D.W. ALLEY & Associates aquatic biology

Fishery and Water Quality Monitoring of Pajaro River Lagoon/Estuary in 2019

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

Bay pipefish (*Syngnathus leptorhynchus*)

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 lagoon breaching. The fish sampling documents the presence/absence, distribution and abundance of steelhead *(Oncorhynchus mykiss*), tidewater goby (*Eucyclogobius newberryi*), and other fish and wildlife. 2019 was the eighth year of annual sampling, which began in 2012.

Summary of 2019 Results

No steelhead or tidewater goby were captured in Pajaro River Estuary in fall 2019. The catch was dominated by jack smelt (*Atherinopsis californiensis*) and various species of crabs. Other captured fish species included threespine stickleback (*Gasterosteus aculeatus*), arrow goby (*Clevelandia ios*), staghorn sculpin (*Leptocottus armatus*), Bay pipefish (*Syngnathus leptorhynchus*), Pacific herring (*Clupea pallasii*), northern (California) anchovy (*Engraulis mordax*), starry flounder (*Platichthys stellatus*) and mosquito fish (*Gambusia affinis*).

2019 Estuary Conditions

An estuary was present with an open sandbar during fish sampling in late September/ early October. Tidal influence occurred daily during the sampling period.

Methods

Pajaro Estuary (open sandbar) was sampled on September 30 and October 1−2, 2019. Sampling locations included the beach area and sites 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) (**Figure 1**).

On 30 September, the main estuary along the beach was sampled for steelhead with the 106-foot bag seine (8 successful seine hauls). On 2 October, tidewater goby was sampled for, using a 30-foot seine with 1/8-inch mesh. Five seine hauls were made in the estuary along the beach, and 3 were made in the upper estuary (model airport, Thurwachter Bridge and boat ramp).

On 1 October, two upper estuary were sampled for steelhead with the 106-foot seine (3/8-inch mesh), 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 the 2 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). 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.

On 2 October during tidewater goby sampling in the lower and upper estuary, water quality was measured at 4 stations. The 3 lower estuary measurements were made nearshore by wading, and the 1 upper estuary measurement was also made mid-channel by wading adjacent to the boat ramp. Secchi depth was not measured, with visibility to the bottom. Water quality measurements taken on 1 and 2 October were sufficient to determine general water quality conditions at the time of fish sampling.

Pajaro Estuary beachfront looking west at lunch time toward Pajaro Dunes Development. 30 September 2019

Pajaro Estuary looking southeast, viewing outlet channel bending south (to the right), with the estuary extending further to the east (on left). (Tyler Suttle photo.) 30 September 2019

Results – Fish Capture

Sampling of the lower estuary along the beachfront with the larger bag seine yielded 4 native fish species (**Table 1**) compared to 7 in 2018, 4 in 2017, 3 in 2016, 1 in 2015, 3 in 2014 and 10 in 2013. Smelt were again the most abundant species with all being identified as jack smelt. Other species, in declining abundance, included Bay pipefish, staghorn sculpin, and one starry flounder. No steelhead or tidewater goby were captured. One harbor seal was present in the lower estuary during sampling.

Results of sampling for steelhead in the upper estuary near the model airport and Thurwachter Bridge with the large seine yielded 6 native fish species, including jack smelt (mostly small YOY), northern anchovy, threespine stickleback, staghorn sculpin, Bay pipefish, Pacific Herring and starry flounder (**Table 2**). No steelhead or tidewater goby were captured. Fish species diversity was greater than when the sandbar was closed during drought. It was unusual to detect greater species diversity in the upper estuary than the lower estuary.

Our tidewater goby sampling with the finer mesh seine in the lower estuary yielded no tidewater gobies along the beachfront where 4 native species were captured, those consisting of arrow goby, staghorn sculpin, bay pipefish and starry flounder (**Table 3**). In 2019 and unlike 2018, no large sea hare slugs were observed mating nearshore in the lower estuary, though their eggs were observed on aquatic vegetation in 2019. In the upper estuary, no tidewater goby were captured. Other species captured in the upper estuary included 4 native species, those being arrow goby, young-of-the-year (YOY) smelt, staghorn sculpin and threespine stickleback, along with nonnative mosquitofish. In 2019 as in 2018, threespine stickleback was captured only in the upper estuary. No tidewater gobies have been captured in Pajaro Lagoon/ Estuary since 2017 (**Table 4**).

Crabs were present in seine hauls in the lower and upper estuary in 2019 (**Tables 1−3**). Only yellow shore crabs were found. Shrimp and snails were also captured with the goby seine. Submerged aquatic vegetation was very scarce in the lower estuary, as had been the case in 2015−2018. The lower estuary was deeper than other recent years, with a thalweg near the beachfront berm. The estuary emptied into the Bay closer to Watsonville Slough than previous years, with the estuary extending further east beyond the outlet channel. In most years, the estuary exited to the Bay at the eastern end.

Bay pipefish- two color phases in Pajaro Estuary. (Tyler Suttle photo.) 30 September 2019

Starry flounder (*Platichthys stellatus*) in Pajaro Estuary. (Tyler Suttle photo.) 30 Sep 2019.

Green-eyed staghorn sculpin (*Leptocottus armatus*) in Pajaro Estuary. (Tyler Suttle photo.) 30 September 2019.

Table 1. Fish capture* results from sampling lower Pajaro estuary *with the 106-foot bag seine (3/8-inch mesh)*, 30 September 2019.

Date	Location	Seine Haul	Steel-head	Tide-water Goby	Arrow goby	Bay pipefish	Jack smelt	Staghorn Sculpin	Pacific Herring	Starry Flounder	Threespine stickleback
30 Sep 2019	East of Watsonville Slough	1				2	8	1		1	
	East of #1	2				2	51				
	East of #2	3					2				
	East of #3	4					46				
	East of #4	5				2	78				
	East of #5	6				1	23	1			
	East of #6	7				1	28				
	East of #7	8					32	1			
Total			**0**	**0**	**0**	**8**	**268**	**3**	**0**	**1**	**0**

*19 yellow shore crabs

Table 2. Fish capture* results from sampling upper Pajaro estuary *with the 106-foot bag seine (3/8-inch mesh)*, 1 October 2019.

Date	Location	Seine Hauls	Steel head	Tide-water Goby	Northern Anchovy	Bay pipefish	Jack smelt	Staghorn Sculpin	Three-spine Stickle-back	Starry Flounder
1 Oct 2019	Model Airport	1−3			86	2	475	2	6	1
	Thurwachter Bridge	4−6			20		205			
Total			**0**	**0**	**106**	**1**	**680**	**2**	**6**	**1**

* 47 yellow shore crabs

Table 3. Fish capture* results from sampling the periphery of lower Pajaro estuary, and upper Pajaro Estuary *with the 30-foot seine (1/8-inch mesh)*, 2 October 2019.

Date	Location	Seine Haul	Steel-head	Tide-water Goby	Arrow goby	Three-spine Stickle-back	Bay pipe-fish	Smelt	Mosquito fish	Staghorn Sculpin	Starry Flounder
2 Oct 2019	Approx. 100 m east of Pajaro Dunes	1			11					1	3
	East of #1	2			1		2				
	East of #2	3			1		2				
	East of #3	4			2						
	East of #4	5			3		1				
	Airport- 0.3 miles down from Thurwachter Br	6			1	1		150+ YOY	30+		
	Thurwachter Br.- 2.1 miles up from Watsonville Slough	7			12	1					
	Boat Ramp- 0.8 miles upstream of Thurwachter Br.	8				1		30+ YOY	100+		
Total			**0**	**0**	**31**	**3**	**5**	**180+**	**130+**	**1**	**3**

* 6 yellow shore crabs, one nudibranch, 5 shrimp 190 snails captured. Sea hare slug eggs on aquatic vegetation.

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

Water Quality

Stress to freshwater acclimatized steelhead would probably not occur until conductivity levels reach 12,000 to 15,000 micro-mhos, associated with sudden increases in salinity to 10 − 12 parts per thousand (ppt) (**J. Cech, personal communication**). However, steelhead acclimatized to estuary conditions with fluctuating salinity and associated stratification can survive where salinity increases with depth and may range from 8 to 20 ppt at depths of 0.75 m and deeper, with salinity in the upper 0.5 m less than 1 ppt. These were estuary conditions in Aptos estuary in 2018 with steelhead present (**Alley 2019**). Similar conditions existed in Aptos Lagoon in 2019 with steelhead present (**Alley 2020a**). Water temperatures above 22º C (72º F) and oxygen levels below 5 parts per million (mg/L) are thought to stress steelhead. After 15 years of water quality monitoring and steelhead/tidewater goby sampling of Santa Rosa Creek Lagoon near Cambria and 29 years at Soquel Creek Lagoon in Capitola, the following were recommendations to insure steelhead habitation. These recommendations would be difficult to attain at Pajaro Lagoon because of the absence of or extremely limited 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.*
- *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 build their nests in sand on the bottom under freshwater conditions without salinity. Therefore, they need freshwater conditions along the bottom to reproduce. This condition may only exist at the upper end of an estuary where freshwater inflow exists. If the sandbar closes and a freshwater lagoon develops, spawning conditions may be extensive. Artificial summer and fall sandbar breaching unassociated with stormflow, especially after freshwater conversion of the lagoon, may be considered a negative impact to tidewater gobies. Tidewater gobies are poor swimmers and require overwintering backwater habitat protected from water velocity to avoid being flushed out of the wet-season estuary during stormflow.

On 1 October, during steelhead sampling in the upper estuary, air and water temperature was cool in late morning and early afternoon (range of 17.2−18.2°C through the water column) and would not likely have been very stressful for steelhead at the airport and Thurwachter Bridge by early afternoon, with water temperature fairly uniform through the water column with strong tidal action (**Table 5**). Salinity was high and increased slightly with depth at the airport and was consistently high throughout the water column at Thurwachter Bridge. These saline conditions may have been stressful to acclimated steelhead because of the absence of low salinity water near the surface. Oxygen was similarly low through the water column at the airport and Thurwachter Bridge and slightly lower near the bottom. Oxygen levels below 5 mg/l throughout the water column at the model airport were likely slightly stressful for steelhead and were probably lower earlier in the morning, as they probably were elsewhere in the upper estuary. At Thurwachter Bridge in early afternoon, oxygen was in the 5−6 mg/l range at slackwater conditions before the tidal action reversed toward the bay. These oxygen levels were not likely stressful for steelhead. However, oxygen concentration was undoubtedly below 5 mg/l at dawn, which would have been somewhat stressful. 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 begin to increase as sunlight penetrates the water column and plants begin to photosynthesize.

On 2 October during tidewater goby sampling in the lower and upper estuary, no stratification was found for water temperature or salinity in the lower estuary in the morning with cool air temperature (**Table 6**). Water temperature was uniformly cool; salinity was uniformly high. Oxygen decreased with depth to stressful levels nearest Watsonville Slough. Oxygen supply was good and above 7 mg/l at the other sites in the lower estuary by 1030 hr. At the boat ramp, 2.9 miles upstream of Watsonville Slough in afternoon, water temperature and salinity were not stratified with water temperature good and below 20°C. Salinity was uniformly high. Oxygen declined slightly with depth but would be well within the steelhead tolerance range except at the bottom where it was nearly absent. Conditions created cool and sufficiently oxygenated water quality for steelhead in late morning and early afternoon. However, the high salinity throughout the water column would likely been stressful in early afternoon, and somewhat stressful though not exclusionary oxygen levels below 5 mg/l were likely at dawn. Water temperature would have warmed later in the day. However, the strong tidal action in 2019 would have kept conditions well within the steelhead temperature tolerance range.

Table 5. Water quality measurements in the upper Pajaro estuary during steelhead sampling, 1 October 2019.

			1-Oct-19					
	Model Airport (mid-channel) Air temp. 16.0°C			1124 hr	**Thurwachter Bridge** (mid-channel) Air temp. 16.0°C			1357 hr
Depth	**Temp**	**Salin**	**Oxygen (%sat.)**	**Cond**	**Temp**	**Salin**	**Oxygen (%sat.)**	**Cond**
(m)	**(C)**	**(ppt)**	**(mg/l)**	**micro-mhos**	**(C)**	**(ppt)**	**(mg/l)**	**micro-mhos**
0	17.2	22.1	4.84	29778	18.2	26.4	6.01	35765
0.25	17.4	23.0	3.88	31062	18.2	26.4	5.14	35770
0.5	17.8	22.8	3.51	30840	18.2	26.3	5.20	35677
0.75	17.9	23.3	3.15	34165	18.2	26.3	5.34	35712
1.0	18.0	25.6	3.23	34570	18.2	26.4	5.22	35753
1.25bot	18.0	25.9	3.14	34991	18.2	26.4	5.37	35755
1.5					18.2	26.3	5.28	35726
1.75bot*					18.2	26.4	5.03	35728

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

Table 6. Water quality measurements in the lower Pajaro estuary (Stations 1, 3 and 4 nearshore) and one upper estuary site during tidewater goby sampling, 2 October 2019.

			2-Oct-19					
	Station 1 (lower estuary) air temp14.8°C		1000 hr		**Station 3 (lower estuary)**			1035 hr
Depth	**Temp**	**Salin**	**Oxygen**	**Cond**	**Temp**	**Salin**	**Oxygen**	**Cond**
(m)	**(C)**	**(ppt)**	**(mg/l)**	**micro-mhos**	**(C)**	**(ppt)**	**(mg/l)**	**Micro-mhos**
0	15.6	26.2	6.42	33546	15.9	27.3	7.43	35117
0.25	15.6	26.2	5.38	33538	16.1	27.2	6.01	35002
0.5	15.0	26.7	2.59	33660	16.0	28.6	7.06	36568
0.75	15.5	29.3	3.54	37092	16.0	29.1	7.56	37186
0.87bot					16.0	29.1	7.55	37284
1.0								
1.25								
	Station 4 (lower estuary) air temp. 17.0°C			1111 hr	**Boat Launch Ramp (mid channel upper estuary) (Adjacent Wastewater Plant)**			1403 hr air 19.8°C
Depth	**Temp**	**Salin**	**Oxygen**	**Cond**	**Temp**	**Salin**	**Oxygen**	**Cond**
(m)	**(C)**	**(ppt)**	**(mg/l)**	**micro-mhos**	**(C)**	**(ppt)**	**(mg/l)**	**micro-mhos**
0	16.6	29.6	9.68	38276	19.4	23.2	8.01	32724
0.25	16.6	29.6	8.14	38247	19.4	23.2	7.02	32637
0.5	16.6	29.6	8.13	38351	19.4	23.3	7.02	32752
0.75	16.6	29.8	8.15	38458	19.4	23.4	6.98	32948
0.85bot	16.6	29.8	8.09	38482				
1.0					19.4	23.4	6.89	32985
1.18bot					19.5	23.3	0.11	32888

Conclusions

No steelhead or tidewater gobies were detected in the Pajaro Estuary in 2019. With its daily tidal fluctuation, the estuary was less favorable to juvenile steelhead for rearing and tidewater goby for spawning than a deeper freshwater lagoon would be. A lagoon with a closed sandbar that had converted to freshwater would not have daily depth fluctuation or highly saline conditions detected in the 2019 estuary, with indications that oxygen levels at dawn may be stressfully low for steelhead. A freshwater lagoon would cool down each night and have the same cool water temperature and high oxygen concentration throughout the water column at dawn, as was found

in the Soquel Lagoon (**Alley 2020b**). Water temperature would remain cool at depth through the day, with oxygen increasing steadily as aquatic vegetation photosynthesized. The 2019 Pajaro estuary was highly saline during sampling, with temporal oxygen fluctuations. Though oxygen concentrations were not prohibitively low for steelhead by late morning during sampling, they may have been stressfully low near the bottom at dawn. Low oxygen would force steelhead nearer the surface in search of higher oxygen levels, where they would be more vulnerable to predation. It appeared from our limited water quality measurements that water temperature was within the steelhead tolerance range on the relatively cool air temperature days of fish sampling. Typically in lagoons without tidal influence, air and water temperatures are higher in July and August than late September and early October when sampling occurred. The cooling effect of tidal influxes maintained water temperatures below 20 °C midday at the model airport and upstream at the boat ramp on relatively cool air temperature days in 2019. While water quality data were not collected throughout the summer and during periods of sandbar closure that may have occurred in 2019, habitat conditions for steelhead could have become difficult if the sandbar closed temporarily to form a lagoon with little stream inflow. After sandbar closure, trapped saltwater would create a stratified water column with higher water temperatures throughout and lower oxygen levels at increasing depth. Much of the Pajaro Estuary was 1.5 meters deep or less at water quality stations, with a narrow thalweg present nearby that was somewhat deeper. A shallow lagoon would heat up quickly with salinity stratification that would ensue after the sandbar closed and stream inflow was absent or nearly so.

The absence of tidewater goby in fall 2019 sampling indicated that a small population still existed, at best, in Pajaro Estuary. Our sampling was too limited to establish that tidewater goby were absent. Steep banks and overhanging vegetation in the leveed estuary upstream of Watsonville Slough makes accessibility for sampling very limited. So, small pockets of tidewater goby may still have been present. This species again appeared absent in the lower estuary along the beach where sampling access was good, as was the case in 2015−2018. Algae and submerged vegetation were largely absent in the lower estuary for the past 5 years. After a high flow winter of 2016−2017, only 1 tidewater goby was captured at the airport site, with none detected at Thurwachter Bridge or the boat ramp where they were abundant in earlier, drier years. Some tidewater gobies may have been flushed from the estuary during high stormflows during that winter, leaving a small population during the 2017 dry season. The 2018-2019 winter also had above median stormflows, which likely made it difficult for gobies to find overwintering refuge. With a leveed channel, protected backwaters with tules are limited for overwintering cover for tidewater goby during high stormflow events. Water quality was adequate for tidewater goby survival during the dry season of 2019, even though oxygen may have been low at times in some locations. This species spawns along freshwater margins, which were absent at sampling sites in the 2017−2019 estuaries. Freshwater habitat may have existed at the most upstream extent of the estuary where the River entered the estuary during the dry season if it was flowing.

Figure 1. Pajaro Lagoon Fish and Water Quality Sampling Sites

Literature Cited

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