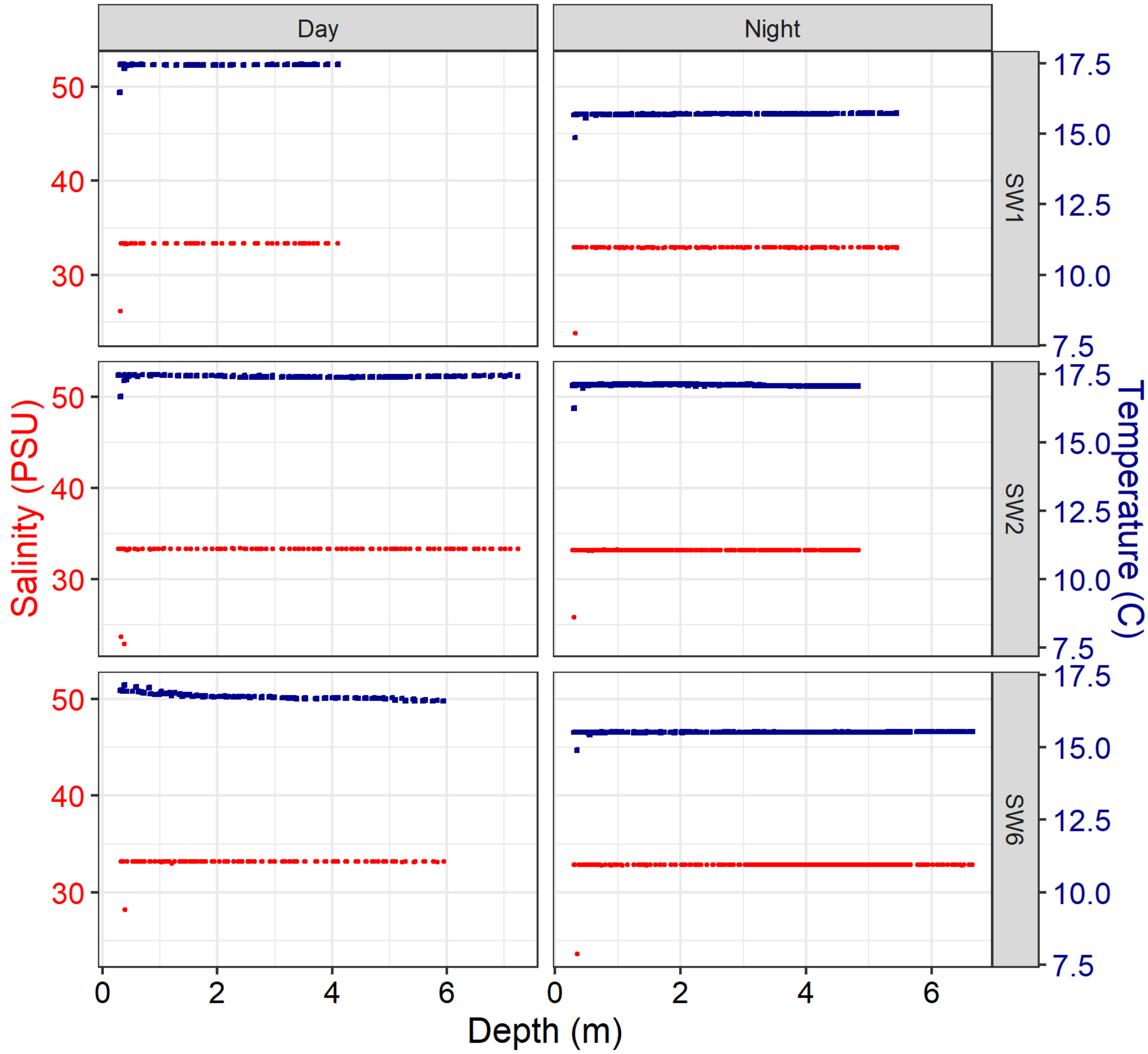

Figure C-23. Plot of Salinity (PSU) and temperature (°C) with depth (m) at source water stations SW1, SW2, and SW6 during Survey 09 on September 22, 2022 during day and night sampling.

Survey 9 – 2022-09-22

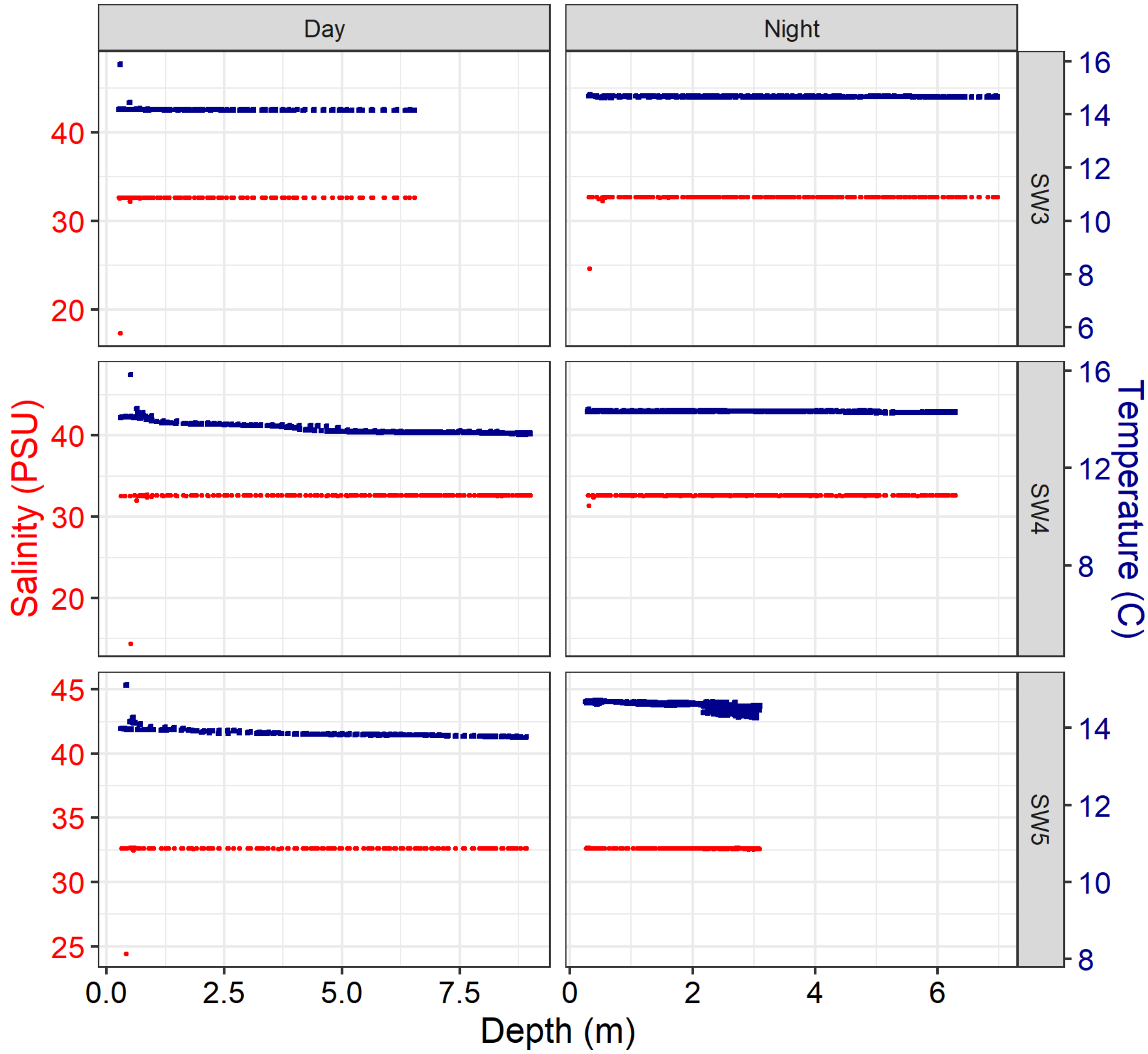

Figure C-24. Plot of Salinity (PSU) and temperature (°C) with depth (m) at source water stations SW3, SW4, and SW5 on Survey 09 on September 22, 2022 during day and night sampling.

Survey 10 – 2022-10-11

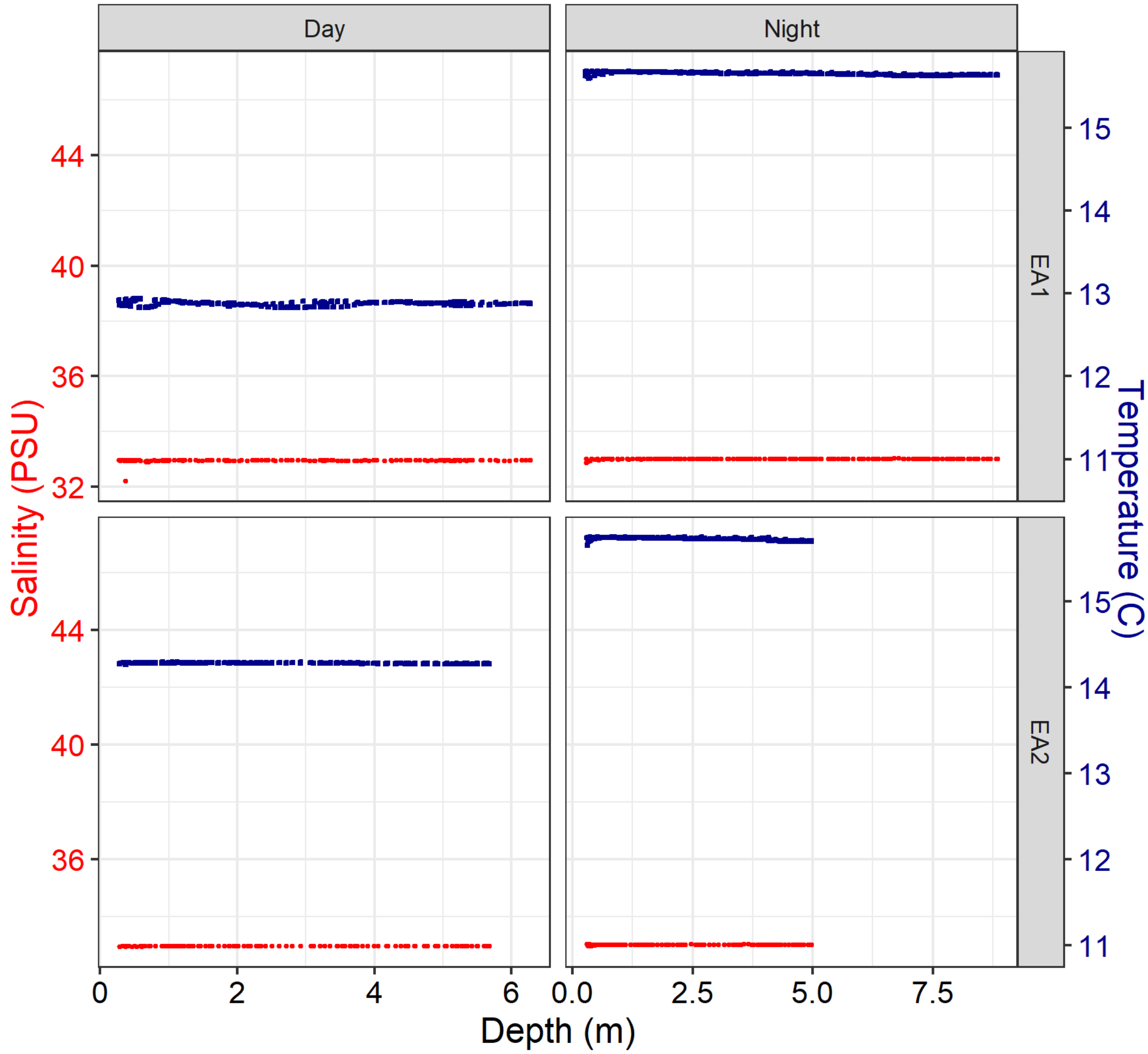

Figure C-25. Plot of Salinity (PSU) and temperature (°C) with depth (m) at entrainment stations EA1 and EA2 during Survey 10 on October 11, 2022 during day and night sampling.

Survey 10 – 2022-10-11

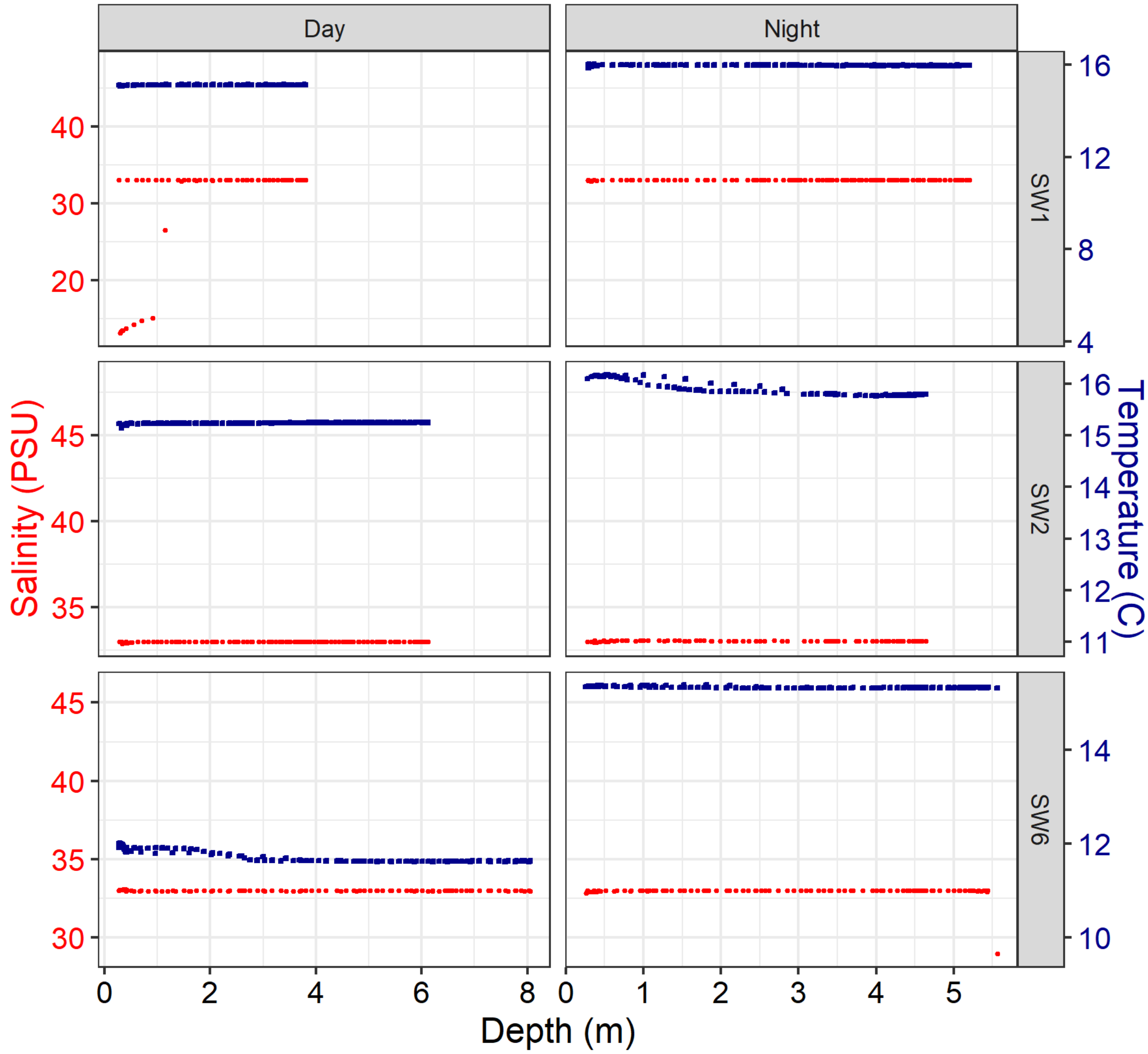

Figure C-26. Plot of Salinity (PSU) and temperature (°C) with depth (m) at source water stations SW1, SW2, and SW6 during Survey 10 on October 11, 2022 during day and night sampling.

Survey 10 – 2022-10-11

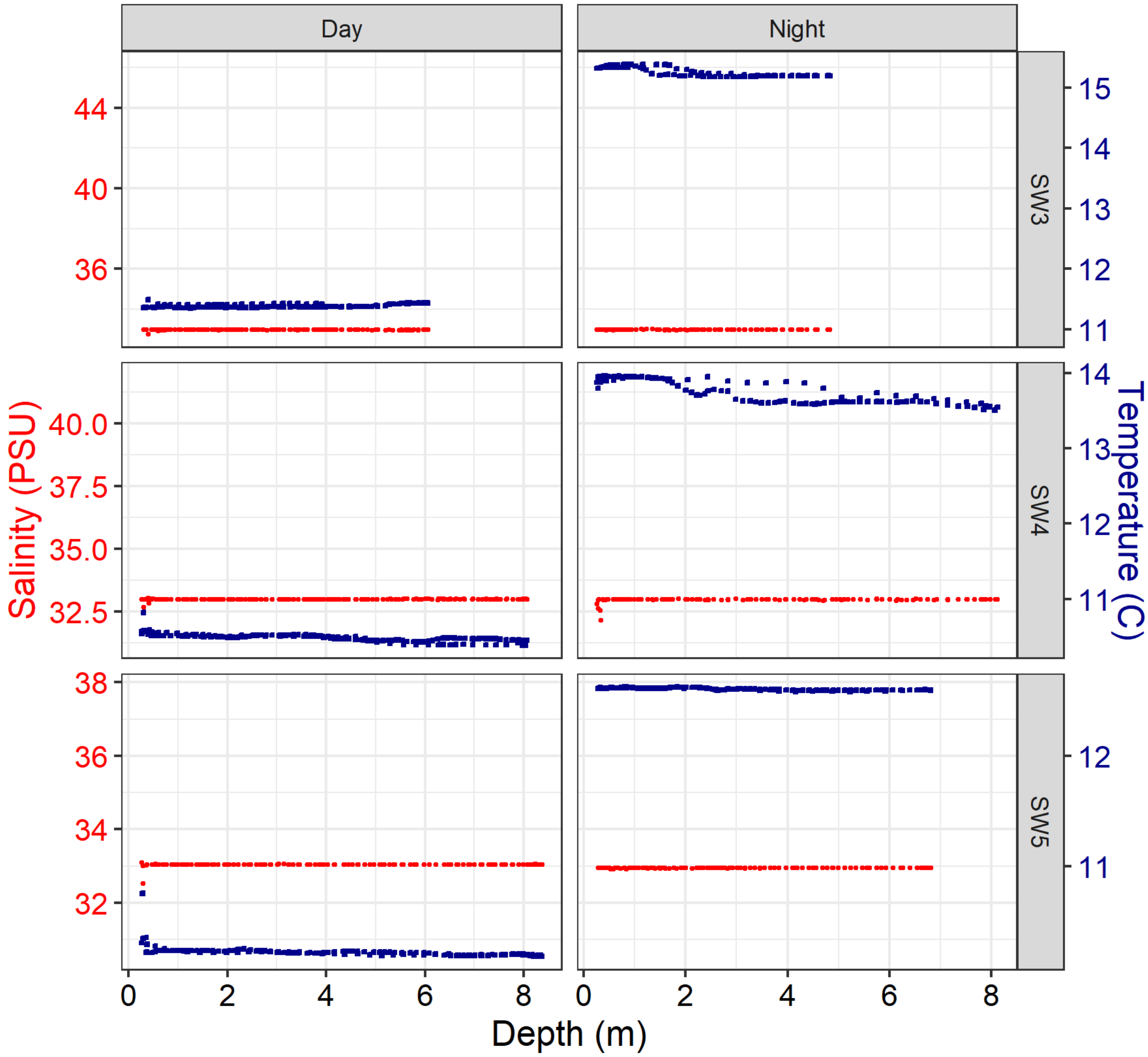

Figure C-27. Plot of Salinity (PSU) and temperature (°C) with depth (m) at source water stations SW3, SW4, and SW5 on Survey 10 on October 11, 2022 during day and night sampling.

Survey 11 – 2022-11-07

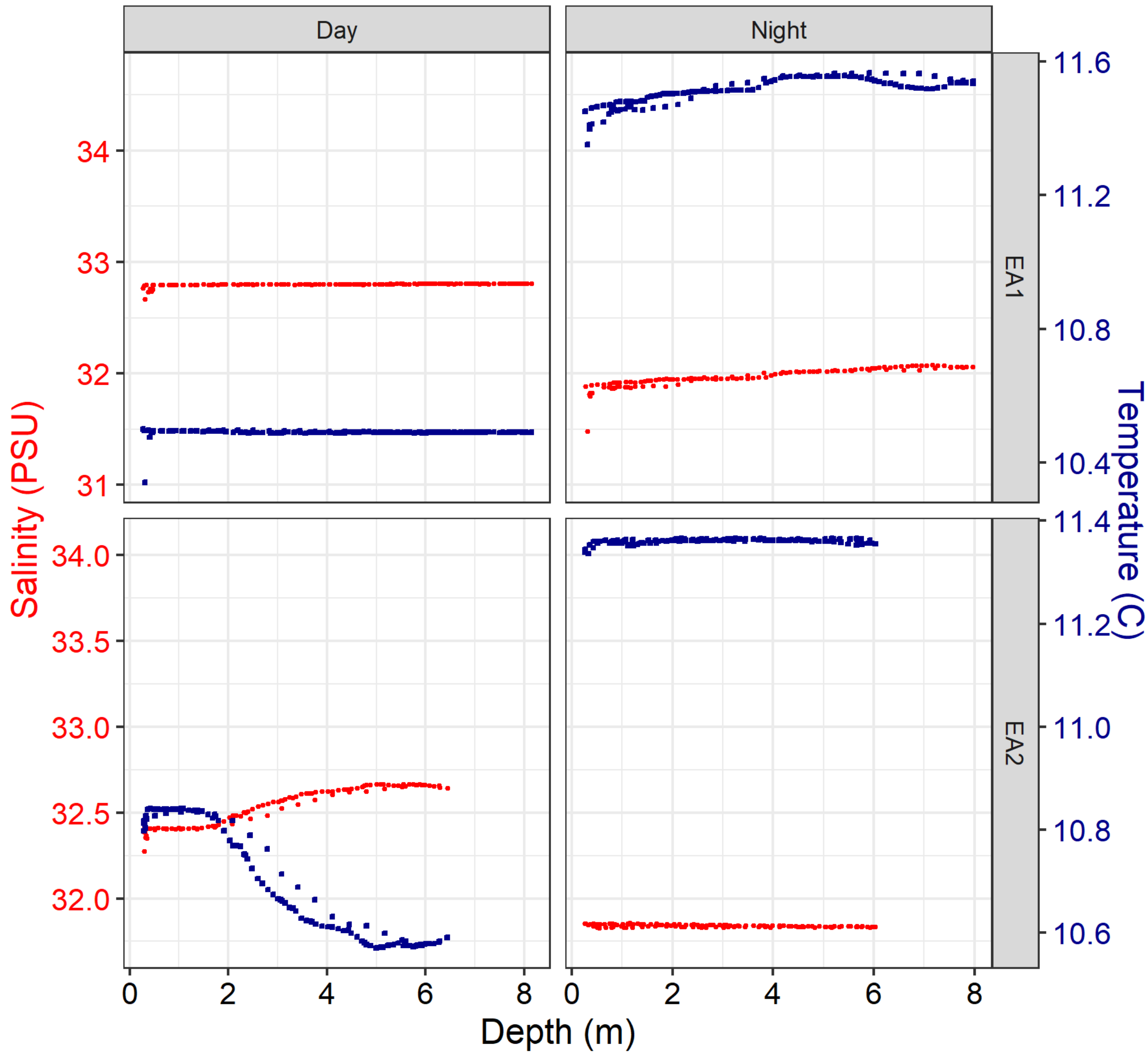

Figure C-28. Plot of Salinity (PSU) and temperature (°C) with depth (m) at entrainment stations EA1 and EA2 during Survey 11 on November 7, 2022 during day and night sampling.

Survey 11 – 2022-11-07

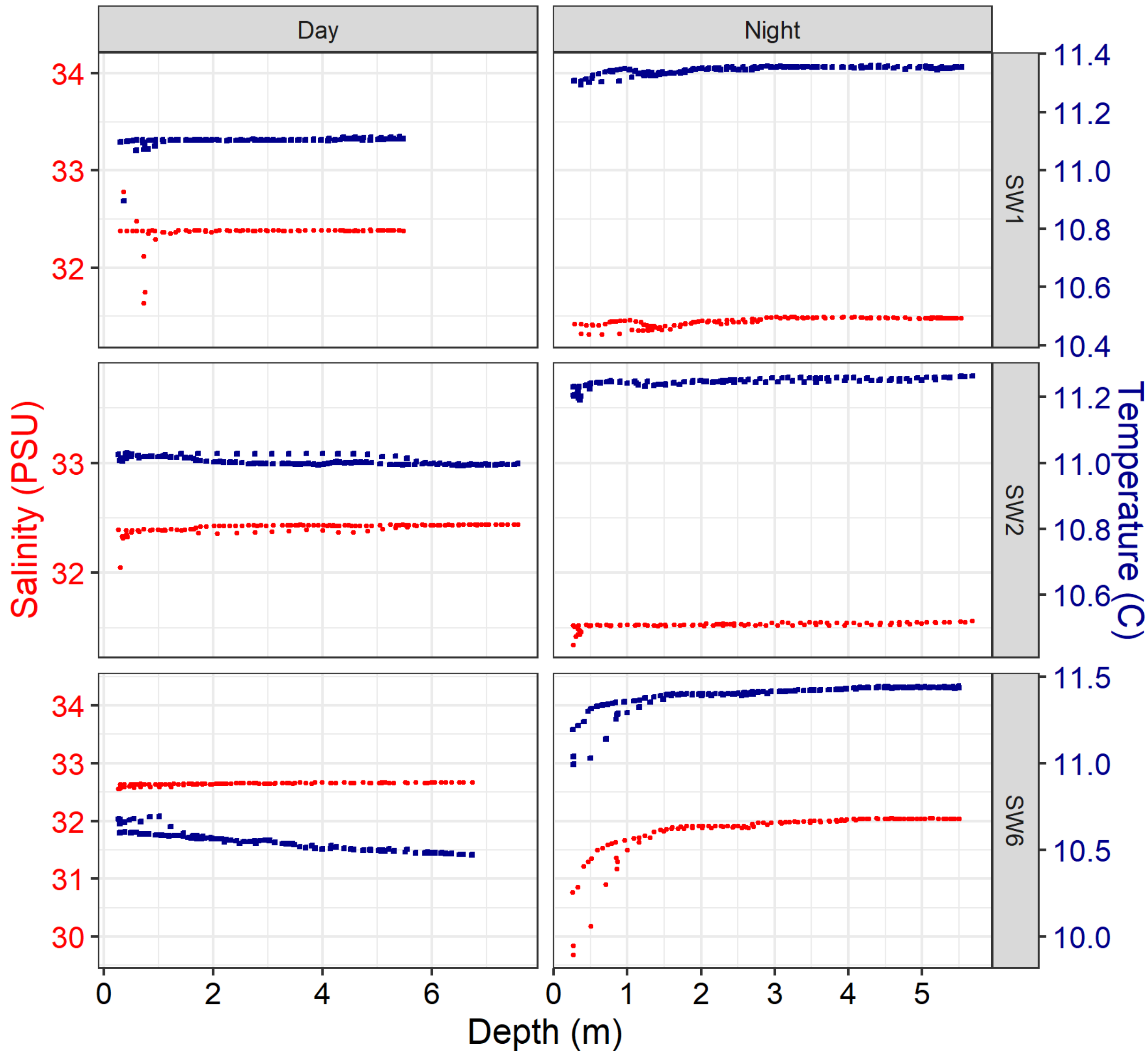

Figure C-29. Plot of Salinity (PSU) and temperature (°C) with depth (m) at source water stations SW1, SW2, and SW6 during Survey 11 on November 7, 2022 during day and night sampling.

Survey 11 – 2022-11-07

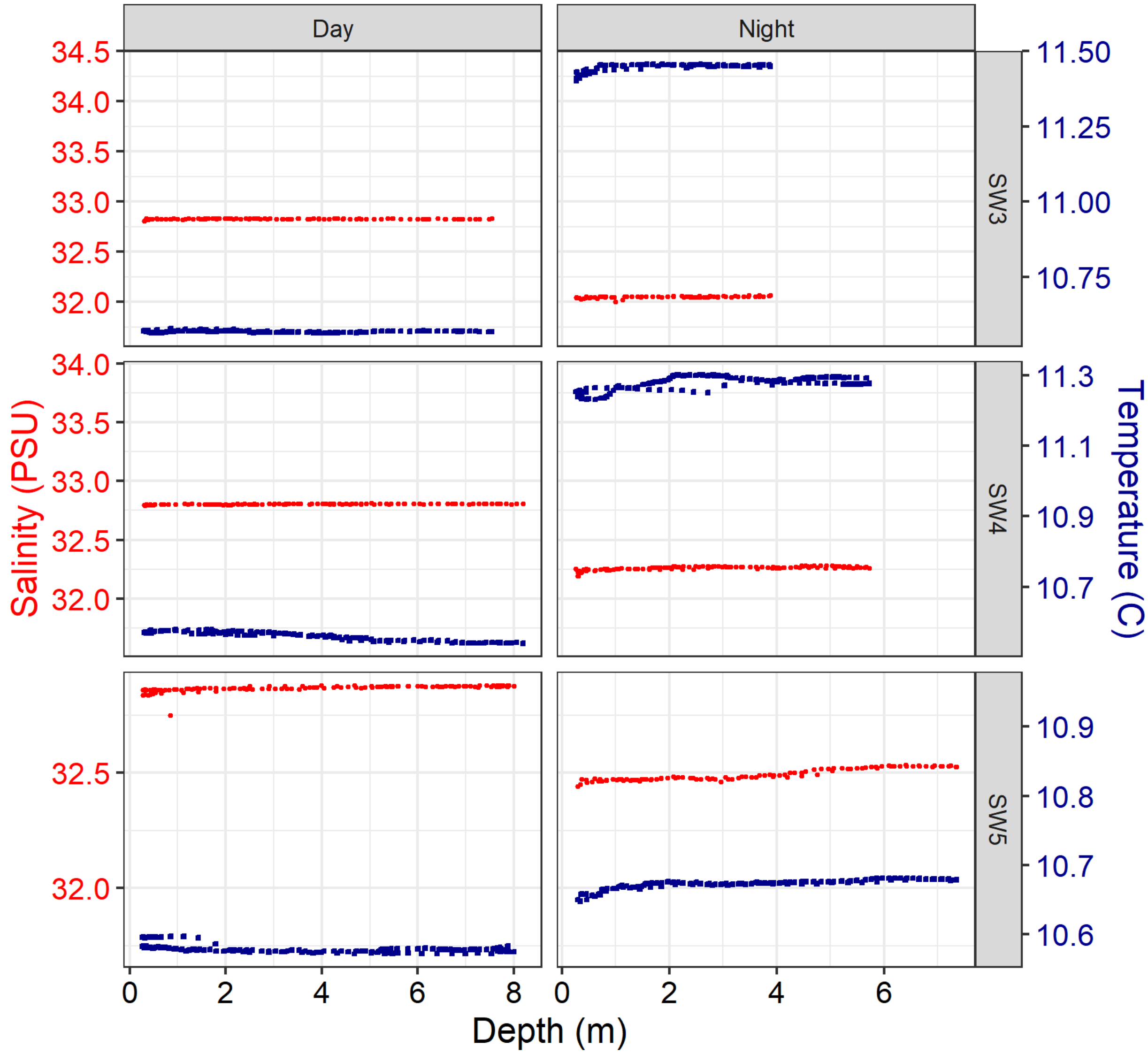

Figure C-30. Plot of Salinity (PSU) and temperature (°C) with depth (m) at source water stations SW3, SW4, and SW5 on Survey 11 on November 7, 2022 during day and night sampling.

Survey 12 – 2022-12-06

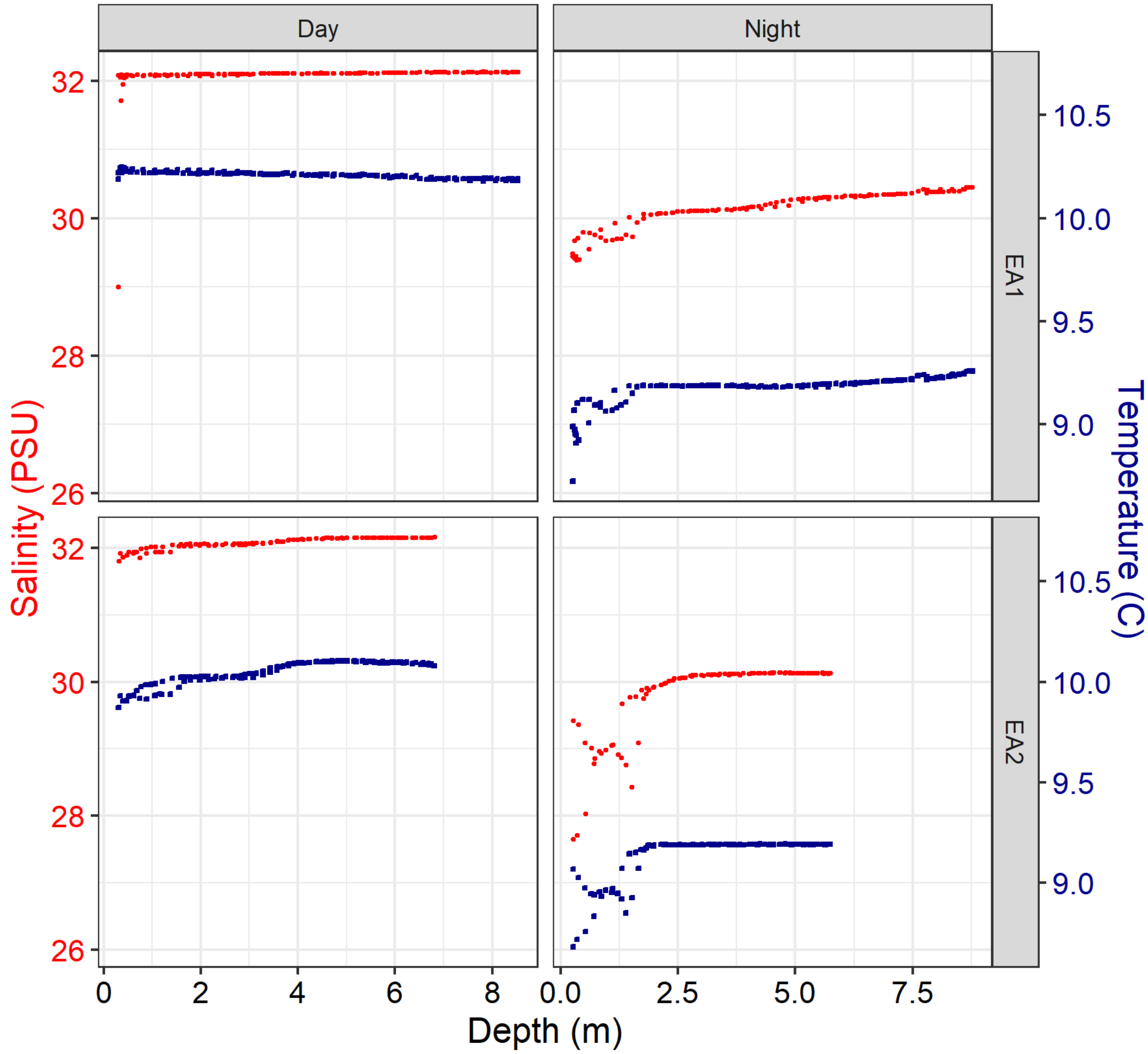

Figure C-31. Plot of Salinity (PSU) and temperature (°C) with depth (m) at entrainment stations EA1 and EA2 during Survey 12 on December 6, 2022 during day and night sampling.

Survey 12 – 2022-12-06

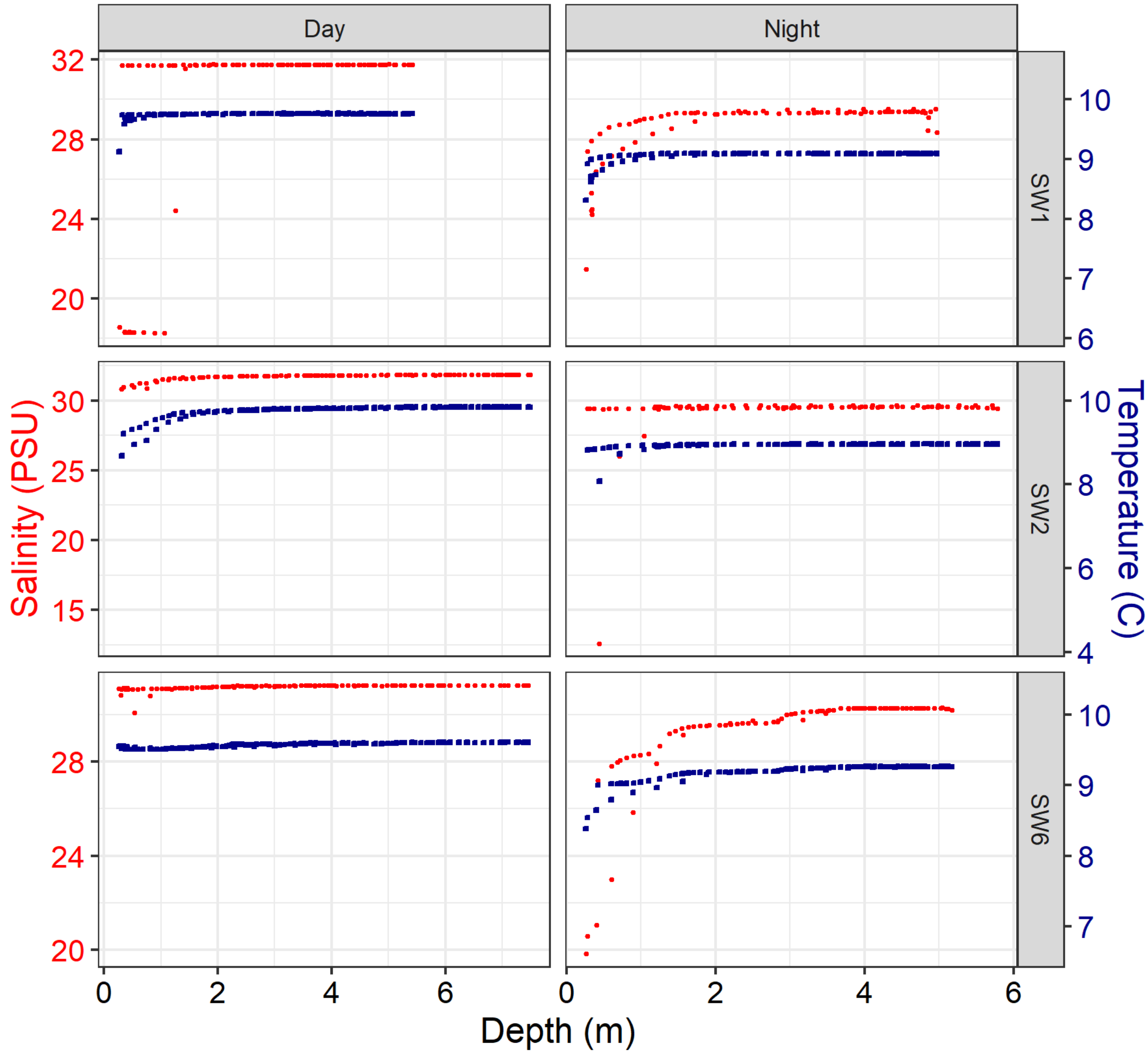

Figure C-32. Plot of Salinity (PSU) and temperature (°C) with depth (m) at source water stations SW1, SW2, and SW6 during Survey 12 on December 6, 2022 during day and night sampling.

Survey 12 – 2022-12-06

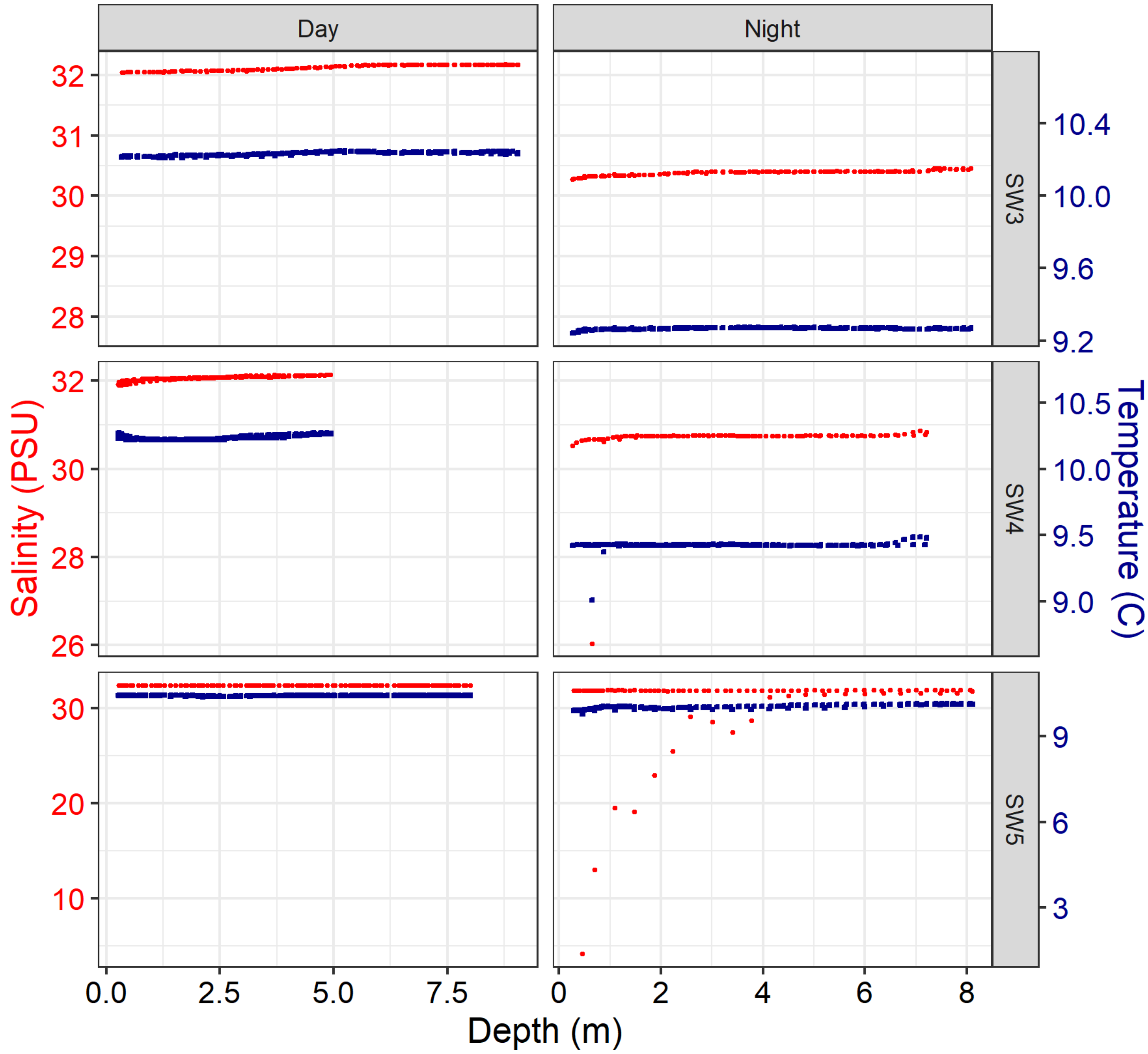

Figure C-33. Plot of Salinity (PSU) and temperature (°C) with depth (m) at source water stations SW3, SW4, and SW5 on Survey 12 on December 6, 2022 during day and night sampling.