D.W. ALLEY & Associates aquatic biology

Fishery and Water Quality Monitoring of Pajaro River Lagoon, 2022

(Sampling for Tidewater Goby under USFWS Endangered Species Recovery Permit TE-793645-4)

Upper Pajaro Lagoon Adjacent to the Model Airport, looking downstream. (D. Alley) 6 October 2022

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 as a permit condition for emergency lagoon breaching. Fish sampling documents the presence/absence, distribution and abundance of steelhead *(Oncorhynchus mykiss*), tidewater goby (*Eucyclogobius newberryi*), and other fish and wildlife. 2022 was the eleventh year of annual sampling, which began in 2012.

Summary of 2022 Results

Tidewater gobies were captured in low numbers in all five small seine hauls in the lower lagoon along the beach berm. The sandbar was closed at the time of sampling, creating deeper conditions than occurred in years when the sandbar was open. Steelhead were not detected, as was the case in the previous 10 years of sampling. The catch in the lower lagoon 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*), mosquitofish (*Gambusia affinis*) , staghorn sculpin (*Leptocottus armatus*), threespine stickleback (*Gasterosteus aculeatus*), starry flounder (*Platichthys stellatus*) , tidewater goby, Plainfin midshipman (*Porichthys notatus*), shiner perch (*Cymatogaster aggregata*), bay pipefish **(***Syngnathus leptorhynchus*) and prickly sculpin (*Cottus asper*). Also, a bat ray (*Myliobatis californica*) was captured along the beach berm with the larger seine. Mosquitofish were nonnative and in low numbers. The lagoon was moderate to heavily saline. The lower lagoon was moderately warm and turbid, with good oxygen levels, tolerable water temperature, but was too saline to sustain steelhead, if they had been present previously. The upper lagoon was very turbid, very warm, devoid of oxygen or nearly so at between 0.5 and 0.75 meters (m) from the surface and below, making only a thin layer between 0.25 m and 0.5 m habitable to steelhead. The upper lagoon was increasingly saline with depth and beyond steelhead tolerance.

2022 Lagoon Conditions

During fish sampling in early October, a lagoon was present due to a closed sandbar. At the time of fish sampling, the lagoon was deeper than in previous years of estuary conditions of open sandbar and tidal influence. The drought years of 2015 and 2021 were the latest previous years of having a closed sandbar. The sandbar had been open earlier in 2022 and likely during the 18 September stormflow, as evidenced by moderate saline conditions at the time of fish sampling. The Santa Cruz County stage recorder indicated that the sandbar had been closed since 19 September, trapping saltwater within the lagoon. In 2022, the lower lagoon remained cooler than the upper lagoon and unstratified nearshore (17-19°C), with good oxygen levels (6- 15 mg/L from bottom to surface) and with moderate salinity (16-17 parts per thousand (ppt)) in late morning, which was supplemented by tidal overwash. These conditions were very adequate for fish life other than steelhead. Salinity there was beyond the tolerance of freshwater acclimated steelhead and would likely have eliminated them if present previously. The secchi depth in the lower lagoon ranged between 0.35 and 0.43 m (14-17 inches). The upper lagoon was inhospitable to fish life except near the surface and in shallow margins. In the early afternoon, the upper lagoon was very warm throughout the water column (21 to 25°C). It had stratified salinity increasing downward through the water column (3 to 28 ppt) and stratified oxygen decreasing downward through the water column (44+ to 0 mg/L). Under very murky conditions in the upper lagoon, light could not penetrate to the bottom in areas deeper than about 0.5 m from the surface. The secchi depth ranged between 0.22 m and 0.28 m (9-11 inches) and was greatest at the uppermost boat launch site. This led to anoxic or near anoxic conditions for fish in the lower water column without photosynthesis to produce any oxygen in the aphotic zone.

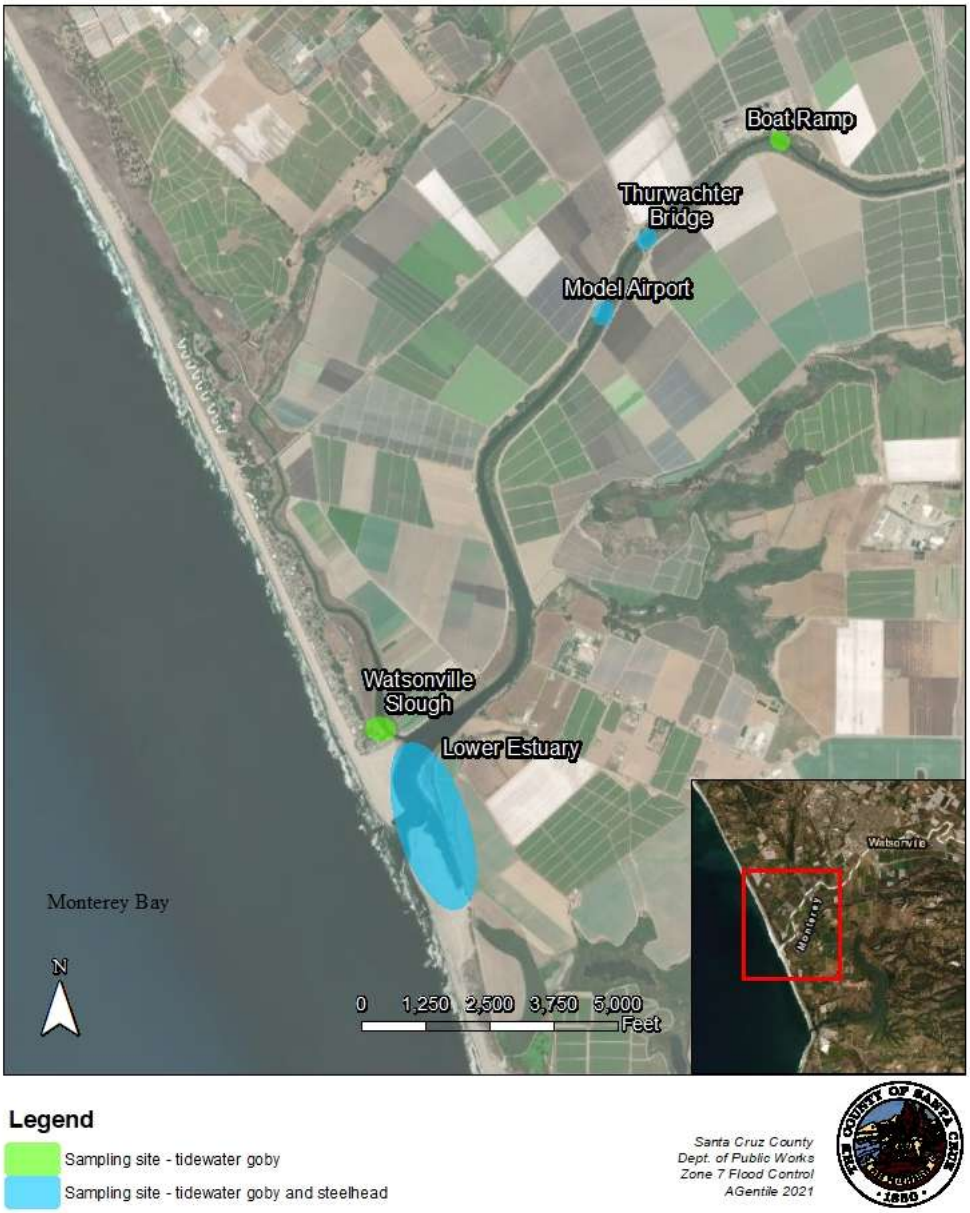
Methods

Pajaro Lagoon (closed sandbar) was sampled on October 4−6, 2022. Sampling locations were spread out in the lower lagoon along the beach berm from the mouth of Watsonville Slough to the east (**Figure 1**). The upper lagoon 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 4 October, the lower lagoon along the beach was sampled for steelhead with the 106-foot bag seine (8 successful seine hauls). On 5 October, the upper lagoon 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 mid-channel 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 disk first becomes visible as it is raised through the water column.

On 6 October, tidewater gobies were sampled for, using a 30-foot seine with 1/8-inch mesh. Five seine hauls were made in the lagoon along the beach. Three seine hauls were made in the upper lagoon (model airport, Thurwachter Bridge and boat ramp). Water quality was measured at four stations. The three lower lagoon measurements were made nearshore by wading at seining locations. The upper lagoon measurements were made nearshore by wading near the boat ramp. Water quality measurements taken on 5 and 6 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



Lower Pajaro Lagoon- Hundreds of roosting brown pelicans along the margin, looking east toward Moss Landing 6 October 2022

Lower Pajaro Lagoon- Hundreds of roosting brown pelicans in shallows and on sandy islands. 6 Oct 2022

Closed sandbar to Pajaro Lagoon, with evidence of tidal overwash. looking east along southern beachfront berm margin. (D. Alley) 6 October 2022

Plainfin Midshipmen. (D. Alley) 6 October 2022

Plainfin Midshipman. (D. Alley) 6 October 2022

Results – Fish Capture

Sampling of the lower lagoon along the beachfront with the larger bag seine yielded 11 native fish species (**Tables 1 and 2**) compared to 10 in 2021, 4 in 2019 and 2020, 7 in 2018, 4 in 2017, 33 in 2016, 1 in 2015, 3 in 2014 and 10 in 2013. Smelt were again the most abundant species, with those being identified as jack and topsmelt. Other captured species, in order of declining numbers, included arrow goby, mosquitofish, staghorn sculpin, threespine stickleback, starry flounder, tidewater goby, Plainfin midshipman, shiner perch, bay pipefish and prickly sculpin. Yellowshore crabs were very common, with Dungeness and green crabs found in low numbers. 100-300 dead clams were hauled out with each seine haul with the larger seine. But no steelhead were detected in the upper or lower lagoon in 2022, as was the case in the previous decade of sampling. Male Plainfin midshipmen produce a "hum" to attract females to their nesting sites. This loud droning hum can be heard by people nearby. Adults usually live most of the year at depths of around 400 meters in the marine environment, but move into shallow intertidal locations during spring and early summer for breeding. They have rows of photophores on their heads and down their bodies, which fluoresce in the dark depths of the ocean floor.

Sampling results with the large seine in the upper lagoon near the model airport and Thurwachter Bridge yielded only smelt and threespine stickleback in low numbers (**Table 2**).

Our tidewater goby sampling with the smaller, fine-meshed seine in the lower lagoon yielded 1-3 adult tidewater gobies on each of 5 seine hauls, totaling 7 individuals, in the lower lagoon along the beachfront. Nine native species were captured with this seine, those being tidewater goby, arrow goby, Plainfin midshipmen, jack smelt, topsmelt, staghorn sculpin, starry flounder, bay pipefish and stickleback (**Table 3**). No tidewater gobies were captured in the upper lagoon in 2022 after being detected most recently in 2020 (**Table 4**). Species captured in the upper lagoon with the smaller seine included 5 native species, those being jack smelt, top smelt, staghorn sculpin, threespine stickleback and arrow goby, all in low numbers. One mosquitofish was also captured.

Bat Ray. (D. Alley) 4 October 2022

Bat Ray. (D. Alley) 4 October 2022

Table 1. Fish capture* results from sampling lower Pajaro Lagoon *with the 106-foot bag seine (3/8-inch mesh)*, 4 October 2022.

Date	Location	Seine Haul #	Steel-head	Tide-water Goby	Arrow Goby	Three spine Stickl eback	Smelt (jack and top)	Staghorn Sculpin	Pacific Herring	Starry Flounder	Bay Pipefish	Shiner Perch	Bat Ray
4 Oct 2022	Just East of Watsonville Slough #8	8					152						
	East of #8	7					77						
	East of #7	1					240			1			
	East of #1	2					1323			1			
	East of #2	3				6	852			5			
	East of #3	4			1		201				1		1
	East of #4	5					477	1				1	
	East of #5	6					495					2	
Total		**8**	**0**	**0**	**1**	**6**	**3,817**	**1**	**0**	**7**	**1**	**3**	**1**

*806 yellowshore crabs, 4 Dungeness crabs, 1 green crab. 400+ mostly brown pelicans and a few white pelicans, cormorants. 100-300 dead clams hauled in with each seine haul.

Table 2. Fish capture* results from sampling upper Pajaro Lagoon *with the 106-foot bag seine (3/8-inch mesh)*, 5 October 2022.

Date	Location	Seine Haul	Steel-head	Tide-water Goby	Northern Anchovy	Bay pipefish	Smelt	Staghorn Sculpin	Three-spine Stickle-back	Starry Flounder	Longjaw mudsucker goby
5 Oct 2022	Model Airport	1−3					27				
	Thurwachter Bridge	4−6					36		3		
Total			**0**	**0**	**0**	**0**	**63**	**0**	**3**	**0**	**0**

Table 3. Fish capture* results from sampling the periphery of lower and upper Pajaro Lagoon *with the 30-foot seine (1/8-inch mesh)*, 6 October 2022.

Date	Location	Seine Haul	Steel-head	Tide-water Goby	Arrow Goby	Three-spine Stickle-back	Bay pipe-fish	Smelt	Mosquito Fish Gambusia	Stag-horn Sculpin	Starry Flounder	Plainfin Midshipman	Prickly Sculpin
6 Oct 2022	Approx. 100 m east of Pajaro Dunes	1		1	7		2	41	1	4			
	East of #1	2		3	4	5		105		1			
	East of #2	3		1	1	1		35		3			
	East of #3	4		1	11			34	1	2			
	East of #4	5		1	14	2	1	67		10	4	5	
	Airport- 0.3 miles down from Thurwachter Br	6			1	1		11	21	1			
	Thurwachter Bridge- 2.1 miles up from Watsonville Slough	7				2							2 adults
	Boat Ramp- 0.8 miles upstream of Thurwachter Br.	8				2			1				
Total		**8**	**0**	**7**	**38**	**13**	**3**	**293**	**24**	**21**	**4**	**5**	**2**

* 99 yellowshore crabs, 1 green crab.

Table 4. Annual Number of Tidewater Gobies Captured in Pajaro Lagoon/ 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 airport)	8
2018	0	8
2019	0	8
2020	11	8
2021	0	8
2022	7	8

Starry Flounders. (D. Alley) 4 October 2022

Shiner Perch. (D. Alley) 4 October 2022

Staghorn Sculpin. (T. Suttle) 5 October 2021

Water Quality

The Santa Cruz County stage recorder indicated that the sandbar had been closed since 19 September, trapping saltwater within the lagoon. In 2022 at the time of sampling, the lower lagoon remained cooler than the upper lagoon and thermally unstratified nearshore (17-19°C), with moderate salinity (16-17 parts per thousand (ppt)) in late morning resulting from saltwater trapped in the lagoon when the sandbar closed, combined with supplemental tidal overwash. These conditions were very adequate for saltwater-tolerant fish life other than steelhead. Salinity there was beyond the tolerance of freshwater acclimated steelhead and would likely have eliminated them if present previously. The upper lagoon in early afternoon was warm throughout the water column (21 to 25°C). It had stratified salinity increasing downward (3 to 28 ppt) and stratified oxygen decreasing downward (44+ to 0 mg/L) (**Tables 5 and 6**). Salinity-related stress to freshwater acclimatized steelhead would not occur until conductivity levels reach 12,000 to 15,000 micro-mhos, associated with sudden increases in salinity to 10−12 ppt (**J. Cech, personal communication**). However, steelhead acclimatized to lagoon 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. Steelhead might survive when salinity ranged from 10 to 28 ppt at depths of 0.75 m and deeper, with reduced salinity in the upper 0.5 m of the water column as it did in the upper Pajaro Lagoon in 2022 (**Tables 5 and 6**). Similar lagoon salinity conditions occurred in Aptos Lagoon with steelhead present in 2018−2020 (**Alley 2019; 2020; 2021**). Water temperatures above 22º C (72º 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 steelhead habitat in the upper lagoon. 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 2022**), 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 25ºC (77°F).*
- *If the maximum daily water temperature should reach 26.5ºC (79.5ºF), 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 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. Therefore, they need freshwater conditions, or nearly so, and oxygen along the bottom to reproduce. This condition may only exist at the upper end of a lagoon 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.

On 5 October, during steelhead sampling in the upper lagoon, air temperature was moderate (range of 17.1−18.5°C). Water temperature was warm throughout the water column (range of 21.3°C at the surface at noon at the model airport to 23.2°C at 0.25 m and generally cooled to 22.2°C at the bottom (**Table 5**). By 1431 hr at the Thurwachter Bridge, surface water temperature was 24.7°C and remained warm at 23.2°C at the bottom. Thus, these thermal conditions would likely have been stressful for steelhead. The Santa Cruz County stage recorder indicated that the sandbar had been closed since 19 September. Salinity was stratified with depth at both sites, increasing with depth. It was a minimum of 3.0 ppt at the surface at the model airport and a maximum of 27.9 ppt at the bottom there. At the Thurwachter Bridge, salinity went from 10.5 ppt at the surface to 24.4 ppt at the bottom. These saline conditions probably would not be stressful to acclimated steelhead because of lower salinity water available nearer the surface but could be at depth. Oxygen levels were well above 5 mg/l and supersaturated in a thin surface layer that was between 0.25 and 0.5 meters in thickness, where steelhead could inhabit. However, oxygen was less than 1.5 mg/ L at 0.5 meters from the surface and below that, even at midday after several hours of photosynthesis. Therefore, in the upper lagoon, the water column below 0.50 m depth from the surface was uninhabitable for steelhead and even for tidewater goby along the bottom below 0.75 m depth from the surface. Algae and other aquatic vegetation do not photosynthesize at night to produce oxygen. At night they only respire like other living things, consuming oxygen and producing carbon dioxide. After a night of plant respiration, oxygen levels are lowest near dawn and normally begin to increase as sunlight penetrates the

water column and aquatic vegetation begins to photosynthesize and produce oxygen. However, the secchi depth in the upper lagoon ranged between 0.22 and 0.28 m (9-11 inches) and was 0.28 m at the uppermost boat launch site, making the lower water column dark and aphotic. Without photosynthesis in this dark zone, oxygen was not detected at 1.25 m from the surface and below. To avoid bird predation, fish seek lower portions of the water column, which were devoid of oxygen in the upper lagoon in 2022, as they had been in 2021.

Water quality measurements nearshore in the upper lagoon indicated that water temperature was only slightly stratified but salinity was stratified at the model airport, Thurwachter Bridge and the boat ramp (**Tables 5 and 6**). Water temperature was warm and stressful at all three sites and most stressful at the boat ramp at near 25°C and higher. Oxygen was stratified at all three upper lagoon sites, with oxygen nearly absent (0.26 mg/L at 0.75 m at the airport) and absent at 1.25 m from the surface and below at the airport and Thurwachter Bridge. Near the bottom at the boat ramp, oxygen was higher than downstream but only 3.4 mg/L at 0.5 m from the surface and less than 0.5 mg/L at the bottom. Salinity at the boat ramp was stratified (4.7 ppt at surface to 13.9 ppt at the bottom) and within the steelhead tolerance range near the surface. Thus, conditions near the bottom at the boat ramp were likely uninhabitable for steelhead (high water temperature and little oxygen) and tidewater goby (little oxygen). In conclusion steelhead could inhabit the upper 0.5 m with regard to oxygen and salinity. However, the entire water column would be too warm for steelhead to tolerate on warmer days. In addition, steelhead near the surface would be vulnerable to predation in the vicinity of the boat ramp and would prefer to be near the bottom in deeper water offshore if oxygen was available there, which it was not.

On 6 October during tidewater goby sampling in Pajaro Lagoon, no stratification was found for water temperature or salinity in the lower lagoon in the morning (cool air temperatures; 14.4°C at 1001 hr; 20.2°C at 1207 hr) (**Table 6**). In the lower lagoon, salinity was uniformly moderate without stratification (16-17 ppt). This was likely too saline for over-summering steelhead. In the lower lagoon, water temperature was moderately warm (17.6°C−18.5°C) with slight cooling with depth below 0.75 m at one sampling location and well within the steelhead tolerance range. Oxygen levels in the lower lagoon between 1000 and 1200 hr were very good and adequate for steelhead and tidewater goby (above 8 mg/L from near the bottom to the surface) and were only slightly reduced with depth at the western most and eastern most sites in the lower lagoon. The central site was stratified for oxygen with depth, with 15 mg/L at the surface and 6.2 mg/L at the bottom by 1100 hr. The secchi depth in the lower lagoon ranged 0.35m−0.43 m (14-17 inches). So, although oxygen levels and water temperature were sufficient for steelhead and tidewater gobies to inhabit the lower lagoon, salinity was too high for steelhead to inhabit the lower lagoon. Tidewater gobies could inhabit the lower lagoon, as sampling confirmed, but salinity would be problematic for successful tidewater goby spawning.

Table 5. Water quality measurements in the upper Pajaro lagoon during fish sampling for steelhead, 5 October 2022.

			5-Oct-2022					
	Model Airport (mid-channel) Air temp. 18.5°C			1159 hr	**Thurwachter Bridge** (mid-channel) Air temp. 17.1°C			1431 hr
Depth	**Temp**	**Salin**	**Oxygen**	**Cond**	**Temp**	**Salin**	**Oxygen**	**Cond**
(m)	**(C)**	**(ppt)**	**(mg/l)**	**micro-mhos**	**(C)**	**(ppt)**	**(mg/l)**	**micro-mhos**
0	21.3	3.0	44+	5498	24.7	10.5	31.74	17670
0.25	22.2	7.6	12.33	13713	24.6	11.0	26.51	18423
0.5	22.2	14.4	1.42	22454	23.3	14.5	0.48	23247
0.75	22.3	17.7	0.26	27153	22.9	16.7	1.15	26072
1.0	22.4	19.4	0.21	29744	23.0	18.7	0.10	28196
1.25bot	22.7	24.6	0	36959	23.2	24.4	0	37222
1.50	22.5	26.7	0	39607				
1.75	22.4	27.7	0	40800				
2.00bot	22.2	27.9	0	40993				

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

Table 6. Water quality measurements in the lower Pajaro lagoon (Seine Hauls 1, 3 and 5 nearshore along beach) and 1 upper lagoon sites during fish sampling for tidewater goby, 6 October 2022.

			6-Oct-2022					
	Seine Haul 1 (l. lagoon) air temp 14.5°C		1001 hr		**Seine Haul 3 (lower lagoon)** air temp 16.0°C			1058 hr
Depth	**Temp**	**Salin**	**Oxygen**	**Cond**	**Temp**	**Salin**	**Oxygen**	**Cond**
(m)	**(C)**	**(ppt)**	**(mg/l)**	**micro-mhos**	**(C)**	**(ppt)**	**(mg/l)**	**Micro-mhos**
0	18.3	16.2	12.73	23032	18.8	16.5	15.06	23645
0.25	18.3	16.3	11.82	23095	18.8	16.5	14.14	23611
0.5	18.3	16.3	11.72	23113	18.4	16.6	11.27	23529
0.75	18.3	16.3	11.59	23128	17.7	16.6	8.05	23185
1.0bot	18.3	16.3	11.36	23178	17.6	16.6	6.21	23129
1.25								
	Seine Haul 5 (lower lagoon) air temp 20.2°C			1207hr	**Seine Haul 8- Boat Launch Ramp (upper lagoon nearshore) (Adjacent Wastewater Plant)**			1448 hr
Depth	**Temp**	**Salin**	**Oxygen**	**Cond**	**Temp**	**Salin**	**Oxygen**	**Cond**
(m)	**(C)**	**(ppt)**	**(mg/l)**	**micro-mhos**	**(C)**	**(ppt)**	**(mg/l)**	**micro-mhos**
0	18.5	16.7	16.57	23837	24.9	4.7	42+	8278
0.25	18.4	16.6	16.53	23613	25.4	8.3	42+	14420
0.5	18.4	16.6	15.91	23607	25.0	10.2	3.40	17694
0.58bot	18.3	16.7	16.0	23612				
0.75bot					24.9	13.9	0.42	22933
1.0								

* "bot" indicates the lagoon bottom where measurements were taken through the water column.

Conclusions

No steelhead were detected in the Pajaro Lagoon in fall 2022. The sandbar was closed at the time of sampling (closed September 19), creating uniformly deeper conditions than occurred in years when the sandbar was open. Insufficient freshwater inflow after sandbar closure had prevented the lagoon from converting to freshwater, leaving somewhat turbid, moderately warm and saline conditions nearshore in the lower lagoon. Saltwater was trapped in the lagoon when the sandbar closed, and more was added with tidal overwash of the sandbar. There was insufficient freshwater inflow to flush out the saltwater and convert the lagoon to freshwater. The lower lagoon had ample oxygen and water within the steelhead thermal tolerance range and could have supported freshwater acclimated steelhead except it was too saline for steelhead. Under murkier conditions, the upper lagoon had an aphotic, anoxic zone below 0.75 m from the surface in deeper areas and where salinity and oxygen were stratified. Water temperatures were very warm throughout the water column in the upper lagoon and likely eliminated any possible steelhead habitat near the surface where oxygen was sufficient. The lower water column was hot, saline and devoid of oxygen. With steelhead seeking deeper water to avoid bird predation and experiencing stress above water temperatures of 22°C in lagoons, the upper lagoon was uninhabitable for steelhead at near 25°C throughout the water column on warm, sunny days and uninhabitable for other fish species at depths greater than 0.75 m from the surface.

Adult tidewater gobies were captured in low numbers in all five small seine hauls in the lower lagoon along the beach berm. Mild wet seasons with limited stormflows like occurred in the 2021-2022 winter/spring period allow better overwinter survival of tidewater gobies than in wetter years. With a leveed channel, protected backwaters with tules are limited for providing overwintering cover for tidewater goby during high stormflow events. The mild winter/spring was associated with relative high abundance of tidewater gobies in Aptos and Soquel Lagoons in 2018 and 2020 and moderate abundance in 2022 (**Alley 2019; 2021; 2023**). However, this was not the case in Pajaro Lagoon in 2022, when they were detected in low numbers. With tidewater goby being a bottom dweller, the upper Pajaro Lagoon provided no spawning habitat at sampling sites for tidewater goby due to anoxic conditions. The lower lagoon may have provided marginal tidewater goby spawning conditions with moderate salinity and adequate oxygen nearshore. However, tidewater gobies prefer to nest along the margins under freshwater conditions, which were absent at Pajaro Lagoon sampling sites in 2022. Freshwater along the lagoon bottom may have existed in spring when sufficient freshwater inflow may have entered at the most upstream extent of the lagoon. However, the Pajaro River typically goes dry upstream of the lagoon in all but the wettest years.

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

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