D.W. ALLEY & Associates aquatic biology

Fishery and Water Quality Monitoring of Pajaro River Lagoon in 2018

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

Dwarf Surperch (*Micrometrus minimus*) captured in Pajaro Lagoon/Estuary
2 October 2018

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. 2018 was the seventh year of annual sampling, which began in 2012.

Summary of 2018 Results

No steelhead or tidewater goby were captured in Pajaro River Estuary in fall 2018. 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*), Cabezon sculpin (*Scorpaenichthys marmoratus*), Dwarf surfperch (*Micrometrus minimus*) and nonnative yellowfin goby (*Acanthogobius flavimanus*).

2018 Estuary Conditions

An estuary was present with an open sandbar during fish sampling in early October. There was daily tidal influence during the sampling period.

Methods

Pajaro Estuary (open sandbar) was sampled on October 1−3, 2018. Sampling locations included the beach area, 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 (2.9 miles upstream of Watsonville Slough) (**Figure 1**).

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, the main estuary along the beach was sampled for steelhead with the 106-foot bag seine (8 successful seine hauls). On 3 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 3 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 mid-channel by wading, and the 1 upper estuary measurement was also made mid-channel by wading. Secchi depth was not measured, with visibility to the bottom. Water quality measurements taken on 1 and 3 October were sufficient to determine general water quality conditions at the time of fish sampling.

Results – Fish Capture

Results of sampling of the upper estuary near the model airport and Thurwachter Bridge with the large seine yielded only jack smelt (**Table 1**).

Sampling of the lower estuary along the beachfront with the larger bag seine yielded 7 native fish species compared to 4 in 2017, 3 in 2016, 1 in 2015, 3 in 2014 and 10 in 2013 (**Table 2**). Smelt were again the most abundant species with all being identified as jack smelt. Other species in declining abundance included arrow goby, staghorn sculpin, Bay pipefish and one each of Pacific herring, Cabezon sculpin and Dwarf surfperch. One nonnative yellowfin goby was captured in the upper estuary adjacent the model airport. No steelhead or tidewater goby were captured. Fish species diversity was greater than when the sandbar was closed during drought. One harbor seal was present in the lower estuary during sampling. Crabs were common in seine hauls in the lower estuary along the beach berm (**Table 2**). They included Dungeness, yellow shore, red rock and kelp crabs. Shrimp were also captured. Submerged aquatic vegetation was very scarce, as had been the case in 2015−2017. The main estuary was very shallow and mostly wadeable except for a narrow thalweg and near the Watsonville Slough confluence.

Our tidewater goby sampling with the finer meshed seine in the lower and upper estuary yielded no tidewater gobies in the lower estuary along the beachfront where arrow goby, jack smelt, staghorn sculpin, bay pipefish and the 4 species of crabs previously mentioned were captured (**Table 3**). Staghorn sculpin was captured mostly in the lower estuary unlike previous years. Large sea hare slugs were observed mating nearshore for the first time in the lower estuary during the tidewater goby sampling effort. In the upper estuary, no tidewater goby were captured. Other species captured in the upper estuary with the fine-meshed seine included arrow goby, young-of-the-year (YOY) smelt, staghorn sculpin, Bay pipefish and threespine stickleback. Threespine stickleback was captured only in the upper estuary and only with the fine-meshed goby seine in 2018. A record of tidewater goby captures since 2012 may be found in **Table 4.**

Cabezon Sculpin captured in Pajaro Lagoon/Estuary, 2 October 2018

Table 1. Fish capture* results from sampling upper Pajaro estuary *with the 106-foot bag seine (3/8-inch mesh)*, 1 October 2018.

Date	Location	Seine Hauls	Steel-head	Tide-water Goby	Arrow Goby	Bay pipefish	Jack smelt	Staghorn Sculpin	Three-spine Stickle-back	Starry Flounder
1 Oct 2018	Model Airport	1−3				1	616			
	Thurwachter Bridge	4−6					164			
Total			**0**	**0**	**0**	**1**	**780**	**0**	**0**	**0**

Table 2. Fish capture* results from sampling lower Pajaro estuary *with the 106-foot bag seine (3/8-inch mesh)*, 2 October 2018.

Date	Location	Seine Haul	Steel-head	Tide-water Goby	Arrow goby	Bay pipefish	Jack smelt	Staghorn Sculpin	Pacific Herring	Dwarf Surfperch	Cabezon sculpin
2 Oct 2018	East of Watsonville Slough	1			1	3	336	3			
	East of #1	2				2	74	1			
	East of #2	3			2	3	352	3			
	East of #3	4			1		244		1		
	East of #4	5			1	3	143	1		1	
	East of #5	6			1	1	141	2			
	East of #6	7			27	2	302	8			1
	East of #7	8					226				
Total			**0**	**0**	**33**	**14**	**1818**	**18**	**1**	**1**	**1**

*44 Dungeness crabs, 37 yellow shore crabs, 18 red rock crabs, 7 kelp crabs, 16 shrimp.

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)*, 3 October 2018.

Date	Location	Seine Haul	Steel-head	Tide-water Goby	Arrow goby	Yellow fin goby	Bay pipe-fish	Smelt (jack and top)	Staghorn Sculpin	Three-spine stickle-back
3 Oct 2018	Approx. 200 m east of Pajaro Dunes	1			1				4	
	East of #1	2			10				4	
	East of #2	3			2		2	13	1	
	East of #3	4			2		1	126 YOY	1	
	East of #4	5			31		1		35	
	Airport- 0.3 miles down from Thurwachter Br	6				1	1			400+
	Thurwachter Br.- 2.1 miles up from Watsonville Slough	7			2		5		4	3
	Boat Ramp- 0.8 miles upstream of Thurwachter Br.	8			5			11 YOY		2
Total			**0**	**0**	**53**	**1**	**10**	**150**	**49**	**405+**

* Crabs− 18 yellow shore, 17 red rock, 10 kelp, 4 Dungeness were captured. Three nudibranch captured. 15−20 large sea hare slugs observed mating.

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 meshed seine adjacent model airport)	8
2018	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 2019a**). 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 28 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 may be lethal and 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, water temperature was warm but would not have been very stressful for steelhead at the airport and Thurwachter Bridge by early afternoon (range of 19.7−20.9°C through the water column), with water temperature fairly uniform through the water column with strong tidal action (**Table 5**). Salinity increased with depth somewhat with saline conditions throughout the water column and would not likely have been stressful to acclimated steelhead. Oxygen was similar through the water column and slightly higher near the bottom. Oxygen levels below 5 mg/l in the upper 0.75 meters of 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. 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 3 October during tidewater goby sampling in the lower and upper estuary, no stratification was found for water temperature, salinity or oxygen in the lower estuary in the morning (**Table 6**). Water temperature was uniformly cool; salinity was uniformly high; and oxygen levels were very good at above 8.5 mg/l throughout the water column as late as noon. At the boat ramp, 2.9 miles upstream of Watsonville Slough in afternoon, water temperature and salinity had become stratified with temperature and salinity increasing somewhat with depth. Conditions created warm and what would be stressful conditions for steelhead by 1440 hr that may have worsened

later in the day because the upper estuary would be less affected by cooler ocean water entering during tidal action. However, oxygen levels remained above 5 mg/l through the water column and would be tolerable to steelhead, had they been present. Here again, oxygen levels may have been lower earlier in the day before aquatic plants began producing oxygen at higher levels.

Table 5. Water quality measurements in the upper Pajaro estuary during steelhead sampling, 1 October 2018.

			1-Oct-18					
	Model Airport (mid-channel) Air temp. 23.2 C			1134 hr	**Thurwachter Bridge** (mid-channel) Air temp. 20.2 C			1402 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	20.4	18.4	4.64	26771	20.7	22.5	5.70	32746
0.25	19.7	18.5	4.02	26165	20.7	22.6	5.01	32851
0.5	20.3	22.8	4.45	32773	20.7	23.2	5.21	33543
0.75	20.5	24.4	4.66	35020	20.8	23.7	5.54	34312
1.0	20.6	24.7	5.22	35450	20.8	24.6	5.77	35526
1.25bot	20.6	24.7	5.01	35528	20.9	24.7	5.88	35677
1.5bot*					20.9	24.7	5.85	35638

* “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 5 in mid-channel) and one upper estuary site during tidewater goby sampling, 3 October 2018.

			3-Oct-18					
	Station 1 (lower estuary) air temp. 17.5 C		0934 hr		**Station 3 (lower estuary)** air temp. 19.7 C			1043 hr
Depth	**Temp**	**Salin**	**Oxygen**	**Cond**	**Temp**	**Salin**	**Oxygen**	**Cond**
(m)	**(C)**	**(ppt)**	**(mg/l)**	**micro-mhos**	**(C)**	**(ppt)**	**(mg/l)**	**Micro-mhos**
0	15.5	30.4	10.7	38117	16.4	29.8	10.53	38258
0.25	15.5	30.4	8.93	38201	16.3	29.7	8.48	38208
0.5	15.5	30.4	9.02	38181	16.2	29.9	8.91	38269
0.75	15.4	30.4	9.00	38185	15.8	30.3	9.94	38356
0.87bot					15.7	30.3	9.88	38364
1.0	15.4	30.4	8.99	38169				
1.15bot	15.4	30.4	8.79	38189				
	Station 5 (lower estuary) air temp. 18.2 C			1133 hr	**Boat Launch Ramp mid channel (above Thurwachter Bridge)**			1444 hr air 20.1 C
Depth	**Temp**	**Salin**	**Oxygen**	**Cond**	**Temp**	**Salin**	**Oxygen**	**Cond**
(m)	**(C)**	**(ppt)**	**(mg/l)**	**micro-mhos**	**(C)**	**(ppt)**	**(mg/l)**	**micro-mhos**
0	16.4	30.2	10.67	38852	20.7	12.9	7.72	19626
0.25	16.4	30.0	8.73	38539	20.8	13.6	6.11	20649
0.5	16.4	30.0	8.69	38501	21.3	17.4	5.20	26185
0.75	16.0	30.2	8.86	38436	21.7	20.7	6.48	30842
0.85bot	16.0	30.3	9.13	38512				
0.95bot					21.7	21.1	6.83	31567

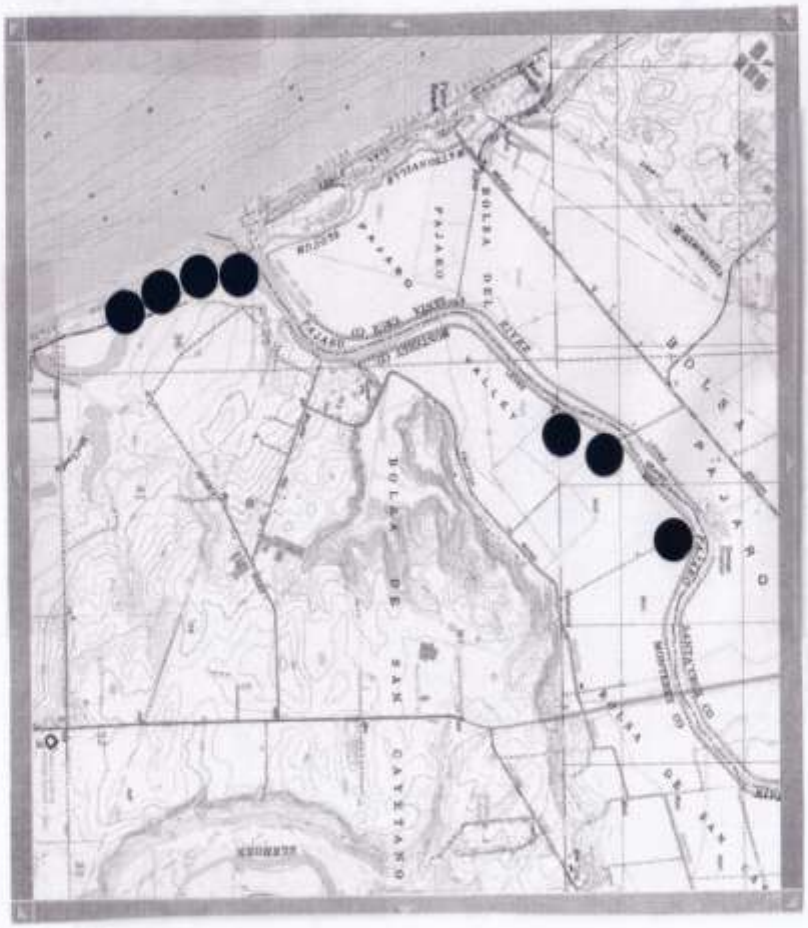
CONCLUSIONS

No steelhead or tidewater goby were detected in the Pajaro Estuary in 2018. With its daily tidal influence, 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 stratified water temperature that the upper estuary experienced in the 2018 estuary, with indications that oxygen levels that 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 2019b**). Water temperature would remain cooler at depth through the day with oxygen increasing steadily as aquatic vegetation photosynthesized. The 2018 Pajaro estuary was highly saline throughout the water column during sampling, with evidence of temporal oxygen fluctuations. Though oxygen concentrations were not prohibitively low for steelhead by late morning during sampling in the upper estuary, they may have been stressfully low near the bottom near dawn in the vicinity of the model airport and upstream to beyond the boat ramp. 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 very limited water quality measurements in fall that water temperature was stressfully high even in fall for steelhead in the upper estuary in the vicinity of the boat ramp but tolerable at the Thurwachter Bridge and downstream. Typically, air and water temperatures are higher in July and August than late September and early October in lagoons without tidal influence. The cooling effect of tidal influxes did not appear to maintain water temperatures below 20 °C midday at the model airport and upstream in 2018. While water quality data were not collected throughout the summer and during periods of sandbar closure that may have occurred in 2018, 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 in the lower estuary that was somewhat deeper. A shallow lagoon would heat up quickly with the salinity stratification that would ensue after the sandbar closed.

The lack of capture of tidewater goby in fall 2018 indicated that a small population still existed, at best, in Pajaro Estuary. Our sampling was not extensive enough to establish that tidewater goby were absent. The steep banks and overhanging vegetation in the leveed upper estuary 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 is good, as was the case in 2015−2017. Algae and submerged vegetation appeared largely absent in the lower estuary in the past 4 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 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. 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 2018, 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 and 2018 estuary. 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. Upper Three Sampling Sites along the Levee and Sampling Zone along the Beach Berm at the Pajaro Lagoon/Estuary.



Literature Cited

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

Alley, D.W. 2019b Soquel Creek Lagoon Monitoring Report, 2018. Prepared by D.W. ALLEY & Associates for the City of Capitola.

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

Farrel, A.P., N.A. Fangue, 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.