D.W. ALLEY & Associates aquatic biology

DRAFT Fishery and Water Quality Monitoring of Pajaro River Lagoon/Estuary, 2020

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

Lower Pajaro Estuary looking east. (Photo by D. Alley) 28 September 2020

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. 2020 was the ninth year of annual sampling, which began in 2012.

Summary of 2020 Results

No steelhead were captured in Pajaro River Estuary in fall 2020. Tidewater goby were captured at the 2 upper sites at Thurwachter Bridge and 0.8 miles upstream. The catch was dominated by jack smelt (*Atherinopsis californiensis*) and top smelt (*Atherinops affinis*) and various species of crabs. Other captured native fish species included northern (California) anchovy (*Engraulis mordax*), threespine stickleback (*Gasterosteus aculeatus*), arrow goby (*Clevelandia ios*), staghorn sculpin (*Leptocottus armatus*), Bay pipefish (*Syngnathus leptorhynchus*), Pacific herring (*Clupea pallasii*) and mosquito fish (*Gambusia affinis*). Native longjaw mudsucker (*Gillichthys mirabilis*) was captured at 2 sites in 2020.

2020 Estuary Conditions

An estuary was present with an open sandbar during fish sampling in late September. Tidal influence occurred daily during the sampling period, with fluctuating depth and current.

Methods

Pajaro Estuary (open sandbar) was sampled on September 28−30, 2020. Sampling locations included the beach area, Watsonville Slough approximately 100 m from its mouth 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 28 September, the main estuary along the beach was sampled for steelhead with the 106-foot bag seine (8 successful seine hauls). On 29 September, the upper estuary was sampled with the 106-foot bag 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 these 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 30 September, tidewater gobies were sampled for, using a 30-foot seine with 1/8-inch mesh. Five seine hauls were made in the estuary along the beach. One seine haul was made in Watsonville Slough near its mouth, and 3 were made in the upper estuary (model airport, Thurwachter Bridge and boat ramp). Water quality was measured at 5 stations. The 4 lower estuary measurements, including 1 in Watsonville Slough approximately 100 m from its mouth, were made nearshore by wading. The 1 upper estuary measurement was also made mid-channel by wading out from the boat ramp. Secchi depth measurement was unnecessary with visibility to the bottom. Water quality measurements taken on 29 and 30 September were sufficient to determine general water quality conditions at the time of fish sampling.

Figure 1. Pajaro Lagoon Fish and Water Quality Sampling Sites

Lower Pajaro Estuary looking north. (J. Wheeler) 28 September 2020

Lower Pajaro Estuary looking east along southern beachfront berm margin. (J. Wheeler) 28 September 2020

Lower Pajaro Estuary looking northeast, sampling the thalweg (deepest portion of the channel) with seine haul #7. (D. Alley) 28 September 2020

Upper Pajaro Estuary, looking upstream from Thurwachter Bridge. (D. Alley) 29 September 2020

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 4 in 2019, 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 those being identified as jack and topsmelt. Other species, in declining abundance, included staghorn sculpin, Pacific herring and arrow goby. In Watsonville Slough, arrow goby were more common than along the beachfront berm, and a longjaw mudsucker goby was captured there, too. Yellowshore crabs were also common. But no tidewater gobies were detected at this slough site. No steelhead or tidewater gobies were captured along the beachfront or in lower Watsonville Slough. Two harbor seals were present in the lower Pajaro estuary during sampling, curious about our activities.

Results of sampling for steelhead in the upper estuary near the model airport and Thurwachter Bridge with the large seine yielded 5 native fish species, including jack smelt and topsmelt, northern anchovy (mostly small YOY), threespine stickleback and staghorn sculpin (**Table 2**). Longjaw mudsuckers were captured at Thurwachter Bridge on separate days. No steelhead or tidewater goby were captured with the long seine (coarse mesh). Fish species diversity was greater than when the sandbar was closed during drought.

Our tidewater goby sampling with the finer meshed seine in the lower estuary yielded no tidewater gobies along the beachfront where 5 native species were captured, those consisting of arrow goby, staghorn sculpin, bay pipefish, jack smelt and topsmelt (**Table 3**). The current was swift along the beach front at 3 of the 5 sampling locations due to incoming tide during sampling. Tidewater goby need slackwater habitat. Water velocity was estimated at between 0.5 and 1 ft/s. Three species of crabs (yellowshore, Dungeness and kelp) were captured along with small snails along the beachfront. Surprisingly, no starry flounder (*Platichthys stellatus*) were captured in Pajaro Estuary in 2020.

In the upper estuary where slackwater habitat existed, tidewater gobies were captured at Thurwachter Bridge and the boat ramp for the first time since 2017 (**Table 4**). Other species captured in the upper estuary included 7 native species, those being arrow goby, young-of-the-year (YOY) smelt and adults (jack and topsmelt), staghorn sculpin and threespine stickleback. Mosquitofish were captured at only these 3 sites, and a longjaw mudsucker was captured again at Thurwachter Bridge, as occurred the previous day.

Longjaw mudsucker goby. (Photo by I.M. Laursen) 29 September 2020

Northern anchovy. (Photo by I.M. Laursen) 29 September 2020.

Table 1. Fish capture* results from sampling lower Pajaro estuary *with the 106-foot bag seine (3/8-inch mesh)*, 28 September 2020.

Date	Location	Seine Haul	Steel-head	Tide-water Goby	Arrow goby	Bay pipefish	Smelt	Staghorn Sculpin	Pacific Herring	Starry Flounder	Threespine stickleback
28 Sep 2020	East of Watsonville Slough	1					113				
	East of #1	2					171		1		
	East of #2	3			1		442				
	East of #3	4					58	2			
	East of #4	5					861	1			
	East of #5	6					158	1			
	East of #6	7					90				
	East of #7	8					407	1			
Total			**0**	**0**	**1**	**0**	**2,300**	**4**	**1**	**0**	**0**

*32 yellowshore crabs, 23 Dungeness crabs, 6 purple shore crabs, 2 red rock crabs, 1 nudibranch captured.
2 harbor seals present.

Table 2. Fish capture* results from sampling upper Pajaro estuary *with the 106-foot bag seine (3/8-inch mesh)*, 29 September 2020.

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
29 Sep 2020	Model Airport	1−3			188		328	1	2	0	
	Thurwachter Bridge	4−6			11		668	2	8		2
Total			**0**	**0**	**199**	**0**	**996**	**3**	**10**	**0**	**2**

* 3 yellowshore crabs captured.

Table 3. Fish capture* results from sampling the periphery of lower Pajaro estuary, lower Watsonville Slough and upper Pajaro Estuary *with the 30-foot seine (1/8-inch mesh)*, 30 September 2020.

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	Longjaw mudsucker goby
30 Sep 2020	Approx. 100 m up Watsonville Slough	6			19							1
	Approx. 100 m east of Pajaro Dunes	1			1	2	1	4				
	East of #1	2				1	2	1		3 YOY		
	East of #2 fast tidal current	3										
	East of #3	4								1 adult, 1YOY		
	East of #4 fast tidal current	5										
	Airport- 0.3 miles down from Thurwachter Br	7			2	5			19			
	Thurwachter Br.- 2.1 miles up from Watsonville Slough	8		2	2	3		6 one year+ 60 YOY	100+	1 YOY		1
	Boat Ramp- 0.8 miles upstream of Thurwachter Br.	9		9	1	66		23 YOY	1			
Total			**0**	**11**	**25**	**77**	**3**	**94**	**120+**	**6**	**0**	**2**

* 77 yellowshore crabs (41 of them in Watsonville Slough), 6 Dungeness crabs, 1 kelp crab, >81 snails captured.

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
2020	11	8

Staghorn Sculpin. (Photo by I.M. Laursen) 29 September 2020

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 and 2020 with steelhead present (**Alley 2020a; 2021a**). 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, CA, and 30 years at Soquel Creek Lagoon in Capitola, CA, 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 typically 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, would negatively impact 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.

Topsmelt. (Photo by I.M. Laursen) 29 September 2020.

On 29 September, during steelhead sampling in the upper estuary, air temperature was cool (range of 16.4−17.2°C). Water temperature was warm and stratified (range of 18.9°C at the surface at the model airport to 23.1 °C at the bottom at Thurwachter Bridge) and would not likely have been stressful for steelhead at the airport and Thurwachter Bridge by early afternoon (**Table 5**). Salinity was stratified with depth at both sites. It was a minimum of 11.5 ppt at the surface at the model airport and a maximum of 27.8 ppt at the bottom there. These saline conditions may have been stressful to acclimated steelhead because of the absence of low salinity water near the surface. Oxygen levels were above 5 mg/l throughout the water column except at the bottom and not stressful for steelhead, though they were probably lower earlier in the morning and may have been stressful near the bottom if it went below 5 mg/l. 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 30 September 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**). In the lower estuary and Watsonville Slough, water temperature was uniformly cool with slight cooling with depth; salinity was uniformly high with a slight increase with depth at the first seine haul before the incoming tide created a strong current. Oxygen was stratified at that first site and decreased with depth to stressful levels nearest Watsonville Slough. Once the tidal current increased, oxygen levels decreased slightly with depth but were good throughout the lower estuary and Watsonville Slough at above 7 mg/l.

At the uppermost seine haul site at the boat ramp (2.9 miles upstream of Watsonville Slough) in the afternoon, water temperature was warm (above 20°C). It increased slightly from 22.5 at the surface to 23.6°C. This was likely stressful for steelhead. But oxygen levels by 1411 hr were good and above 7 mg/l through most of the water column. They increased with depth to supersaturated conditions. They could have dipped below 5 mg/l near dawn to stress steelhead, though, with respiring aquatic algae consuming oxygen through the night. Salinity was stratified from 6.5 ppt at the surface to 19.4 ppt at the bottom but much lower than in the lower estuary. The high salinity near the bottom would likely been stressful to steelhead in early afternoon at this upper site. Water temperature would have warmed later in the day. However, the strong tidal action in 2020 probably would have kept conditions within the steelhead temperature tolerance range in late September 2020.

Table 5. Water quality measurements in the upper Pajaro estuary during fish sampling for steelhead, 29 September 2020.

			29-Sep-2020					
	Model Airport (mid-channel) Air temp. 17.2°C			1111 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	18.9	11.5	9.22	17410	21.2	17.7	7.32	26630
0.25	21.6	15.6	8.01	24019	21.3	17.6	6.81	26563
0.5	21.6	23.7	7.33	34856	23.0	21.1	8.18	33720
0.75	21.9	26.5	5.95	38826	23.0	24.9	7.04	37581
1.0	22.1	27.0	6.08 (82%)	39648	22.9	26.0	6.94	39019
1.25bot	22.1	27.8	6.41 (87%)	40718	23.1	26.6	4.90	39933
1.5bot	22.2	27.8	4.62	40766				

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

Pacific herring. (Photo by T. Suttle) 28 September 2020

Mosquitofish. (Photo by T. Suttle) 28 September 2020

Table 6. Water quality measurements in the lower Pajaro estuary and Watsonville Slough (Seine Haul 1, 3, 5 and 6 nearshore) and one upper estuary site during fish sampling for tidewater goby, 30 September 2020.

			30-Sep-2020					
	Seine Haul 1 (l. estuary) air temp17.1°C		0924 hr		**Seine Haul 3 (lower estuary)**			1011 hr
Depth	**Temp**	**Salin**	**Oxygen**	**Cond**	**Temp**	**Salin**	**Oxygen**	**Cond**
(m)	**(C)**	**(ppt)**	**(mg/l)**	**micro-mhos**	**(C)**	**(ppt)**	**(mg/l)**	**Micro-mhos**
0	18.9	24.7	7.11	33978	15.6	30.4	9.56	38214
0.25	18.4	26.6	5.23	36210	15.6	30.4	7.86	38314
0.5bot	17.8	27.9	3.80	37364	15.6	30.4	7.93	38321
0.75bot	16.8	29.4	2.70	38188				
1.0								
1.25								
	Seine Haul 5 (lower estuary) air temp. 17.0°C			1054 hr	**Seine Haul 6 (lower estuary) Watsonville Slough**			1144 hr
Depth	**Temp**	**Salin**	**Oxygen**	**Cond**	**Temp**	**Salin**	**Oxygen**	**Cond**
(m)	**(C)**	**(ppt)**	**(mg/l)**	**micro-mhos**	**(C)**	**(ppt)**	**(mg/l)**	**micro-mhos**
0	16.2	30.5	9.96	38755	16.5	30.6	9.27	39344
0.25	15.5	30.5	7.99	38443	16.3	30.3	7.70	38843
0.5bot	15.5	30.5	8.03 (97%)	38424	16.3	30.3	8.22 (101%)	38879
0.75bot					16.3	30.3	8.52	38861
1.0								
1.25								

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

Table 6 (continued). Water quality measurements in the lower Pajaro estuary and Watsonville Slough (Seine Haul 1, 3, 5 and 6 nearshore) and one upper estuary site during tidewater goby sampling, 30 September 2020.

			30-Sep-2020					
	Seine Haul 9- Boat Launch Ramp (mid channel upper estuary) (Adjacent Wastewater Plant)			1441 hr air 21.7°C				
Depth	**Temp**	**Salin**	**Oxygen**	**Cond**				
(m)	**(C)**	**(ppt)**	**(mg/l)**	**micro-mhos**				
0	22.5	6.5	7.31	10692				
0.25	22.0	8.3	6.76	13362				
0.5	22.7	13.6	7.21	21472				
0.75	23.5	16.2	10.55 (136%)	25479				
0.95bot	23.6	19.4	11.24	30366				
1.0								
1.25								

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

Conclusions

No steelhead were detected in the Pajaro Estuary in fall 2020. Tidewater gobies were captured at the upper two sites in the upper estuary. 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. However, the sandbar at the Pajaro rivermouth has seldom been closed during our fall sampling except during the driest of years, such as 2015. A lagoon with a closed sandbar that had converted to freshwater would not have daily depth fluctuation or highly saline conditions detected in the 2020 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 2021b**). Water temperature would remain cool at depth through the day, with oxygen increasing steadily as aquatic vegetation photosynthesized. The 2020 Pajaro estuary was highly saline during sampling except at the uppermost site near the surface, 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. But water temperature was

stressfully high for steelhead at the 3 upper estuary sites. Typically in lagoons without tidal influence, air and water temperatures are higher in July and August than late September when sampling occurred. Despite the cooling effect of tidal influxes, water temperatures were not below 20 °C midday at the model airport, Thurwachter Bridge or the boat ramp on relatively cool air temperature days in 2020. While water quality data were not collected throughout the summer and during periods of sandbar closure that may have occurred in 2020, 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 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 capture of tidewater goby at the two uppermost sites during fall 2020 sampling indicated that a small population still existed in Pajaro Estuary. The mild winter stormflows allowed better overwinter survival of tidewater gobies than in wetter years. With a leveed channel, protected backwaters with tules are limited for overwintering cover for tidewater goby during high stormflow events. The mild winter probably made tidewater gobies much more abundant than usual in Aptos and Soquel Lagoons in 2020 (**Alley 2021a; 2021b**). As was the case in 2015−2019, this species appeared absent again in the lower estuary along the beach in 2020. The strong water current created by the incoming tide in 2020 made much of the lower estuary margin uninhabitable for gobies during our sampling. Gobies are poor swimmers and require slackwater. In addition, algae and submerged vegetation which attract tidewater gobies were largely absent in the lower estuary for the past 6 years, thus reducing its habitat value. Water quality was adequate for tidewater goby survival during the dry season of 2020, 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 2017−2020 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.

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

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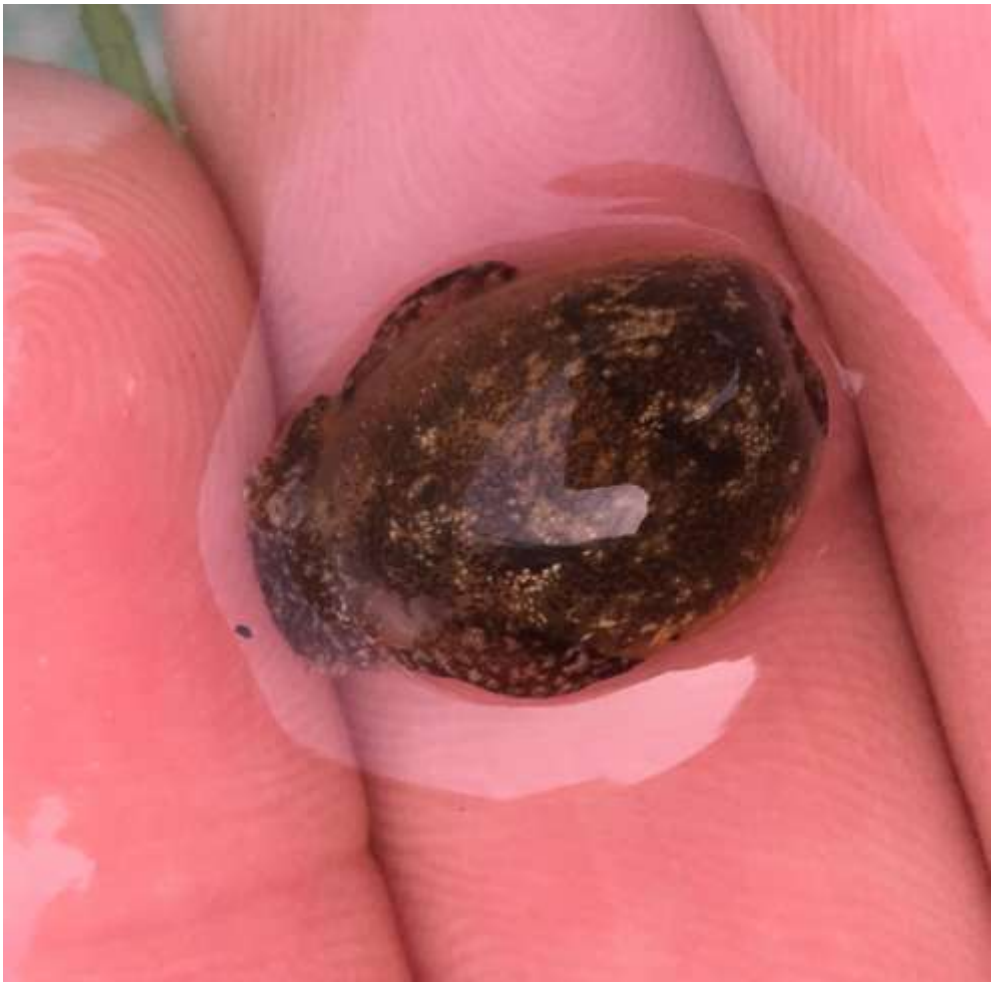
Dungeness crab. (Photo by I.M. Laursen) 29 September 2020

Yellow Shore Crab. (Photo by I.M. Laursen) 29 September 2020.

Opalescent nudibranch. (Photo by I.M. Laursen) 29 September 2020

Smooth bay shrimp. (Photo by I.M. Laursen) 29 September 2020



Bubble snail. (Photo by I.M. Laursen) 29 September 2020