



**Fishery and Water Quality Monitoring of Pajaro River Estuary, 2023**  
(Sampling for Tidewater Goby under USFWS Endangered Species Recovery Permit TE-793645-5)



**Chad Steiner and Erin McCarthy setting the seine in Pajaro Estuary (I.M. Laursen). 3 October 2023**

**Purpose of Sampling**

The Santa Cruz County Flood Control and Water Conservation District Zone 7 is required to conduct annual fish sampling in the Pajaro Lagoon/Estuary as a permit condition for emergency lagoon breaching to avoid flooding. Fish sampling documents the presence/absence, distribution and abundance of steelhead (*Oncorhynchus mykiss*), tidewater goby (*Eucyclogobius newberryi*), and other fish and wildlife. 2023 was the 12<sup>th</sup> year of annual sampling, which began in 2012.

## **Summary of 2023 Results**

No tidewater gobies were captured in the lower estuary along the beach berm or at sites upstream adjacent to the model airplane airport, Thurwachter Bridge and the boat ramp, 2.9 miles upstream of Watsonville Slough. In other sampling efforts in the county by our group, no tidewater gobies were captured in nearby Soquel Lagoon or Aptos Estuary in 2023, although they had been present there in 2022, as they had been in Pajaro Lagoon in 2022 (Alley 2023a; Alley 2023b; Alley 2024a; 2024b). The sandbar was open at the time of sampling Pajaro Estuary in 2023, with frequent tidal action adding to saline conditions. Steelhead were not detected in 2023. The catch was dominated by jack smelt (*Atherinopsis californiensis*) and top smelt (*Atherinops affinis*) (Tables 1-4). Other captured species, in order of declining numbers, included arrow goby (*Clevelandia ios*), staghorn sculpin (*Leptocottus armatus*), starry flounder (*Platichthys stellatus*), bay pipefish (*Syngnathus californiensis*), shiner perch (*Cymatogaster aggregata*), prickly sculpin (*Cottus asper*) and California halibut (*Paralichthys californicus*). No threespine sticklebacks (*Gasterosteus aculeatus*) were captured. Arrow gobies were most abundant at the site closest to the area of tidal influences where the sandbar was open. The estuary was lightly to moderately saline near the surface and heavily saline in the lower water column. The lower estuary was moderately warm and generally below 18°C in the morning, with good morning oxygen levels, tolerable water temperature, but was too saline to sustain steelhead, if they had been present previously. The upper estuary was warmer and generally between 18 and 22°C in the early afternoon, and with oxygen adequate between 5 and 9 mg/L to the bottom in the afternoon. Salinity near the surface at the boat ramp was 3-5 parts per thousand (ppt) in the upper 0.5 m of the water column, making only a thin layer down to 0.5 m from the surface habitable to steelhead in the upper estuary on the day of monitoring. However, expected higher water temperatures later in the day or on warmer days earlier in the summer likely made this limited habitat very marginal or absent at other times. The upper estuary was increasingly saline with depth and beyond steelhead tolerance.

Tidewater gobies could have inhabited the lower and upper estuary in 2023, as water quality measurements confirmed that oxygen was available throughout the water column. But high salinity measured at the bottom, combined with the tidal fluctuations and water current would be problematic for successful tidewater goby spawning. With the limited overwintering refuge between the levees during the previous wet winter having high stormflows, the surviving tidewater goby population may have been small in spring 2023 when nesting began. Their absence in our sampling was consistent with likely low survival over the winter. Tidewater gobies were also absent during our sampling of Soquel Lagoon and Aptos Estuary in 2023.

## **2023 Estuary Conditions**

During fish sampling in early October, an estuary with fluctuating depth and current was present due to an open sandbar. On an incoming tide, water entered the estuary with upstream current. On an outgoing tide, water evacuated from the estuary, reversing the current direction. The drought years of 2015, 2021 and 2022 were the latest previous years of having a closed sandbar.

In 2023, the lower estuary remained cooler than the upper estuary and unstratified at depth to 1 meter in regard to temperature (15-19°C), and oxygen concentration was good (7- 10 mg/L from bottom to surface). Salinity was stratified between 18 ppt at the surface to 30 ppt at the bottom in late morning. These conditions were very adequate for saltwater fish life but not steelhead and other freshwater fish species. Salinity there was beyond the tolerance of freshwater acclimated steelhead and would likely have eliminated them if they were present earlier in the spring when stream inflow was high. The secchi depth in the lower estuary was to the bottom (1 meter where measurements were taken). The upper estuary was inhospitable to freshwater fish life except near the surface and in shallow margins in the vicinity of the boat ramp and presumably upstream. In the upper estuary, habitat for saline-tolerant species was present throughout the water column. In the early afternoon, the upper estuary's water temperature was moderate to warm throughout the water column (19 to 22.5°C). In the upper estuary, salinity was stratified between 3 ppt at the surface at the boat ramp to 30 ppt at the bottom at all three upper estuary sites. Water temperature and oxygen were unstratified in the upper estuary, although water temperature was somewhat warmer near the surface in the afternoon. Oxygen ranged between 5 and 9 mg/L throughout the water column in late morning and early afternoon. The secchi depth was to the bottom (2 meters at our deepest measuring site near Thurwachter Bridge).

## **Methods**

Pajaro Estuary (open sandbar) was sampled on October 3 – 5, 2023. Sampling locations were spread out in the lower estuary along the beach berm from the mouth of Watsonville Slough to the east (**Figure 1**). The upper estuary was sampled adjacent to the model airport (1.8 miles upstream of Watsonville Slough), at Thurwachter Bridge (2.1 miles upstream of Watsonville Slough) and behind the City of Watsonville wastewater treatment plant at the boat ramp (2.9 miles upstream of Watsonville Slough).

On 3 October, the lower estuary along the beach was sampled for steelhead with the 106-foot bag seine (8 successful seine hauls). On 4 October, the upper estuary was sampled with the 106-foot bag seine (3/8-inch mesh) at the airport and Thurwachter Bridge sites, and water quality data were collected. Three seine hauls were made at the model airport, with 3 more at Thurwachter Bridge. Water quality was measured from a boat at the perceived thalweg (deepest portion) at these two sites (water temperature (°C), salinity (parts per thousand), conductivity (umho = micro-siemens = 1 millionth of a siemens) and oxygen (mg/L = parts per million) measured through the water column at 0.25 meter intervals). Secchi depths were measured at the two sites.

Conductivity is a measure of water's capability to pass electrical flow. This ability is directly related to the concentration of ions in the water. These conductive ions come from dissolved salts and inorganic materials such as alkalis, chlorides, sulfides and carbonate compounds and not just sodium chloride. Secchi depth is the depth in the water column at which the black and white secchi disc first becomes visible as it is raised through the water column.

On 5 October, tidewater gobies were sampled for, using a 30-foot seine with 1/8-inch mesh.

Five seine hauls were made in the lower estuary along the beach. Three seine hauls were made in the upper estuary (model airport, Thurwachter Bridge and boat ramp). Water quality was measured at four stations. Water quality measurements at the three lower estuary stations were made nearshore by wading in at seining locations. The upper estuary measurements were made nearshore by wading near the boat ramp. Water quality measurements taken on 4 and 5 October were sufficient to determine general water quality conditions during the fish sampling period in early fall.

*Figure 1. Pajaro Lagoon Fish and Water Quality Sampling Sites*







Farm equipment collected in the seine under Thurwachter Bridge. 4 Oct 2023

### **Results – Fish Capture**

Sampling of the lower estuary along the beachfront with the larger bag seine yielded 6 native fish species (**Table 1**). Smelt were again the most abundant species, with those being identified as jack and topsmelt. Many young-of-the-year smelt were very small and escaped through the seine mesh. Other captured species, in order of declining numbers, included staghorn sculpin, starry flounder, bay pipefish, shiner perch and prickly sculpin. No threespine sticklebacks (*Gasterosteus aculeatus*) were captured. Yellowshore and Dungeness crabs were found in low numbers. No steelhead were detected in the upper or lower estuary in 2023.

Sampling results with the large seine in the upper estuary near the model airplane airport and Thurwachter Bridge yielded smelt, staghorn sculpin and shiner surfperch (**Table 2**).

Our sampling for tidewater goby in the lower estuary with the smaller, fine-meshed seine yielded four native species, those being jack smelt, topsmelt, arrow goby and California halibut (**Table 3**). Arrow gobies were captured on each of 5 seine hauls along the beachfront. But no tidewater gobies were detected. In 2022, tidewater gobies had been captured on all 5 seine hauls. In 2023, arrow gobies were most abundant at the site closest to the open sandbar and tidal overwash.

Sampling results with the small seine at the 3 sites in the upper estuary yielded no tidewater gobies (**Tables 3 and 4**). Species captured with this seine included 4 native species, those being jack smelt, top smelt, arrow goby and staghorn sculpin all in relatively low numbers.

**Table 1. Fish capture\* results from sampling lower Pajaro Estuary with the 106-foot bag seine (3/8-inch mesh), 3 October 2023.**

Date	Location	Seine Haul #	Steel-head	Tide-water Goby	Arrow Goby	Three spine Stickleback	Smelt (jack and top)**	Staghorn Sculpin	Pacific Herring	Starry Flounder	Bay Pipefish	Shiner Perch	Prickly Sculpin
3 Oct 2023	East of Watsonville Slough	1						3		1	1		1
	East of #1	2											
	East of #2	3						1					
	East of #3	4					9						
	East of #4	5									1		
	East of #5	6					12						
	East of #6	7					65						
	East of #7	8					205						
<b>Total</b>		<b>8</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>291</b>	<b>4</b>	<b>0</b>	<b>1</b>	<b>2</b>	<b>0</b>	<b>1</b>

\*6 Yellowshore crabs, 28 Dungeness crabs.

\*\*Many YOY smelt escaped through the seine due to their small size.

**Table 2. Fish capture\* results from sampling upper Pajaro Estuary with the 106-foot bag seine (3/8-inch mesh), 4 October 2023.**

Date	Location	Seine Haul	Steel-head	Tide-water Goby	Arrow Goby	Bay pipefish	Smelt	Staghorn Sculpin	Three-spine Stickleback	Starry Flounder	Longjaw mudsucker goby
4 Oct 2023	Model Airport	1-3				2	6	3			
	Thurwachter Bridge	4-6					2	1		1	
<b>Total</b>			<b>0</b>	<b>0</b>	<b>0</b>	<b>2</b>	<b>8</b>	<b>4</b>	<b>0</b>	<b>1</b>	<b>0</b>

**Table 3. Fish capture\* results from sampling the periphery of lower and upper Pajaro Estuary with the 30-foot seine (1/8-inch mesh), 5 October 2023.**

Date	Location	Seine Haul	Steel-head	Tide-water Goby	Arrow Goby	Three-spine Stickleback	Bay pipefish	Smelt	Mosquito Fish Gambusia	Staghorn Sculpin	California Halibut	Prickly Sculpin
5 Oct 2023	Approx. 100 m east of Pajaro Dunes	1			8							
	East of #1	2			39							
	East of #2	3			9						1	
	East of #3	4			4			20				
	East of #4	5			132							
	Model Airport- 0.3 miles down from Thurwachter Br	6			30					1		
	Thurwachter Bridge- 2.1 miles up from Watsonville Slough	7			8			100 YOY				
	Boat Ramp- 0.8 miles upstream of Thurwachter Br.	8			7							
<b>Total</b>		<b>8</b>	<b>0</b>	<b>0</b>	<b>238</b>	<b>13</b>	<b>3</b>	<b>120</b>	<b>0</b>	<b>1</b>	<b>1</b>	<b>0</b>

\* 11 Yellowshore crabs.

**Table 4. Annual Number of Tidewater Gobies Captured in Pajaro Estuary/ Lagoon in Fall.**

Year	# of Tidewater Gobies Captured in Pajaro Lagoon/Estuary	# of Seine Hauls at Approximately Similar Locations with 30-foot Seine (1/8-inch mesh)
2012	111	8
2013	436	8
2014	414	8
2015	42	8
2016	29	8
2017	0 (1 with 3/8-inch mesh seine adjacent model airplane airport)	8
2018	0	8
2019	0	8
2020	11	8
2021	0	8
2022	7	8
2023	0	8



California Halibut (C. Steiner) 5 October 2023



**Staghorn Sculpin. (T. Suttle) 5 October 2021**





**Starry Flounder (I.M. Laursen) 3 October 2023**



**Shiner Surfperch (I.M. Laursen) 3 October 2023**



Arrow Goby (I.M. Laursen) 3 October 2023



Tidewater gobies captured in Soquel Lagoon. (Photo by I.M. Laursen) 4 October 2020



**Bay Pipefish (I.M. Laursen) 3 October 2023**



**Dungeness Crabs (I.M. Laursen) 3 October 2023**





Native Hitch once common in Pajaro Lagoon in the 1960's, now rarely observed. (D. Alley) 7 October 2014

### **Water Quality**

In 2023 at the time of sampling, the lower estuary was cooler in mid to late morning than the upper estuary in late morning and early afternoon and was slightly thermally stratified nearshore (15-19°C), with slightly cooler water near the bottom. Salinity was stratified furthest away from the open rivermouth and less so closer to it (ranging 18-30 ppt). These conditions were very adequate for saltwater-tolerant fish life but too salty for steelhead. Salinity-related stress to freshwater acclimatized steelhead would occur when conductivity levels reach 12,000 to 15,000 micro-mhos, associated with sudden increases in salinity to 10–12 ppt (**J. Cech, fish physiologist, personal communication**). However, steelhead acclimatized to estuary conditions with fluctuating salinity and stratification can survive where salinity increases with depth as long as near surface, salinity is low and water temperature is cool enough. Salinity there was beyond the tolerance of freshwater acclimated steelhead throughout the water column in the lower estuary and would likely have eliminated them from this portion of the estuary if they had been present earlier in the spring and early summer when good stream inflow still existed.

The upper estuary sites at the model airport and Thurwachter bridge in late morning and early afternoon on sunny 4 October had unstratified water temperature, although the surface layers were beginning to warm up in the afternoon to 21.5°C by 1400 hr. Oxygen was unstratified at the model airport and slightly stratified at Thurwachter Bridge later on, with oxygen increasing with depth there (**Table 5**). Oxygen was adequate for fishes throughout the water column at both sites (5-9 mg/L). Salinity was stratified at these two sites and near the upper tolerance range for



freshwater acclimated steelhead in the upper 0.25 meters of the water column (8.9-11.8 ppt) and beyond their tolerance at great depths. With this potential salinity stress plus the warm surface water temperature noted in the early afternoon, it is unlikely that steelhead could inhabit even the uppermost water column at these upper estuary sites.

The upper estuary site further upstream at the boat ramp in early afternoon (1351 hr) on the next sunny day 5 October had the warmest water temperature at the surface at 22.3°C and less than 20 C below, throughout the water column. This uppermost site had stratified salinity increasing downward (3 to 29 ppt), with no oxygen stratification at fair to good levels (5-7.5 mg/L) (**Table 6**). Steelhead might survive in the upper 0.5 m of the water column with salinity less than 10 ppt as it did at this site in 2023 (**Table 6**). However, the warming of the upper estuary layer to beyond 22°C in the early afternoon indicated that on some warmer days and later in the afternoon, the potentially inhabitable, upper water column may exceed the tolerance limit for steelhead there. Steelhead would be especially vulnerable to bird predation near the surface, and they prefer to swim near the bottom, given the choice. Water temperatures above 22° C (72° F) and oxygen below 5 mg/L are considered stressful for steelhead. The high water temperature detected near the surface (and that undoubtedly occurred earlier in summer) would likely eliminate the sometimes marginal steelhead habitat at this site.

**Table 5. Water quality measurements in the upper Pajaro estuary during fish sampling for steelhead, 4 October 2023.**

		4-Oct-2023							
		Model Airport (mid-channel)			1125 hr	Thurwachter Bridge (mid-channel)			
		Air temp. 24°C				Air temp. 24.6°C			1400 hr
Depth	Temp	Salin	Oxygen	Cond	Temp	Salin	Oxygen	Cond	
(m)	( C )	(ppt)	(mg/l)	micro-mhos	( C )	(ppt)	(mg/l)	micro-mhos	
0	16.9	8.9	6.16	12856	21.5	11.6	6.91	17888	
0.25	16.5	9.2	5.85	13176	20.7	11.8	8.30	18058	
0.5	18.0	16.0	5.27	22364	18.8	21.0	7.79	29250	
0.75	18.3	24.4	5.27	33385	18.8	25.2	7.91	34774	
1.0	18.3	24.7	5.53	33795	18.8	25.8	8.36	35455	
1.25	18.3	24.8	5.97	33926	18.8	25.8	8.69	35558	
1.50	18.3	24.9	6.09	34015	18.8	25.9	8.82	35634	
1.75	18.4	24.9	6.16	34065	18.8	25.9	9.28	35664	
2.00	18.4	24.9	6.11	34086	18.8	25.9	9.35	35715	
2.25b	18.5	25.0	1.35	34259	18.8	26.0	9.05	35751	

\* “bot” indicates the estuary bottom where measurements were taken through the water column.

**Table 6. Water quality measurements in the lower Pajaro estuary (Seine Hauls 1, 3 and 5 nearshore along beach) and 1 upper estuary sites during fish sampling for tidewater goby, 5 October 2023.**

5-Oct-2023									
	Seine Haul 1 (l. estuary) air temp 22.3°C			0945 hr		Seine Haul 3 (lower estuary) air temp			1026 hr
Depth	Temp	Salin	Oxygen	Cond	Temp	Salin	Oxygen	Cond	
(m)	( C)	(ppt)	(mg/l)	micro- mhos	( C)	(ppt)	(mg/l)	Micro- mhos	
<b>0</b>	16.7	18.2	9.12	23755	17.3	18.0	8.93	24740	
<b>0.25</b>	16.8	21.3	7.77	28406	17.1	17.9	8.14	24549	
<b>0.5</b>	16.2	28.2	7.58	36256	15.9	27.8	8.53	35627	
<b>0.75</b>	15.5	30.0	8.71	37738	15.8	30.1	8.91	38155	
<b>1.0bot</b>	15.4	30.1	8.67	37866	15.8	30.1	8.82	38177	
<b>1.25</b>									
	Seine Haul 5 (lower estuary) Tidal overwash air temp			1119 hr	Seine Haul 8- Boat Launch Ramp (upper estuary nearshore) air temp 27° C (Adjacent to Wastewater Plant)			1351 hr	
Depth	Temp	Salin	Oxygen	Cond	Temp	Salin	Oxygen	Cond	
(m)	( C)	(ppt)	(mg/l)	micro- mhos	( C)	(ppt)	(mg/l)	micro- mhos	
<b>0</b>	18.8	23.4	9.93	32189	22.3	3.2	6.70	5464	
<b>0.25</b>	18.1	27.7	8.66	37308	19.0	3.1	6.78	4989	
<b>0.5</b>	17.9	29.8	8.42	39527	18.2	4.5	6.46	7038	
<b>0.75t</b>	17.6	30.2	8.40	39787	18.4	6.7	5.16	10187	
<b>1.0bot</b>	17.3	30.2	7.84	39607	19.3	18.3	7.42	25707	
<b>1.07bot</b>					19.3	29.1	7.56	29922	

\* “bot” indicates the estuary bottom where measurements were taken through the water column.

After 15 years of water quality monitoring and steelhead/tidewater goby sampling of Santa Rosa Creek Lagoon near Cambria, CA (Alley 2008), and 30+ years of the same at Soquel Creek Lagoon in Capitola, CA (Alley 2024a), the following recommendations were made to insure steelhead habitation in Central Coast lagoons. They would be difficult to attain in Pajaro Lagoon/Estuary due to the absence of/ or extremely limited summer stream inflow.

- *The 7-day rolling average water temperature within 0.25 m of the bottom should be 19°C or less.*
- *Maintain the daily maximum water temperature below 25°C (77°F).*
- *If the maximum daily water temperature should reach 26.5°C (79.5°F), it should be considered the lethal limit for steelhead.*
- *Water temperature at dawn near the bottom for at least one monitoring station should be 16.5°C (61.7°F) or less on sunny days **without** morning fog or overcast **and** 18.5°C (65.3°F) or less on days **with** morning fog or overcast.*
- *Maintain the daily dissolved oxygen concentration near the bottom at 5 milligrams/liter or greater, though it does not become critically low and potentially lethal until it is less than 2 mg/l throughout the water column for several hours, with the daily minimum occurring near dawn or soon after.*

Coastal lagoons/estuaries are very food-rich environments where steelhead growth rates are very high, despite warmer water temperatures. A study completed by **Farrel et al. (2015)** indicated that the thermal range over which a Tuolumne River *O. mykiss* population could maintain 95% of peak aerobic capacity was 17.8°C to 24.6°C. Furthermore, up to a temperature of 23°C, all individual fish could maintain a factorial aerobic scope (FAS) value >2.0 (FAS = Maximum metabolic rate (MMR) / Routine metabolic rate (RMR)), one that is predicted to provide sufficient aerobic capacity for the fish to properly digest a meal.

Tidewater gobies can physiologically tolerate the warmest, most saline, and lowest oxygen conditions that may be found in lagoon/estuary conditions, so long as some oxygen is present on the bottom. However, they typically build their nests in sand on the bottom under freshwater conditions or low salinity and minimal tidal fluctuation and current. Therefore, they need freshwater conditions, or nearly so, and oxygen along the bottom away from tidal fluctuations to reproduce. This condition may only exist at the upper end of a lagoon/estuary where freshwater inflow exists. If the sandbar closes and a freshwater lagoon develops from sufficient freshwater inflow in the summer, spawning conditions may be extensive. Artificial summer and fall sandbar breaching unassociated with stormflow, especially after freshwater conversion of the lagoon, would negatively impact tidewater gobies. Tidewater gobies are poor swimmers and require overwintering backwater habitat that is protected from river water current to avoid being flushed out of the wet-season estuary by stormflow.

Tidewater gobies could inhabit the lower and upper estuary in 2023, as water quality

measurements confirmed that oxygen was available throughout the water column. But high salinity measured at the bottom, combined with the tidal fluctuations and water current would be problematic for successful tidewater goby spawning. With the limited overwintering refuge between the levees during the previous wet winter having high stormflows, the surviving tidewater goby population may have been small in spring 2023 when nesting began. Their absence in our sampling was consistent with likely low survival over the winter. Tidewater gobies were also absent during our sampling of Soquel Lagoon and Aptos Estuary in 2023.

### **Conclusions**

No steelhead or tidewater gobies were detected in the Pajaro Estuary in fall 2023, as was the case for steelhead in the previous 11 years of annual monitoring. The sandbar was open at the time of sampling, creating a moderate to highly saline estuary except near the surface at our uppermost monitoring site, 2.9 miles upstream of Watsonville Slough. The lower estuary had ample oxygen and water temperature within the steelhead thermal tolerance range and could have supported freshwater acclimated steelhead, except it was too saline for steelhead. The same was true at the two lower sites in the upper estuary to the Thurwachter Bridge with respect to tolerable water temperature, adequate oxygen but too high salinity for steelhead. The uppermost site in the upper estuary, adjacent the wastewater plant, had salinity within the steelhead tolerance range in the upper 0.5 m layer of the water column, with adequate oxygen on the monitoring day in early October. However, water temperature in this layer was already stressful for steelhead above 22 C by 1400 hr on 5 October, indicating that steelhead habitat near the surface was marginal at best and likely disappeared from time to time at this site on warm days earlier in the summer, especially later in the afternoon/evening. For comparison, July and August are typically the warmest months in Soquel Lagoon (Alley 2024a), as well as in other smaller lagoons in San Luis Obispo County, San Simeon and Santa Rosa Creek Lagoons (Alley 2003; 2004). Water temperature declines by October. These comparisons are weak because these are smaller lagoons which have sandbars that close to the ocean every summer. However, it is reasonable to assume that with longer day lengths and warmer air temperature earlier in the summer, water temperatures will be cooler near the surface in early October in the Pajaro Estuary than earlier in the summer, even without a closed sandbar.

Water quality was adequate for tidewater gobies in 2023. But spawning conditions were likely very marginal only in the uppermost estuary and absent in the lower estuary due to high salinity at the bottom and tidal fluctuations, with strong water currents associated with an open sandbar. With the leveed channel in Pajaro Estuary, protected backwaters with tules are limited for providing overwintering cover during high stormflow events that occurred the previous winter and spring. Tidewater gobies were not detected at Soquel Lagoon or Aptos Estuary in 2023 either, presumably due to their poor overwinter survival.



## LITERATURE CITED AND PERSONAL COMMUNICATIONS

Alley, D.W. 2003. Monitoring Results for Lower San Simeon and Santa Rosa Creeks in 2000-2001; Water Quality in Lagoons, Lagoon IN-flow and Fishery Resources in Lagoons and Immediately upstream, San Luis Obispo County, CA. Prepared for the Cambria Community Services District.

Alley, D.W. 2004. Monitoring Results for Lower San Simeon and Santa Rosa Creeks in 2002-2003; Water Quality in Lagoons, Lagoon IN-flow and Fishery Resources in Lagoons and Immediately upstream, San Luis Obispo County, CA. Prepared for the Cambria Community Services District.

Alley, D.W. 2008. Santa Rosa Creek Fishery Summary, Habitat Conditions, Watershed Management Guidelines and Enhancement Goals, 2008. Prepared for the Land Conservancy of San Luis Obispo County.

Alley, D.W. 2019. 2018 SUMMARY REPORT- Juvenile Steelhead Densities in the San Lorenzo, Soquel and Aptos Watersheds, Santa Cruz County, California.

Alley, D.W. 2020. 2019 SUMMARY REPORT- Juvenile Steelhead Densities in the San Lorenzo, Soquel and Aptos Watersheds, Santa Cruz County, California.

Alley, D.W. 2021. 2020 SUMMARY REPORT- Juvenile Steelhead Densities in the San Lorenzo, Soquel and Aptos Watersheds, Santa Cruz County, California.

Alley, D.W. 2023a. Soquel Creek Lagoon Monitoring Report, 2022. Prepared by D.W. ALLEY & Associates for the City of Capitola.

Alley, D.W. 2023b. Fishery and Water Quality Monitoring of Pajaro River Estuary, 2022. Prepared by D.W. ALLEY & Associates for the County of Santa Cruz.

Alley, D.W. 2024a. Soquel Creek Lagoon Monitoring Report, 2024. Prepared by D.W. ALLEY & Associates for the City of Capitola.

Alley, D.W. 2024b. 2023 SUMMARY REPORT- Juvenile Steelhead Densities in the San Lorenzo, Soquel and Aptos Watersheds, Santa Cruz County, California.

Cech, Joseph. 1993. Personal Communication. Retired Fish Physiologist and Professor. University of California, Davis, CA.

Farrel, A.P., N.A. Fangué, C.E. Verhille, D.E. Cocherell, K.K. English. 2015. Thermal Performance of Wild Juvenile *Oncorhynchus mykiss* in the Lower Tuolumne River: A Case for Local Adjustment to High River Temperature. Prepared for Turlock Irrigation District and Modesto Irrigation District.