Central Coast Watershed Studies

CCoWS

Carmel Lagoon Water Quality and Steelhead Soundings: Fall 2007

CSUMB Class ESSP 660:

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Executive Summary

ESSP 660 Advanced Watershed Science and Policy is a graduate class taught in the Master of Science in Coastal and Watershed Science & Policy program at California State University Monterey Bay. In 2007, the class was taught in four 4-week modules, each focusing on making a small contribution to a local watershed issue. This report describes the results of one of those 4-week modules – on Carmel Lagoon Water Quality and Ecology. The module was lead instructed by Fred Watson (CSUMB) and Kevan Urquhart (MPWMD).

Results are presented from water quality sampling and sonar fish soundings made in Fall 2007, as well as some very brief invertebrate sampling.

Depth profiles of temperature, salinity, and dissolved oxygen were measured at 25 sampling locations throughout the lagoon. Measurements were made from kayaks, as well as the pipe that crosses the South Arm. With respect to the parameters measured, the water quality of the lagoon was suitable for steelhead. Most of the lagoon was relatively fresh and well oxygenated, and not excessively warm. Low dissolved oxygen was observed only near the very bottom of the South Arm sump, and in a narrow tule-lined channel in the North Arm. A longitudinal gradient in salinity existed between an apparent freshwater source at the terminus of the Odello Arm, and the areas closest to the ocean.

The steelhead sounding centered on novel, experimental use of a simple fish-finder single-beam sonar unit to detect and count fish in the lagoon. The sonar was mounted on a kayak, and surveys were conducted along 12 transects between 10 and 200 meters long. Sonar echoes classified as fish by the sounder appeared to be accurate, although we acknowledge the possibility of false detections. The number of fish observed along each transect ranged from 0 to 80.

A typical suite of invertebrates were found in two D-net scrapes, with the notable absence of *Corophium* – probably due to bias toward sampling weedy and muddy habitat, rather than sandy-bottom habitat.

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1 Introduction

The Carmel River Lagoon lies at the mouth of the Carmel River along the Central Coast of California. This body of water provides critical habitat for the federally threatened steelhead trout (*Oncorhynchus mykiss*). During the winter and spring when the lagoon empties out to the ocean, it serves as the migration zone for juvenile steelhead traveling from freshwater to the ocean and adults traveling both upstream to spawn and for some back to the ocean. In the summer and fall months, the lagoon is sealed off from the ocean by a sand bar and provides important rearing habitat for steelhead and provides a brackish environment which steelhead can use to acclimate to saltwater conditions. In addition, a great number of juvenile steelhead undergo the smoltification process in the lagoon (Bond, 2006).

Lagoon water quality is an important factor in determining the rearing potential for juvenile steelhead. In general steelhead prefer lagoons with sufficient depth and volume, low to mild temperatures, high dissolved oxygen, and low salinity (Smith, 1990; Bond, 2006). These historically dynamic environmental parameters are highly sensitive to the artificial hydrology introduced to the lagoon as a result of development directly in the flood plain of the lagoon and its watershed (Watson and Casagrande 2004)

The two primary anthropogenic practices that affect the lagoon habitat quality are upstream water diversions and artificial breaching of the lagoon (K. Urquhart, pers. comm.). Diversions, primarily via groundwater extraction, in the upper watershed reduce freshwater inflows which potentially degrades water quality by increasing salinity and stratification during the dry season. Breaching is a natural process that occurs in the lagoon, draining the lagoon volume within hours. However, due to the historic lack of zoning standards in California, homes exist within the floodplain surrounding the lagoon, and artificial breaching of the lagoon has been a regular practice to protect these homes. The act of breaching is carried out by the Monterey County Public Works Department a few hours to a week earlier than the lagoon would breach naturally (Entrix 2001). In some years the lagoon is artificially breached during the spring resulting in near total loss of lagoon habitat for over summering steelhead (Larson et al. 2006). The lagoon has been breached since the 1930's (K. Urquhart, pers. comm.) and is also occasionally done by families enjoying the beach (Larson et al. 2006).

1.1 Agencies Responsible for Lagoon Management

Jurisdictional responsibility over the management of the lagoon overlaps among several agencies. Monterey County Water Resources Agency (MCWRA) is charged with managing flood control issues in Monterey County. Prior to 1998 the County was permitted to breach the lagoon for flood control purposes. In 1998 a statewide lawsuit made the State permits issued by the Dept. of Fish & Game for the breaching of the Carmel River Lagoon subject to CEQA. This eventually resulted in the county being unable to renew their permit to breach the lagoon, until they produced an Environmental Impact Report (EIR) for the activity. The County continues to breach the lagoon for flood control without having completed an EIR for the State permits. This activity is justified as an emergency action to prevent a threat to public health and private property, via annual emergency resolutions by the Board of Supervisors. The California Department of Parks and Recreation (CDPR) is the landowner and trustee of most of the lagoon and its surroundings and also requires permits for any modification of the lagoon or beach. The California Department of Fish and Game (CDFG) and the California State Coastal Commission (CSCC) also require permits for any modifications to the beach or the lagoon with their own separate permit processes. The Central Coast Regional Water Quality Board (CCRWQB) has jurisdiction over regulating water quality in the lagoon and is in charge of permitting the Carmel Area Wastewater District (CAWD) which is proposing to discharge treated waste water directly into the lagoon (instead of the ocean), if it will improve water quality and quantity for wildlife. The local regulatory special district Monterey Peninsula Water Management District (MPWMD) has a mission to restore the aquatic resources of the Carmel River Watershed, of which the lagoon is a key, but has no specific authority to do so (K. Urquhart, pers. comm..).

Although the jurisdiction of State regulatory agencies over wildlife traditionally supersedes that of federal agencies under principals of constitutional law, several federal agencies do have regulatory control over the lagoon since the lagoon supports species under the Endangered Species Act (ESA). The U.S. Fish and Wildlife Service (USFWS) has jurisdiction over the red-legged frog and is currently underway on a Habitat Conservation Plan for red-legged frogs in the Carmel River Watershed. The National Marine Fisheries Service has jurisdiction of steelhead and develops Habitat Conservation Plans for this species.

1.2 Goal

To enhance general habitat and to return the park to a more natural state, the CDPR implemented the Carmel River Lagoon Enhancement Plan (CRLEP), which called for the expansion of the deeper water south arm of the lagoon by excavating a new channel on the former Odello farmland adjacent to the remnant south channel. Since the construction of the new channel CDPR and CCoWS have conducted water quality and biological monitoring to assess the effects of the CRLEP (Perry et al. 2007). The overarching goal of our study was to continue monitoring the water quality of the entire lagoon for a short period in Fall 2007, focusing on the new channel, to assess the quality of steelhead habitat. In addition to water quality monitoring, relative abundance of juvenile steelhead was estimated using sonar sounding techniques along several transects, and brief invertebrate sampling was conducted at selected sites.

We present our results in the following three sections: Water Quality, Sonar Survey for Steelhead Trout, and Macroinvertebrates.

1.3 Study area – Carmel Lagoon

The Carmel Lagoon forms at the mouth of the Carmel River (Fig. 1) and is considered critical habitat for steelhead. Steelhead trout are anadromous, migrating from freshwater rivers to the ocean and back. During the summer and fall the sandbar of the Carmel Lagoon is closed making the lagoon an isolated water body providing steelhead with rearing and smoltification habitat. During the winter and spring the Carmel River flows into the ocean through an opening in the sandbar allowing steelhead to migrate between the river and ocean.

Aquatic habitat types in the lagoon are contingent on water volume, which is determined by river flow, sediment accumulation, wave and tide conditions, and status of the sandbar (open or closed) (Watson & Casagrande, 2004; Casagrande, 2006). Larger lagoon volumes, especially those dominated by fresh water, increase the total amount of steelhead habitat and greatly influence seasonal water quality conditions. Some areas of the lagoon are perennial, while other areas are inundated only during high stages. Areas of the lagoon that are permanently flooded include the main embayment, the South Arm, small portion of the North Arm, and a portion of the new Odello Extension.

Figure 1. Carmel Lagoon study area.

2 Water Quality

2.1 Goal

In lagoon environments, suitable water quality conditions for juvenile steelhead are cool-mild, well oxygenated and fresh to brackish waters that support robust invertebrate populations (Smith, 1990). Lagoon depth and volume are also critical especially during the dry season when surface flows from the Carmel River no longer reach the lagoon.

Stratification of the water column can occur especially in deeper areas that are protected from wind. Depending on the season, saltwater on the bottom of the lagoon can have its benefits and detriments with respect to water quality and rearing habitat for juvenile steelhead. In summer, a primarily fresh lagoon is more optimal for rearing steelhead. This keeps thermal stratification to a minimum and allows the water column to mix more readily thus maintaining suitable oxygen concentrations throughout. In fall, when temperatures decline and juvenile steelhead begin to smolt, a stratified lagoon, with brackish waters at depth, provides areas for saltwater acclimation which helps to facilitate smoltification (Smith, 1990; Bond, 2006).

The goal of this component of the study was to characterize these key parameters (temperature, dissolved oxygen, and salinity) with respect to habitat quality for steelhead. We adopted thresholds of interest at 2 mg/L and 5 mg/L DO, and 26°C (Hunter 1991). Our objective area was the entire lagoon with focus on the deeper south channel.

Dissolved oxygen and temperature are important parameters for steelhead. Dissolved oxygen levels lower than 5 mg/L can harm fish (Morris 1992), and levels lower than 2 mg/L are usually lethal especially at warmer temperatures (K. Urquhart, pers. comm.). Temperature thresholds for rearing steelhead vary depending on food availability and habitat conditions. Temperature affects metabolism and oxygen demand and therefore feeding rates. If food resources are abundant, steelhead can grow substantially and survive in mild to slightly warm temperatures in lagoons (Smith, 1990).

In streams, studies often report that steelhead prefer temperatures in the range of 4-15.5°C, usually at or below 11°C (McEwan & Jackson 1996). These numbers generally pertain to fish acclimated to cooler environments in more northern, densely forested systems. Other, more local, studies have demonstrated that when food is abundant steelhead survive and grow bigger in their first year where summer stream temperatures routinely exceed 20ºC (Smith and Li, 1983; Casagrande, in prep). When temperatures reach or exceed 26°C it can be lethal (Hunter 1991).

2.2 Methods

We measured water quality parameters that are known to affect steelhead in the lagoon. Measurements were made during afternoon hours (1500-1630 hours) between October 23rd and November 6th, 2007, when the lagoon typically has a low volume and is highly stratified with respect to salinity, temperature, and dissolved oxygen.

The water quality parameters we measured were temperature, salinity and dissolved oxygen (DO). All parameters were measured in situ with an YSI Environmental 556 MPS Multiprobe System or a Hach HydroLab DS5X. At each sampling location, a profile of measurements at different depths was made – in either 0.25 m or 0.50 m depth increments. See Table **Error! Reference source not found.** for instrument specifications for each parameter. The YSI MPS and Hach HydroLab were calibrated on October 23rd, 2007. Depth Profiles were taken at the pipe in the South Arm on October 23rd and November 6th, and depth profiles were taken via a kayak/dingy throughout the lagoon on October 30th. See Figure 2 and Table **Error! Reference source not found.** for all depth profile locations.

Figure 2. Locations of water quality profile sampling sites in Carmel Lagoon. Background image from Perry et al. (2007).

Table 1. List of parameters for instrument specifications.

Instrument	Parameter/Sensor	Accuracy	Range	Resolution
YSI	**Temperature** (Precision TM thermistor)	± 0.15 ºC	-5 to 45 ºC	0.1 ºC
YSI	**Dissolved Oxygen** (DO, mg/L) (Steady state polargraphic)	± 0.2 (or 2%) up to 20 mg/L	0 to 50 mg/L	0.01 mg/L
YSI	**Salinity** (Calculated from conductivity and temperature)	± 1.0% of reading or 0.1 ppt	0 to 70 ppt	0.01 ppt
HydroLab	**Temperature** (30K ohm thermistor)	± 0.1 ºC	-5 to 50 ºC	0.1 ºC
HydroLab	**Dissolved Oxygen** (DO, mg/L) (Hach LDO)	± 0.1 up to 8 mg/L	0 to 12 mg/L	0.01 mg/L
Hydrolab	**Salinity** (Calculated from conductivity and temperature)	± 1.0% of reading or 0.1 ppt	0 to 70 ppt	0.01 ppt

Table 2. Water quality sampling site coordinates.

Depth Profile	Coordinates UTM E	N
Pipe	596221	4043841
TZ1	596730	4043700
TZ2	596607	4043610
TZ3	596562	4043604
TZ4	596535	4043628
TZ5	596480	4043724
TZ6	596362	4043793
TZ7	596299	4043818
TZ8	596258	4043824
TZ9	596207	4043865
TZ10	596293	4044096
TZ11	596390	4044157
TZ12	596439	4044231
C1	596811	4043689
C2	596576	4043591
C3	596008	4044046
C4	596018	4044246
C5	596145	4044012
C6	596205	4044026
C7	596217	4043875
N2	596036	4044229
R2	596047	4044113
S2	596229	4043851
O1	596510	4043619
O4	596680	4043645

2.3 Results

Figure 2 details the sampling locations for water quality profiles throughout the Carmel Lagoon. The sampling locations extend from the North Arm, through the main embayment of the lagoon, into the South Arm and the Odello Extension. This series of water quality sampling points was used to create a longitudinal transect along the length of the lagoon (Fig. 3). Figure 3 shows a side-on profile of the lagoon along this transect. In other words, the diagram shows the lagoon as if viewed horizontally through the water, with the bathymetry depicted by the thick black line at the bottom, and the water surface the thick blue line at the top. Figure 3a reveals the salinity gradient present in the lagoon at the time of sampling. There was a general longitudinal gradient of declining salinity from the North Arm through the main lagoon to the Odello Arm, with highest salinity in the North Arm, and lowest salinity in the southern Odello Arm. Figure 3a shows isopleths that represent a particular salinity threshold. The green line is the isohaline at 4 ppt, where everything under this line had greater than 4 ppt salinity. There was a deep sump of higher salinity in the two deepest sections of the transect, as well as an apparently more localized zone of higher salinity at the north end of the transect, in the shallow North Arm. The southern part of the transect had the lowest salinity; everything south of the light blue 2 ppt isohaline was fresher than 2 ppt.

Figure 3b illustrates the pattern of dissolved oxygen concentrations along the transect. Dissolved oxygen did not follow an obvious longitudinal gradient like salinity, but there was a distinct vertical gradient in parts of the transect. Dissolved oxygen dropped below 5 mg/L at the north end of the transect and in the deep sumps in the middle of the transect. In general, the deeper places in the lagoon tended to have lower oxygen. The yellow line delineates the 8 mg/L isopleths, where everything below that line had less than 8 mg/L dissolved oxygen. This line shows areas of lower oxygen where the water is deeper. Figure 3b also shows that dissolved oxygen in the lagoon was lower than 2 mg/L in a few places, particularly at the north end of the lagoon, and in the deepest part of the transect.

Figure **Error! Reference source not found.** shows water quality profiles for several sampling sites throughout the lagoon. Surface temperatures ranged from approximately 14°C-19°C (Fig 4) with the warmest temperatures occurring at the back end of the Odello Extension. Temperature profiles collected in the South Arm shows relatively uniform and mild (14-15°C) temperatures in the top meter or so of the water column. The deeper profiles had a warmer layer at depth approaching 18°C at the bottom.

In shallow areas of the lagoon salinity was relatively uniform throughout the water column (Fig 4). The deeper profiles do show stratification with a higher salinity layer at depth. The halocline was at about -0.5 m NGVD on October 23rd near the pipe, but the following week the halocline was lower at about -1.25 m NGVD.

Dissolved oxygen was generally high in the lagoon, in the range of about 10 mg/L. Figure **Error! Reference source not found.** shows a dive in dissolved oxygen below about -0.5m NGVD, with a hypoxic zone lower than 5mg/L below this level.

2.4 Comparison to previous year

Salt concentrations in the upper layers of the water column were, on average, similar to conditions measured last year at this time (Perry et al. 2007). However, at depth, waters were not as saline in 2007 (8 ppt) as they were in the previous year (15 ppt). This is likely due to timing of wave events and over bar wave inputs to the lagoon versus timing of sampling.

The longitudinal gradient of salinity observed in this year's study is consistent with results from a 2005 study, which documented a freshwater spring in the Odello Arm (Larson et al. 2006). That study showed a distinct pattern of increasing salinity with increasing distance from the freshwater spring. These results were corroborated by this year's sampling of salinity across the lagoon. The freshwater spring in the Odello Arm creates a localized area of fresher waters.

Overall, surface temperatures were slightly warmer in 2007 than in 2006, although this could be related more to the time of day that the data were collected. In 2007, the surface temperatures in the lagoon ranged from 15 °C to 19 °C and in 2006 surface temperatures ranged from 13°-17°C (Perry et al. 2007) .

The pattern of dissolved oxygen was generally similar to the previous year. In the South Arm, dissolved oxygen concentrations were around 10 mg/L at the surface, with a more oxygen limited zone (< 5 mg/L) below about -1 m NGVD. In the most shallow areas of the lagoon (main embayment and river arm), the water column was well mixed with suitable oxygen concentrations top to bottom.

2.5 Discussion

Water quality in the lagoon in Fall 2007 was sufficient to support good habitat for steelhead and other organisms in the lagoon community. Most of the lagoon had high enough dissolved oxygen to support steelhead. There was a distinct stratification in the lagoon, with a saline, warm, low oxygen layer below -1 m NGVD. The stratification could be a result of a combination of low wind energy and resistance to mixing from the deep, dense, saline layer.

There was a longitudinal gradient of salinity in the lagoon, with highest salinity at the north end, and lowest salinity in the South Arm (Figure 3a). This indicates a freshwater source seeping into the south lagoon through groundwater, which is consistent with the findings of Larson et al. (2006).

Temperature in the lagoon was in the appropriate range to support steelhead. Three shallow profiles reached 19°C during the day. However, these temperature maximums were only observed in the shallow areas of the Odello Arm and the Carmel River mouth and likely cooled at night.

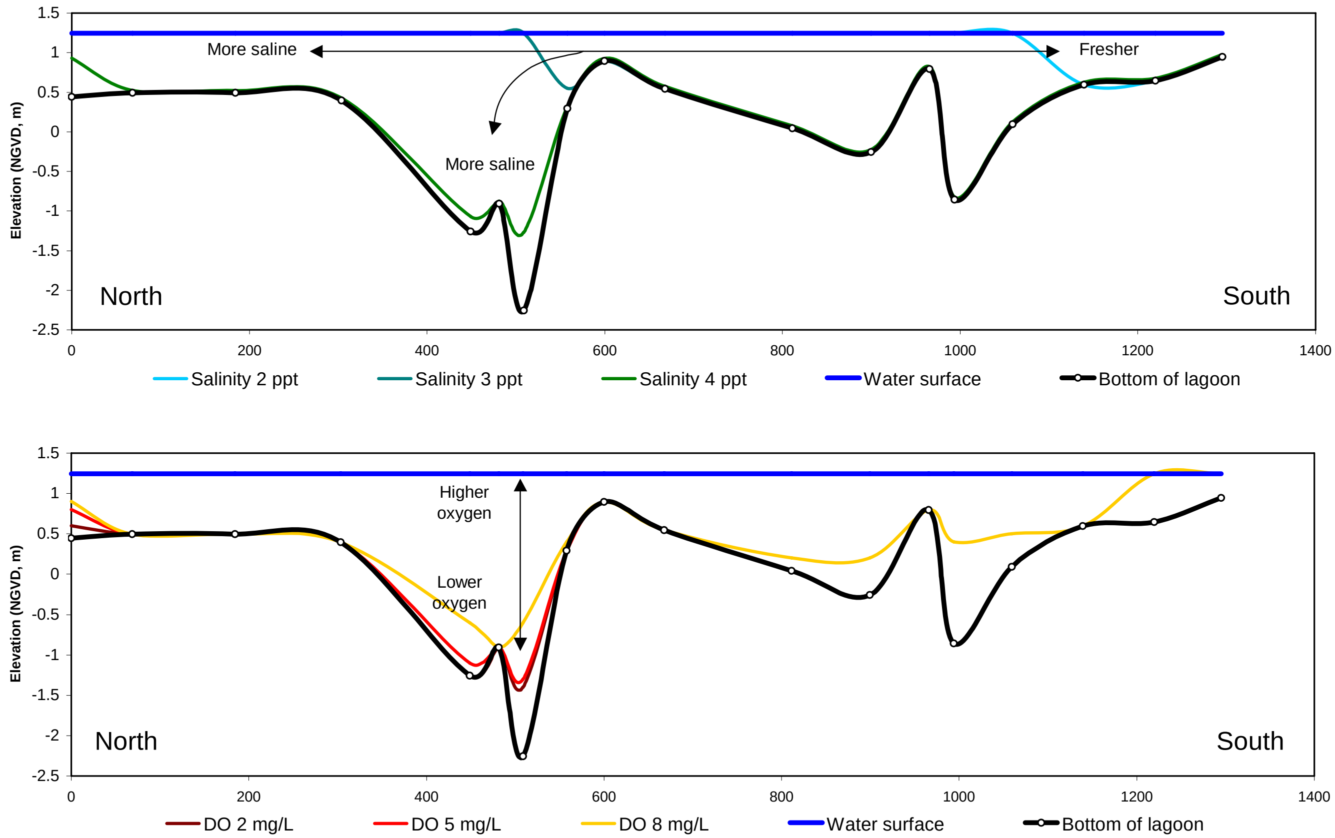

Figure 3. Longitudinal profile of water quality along a transect in Carmel Lagoon extending from the North Arm to the Odello Arm.

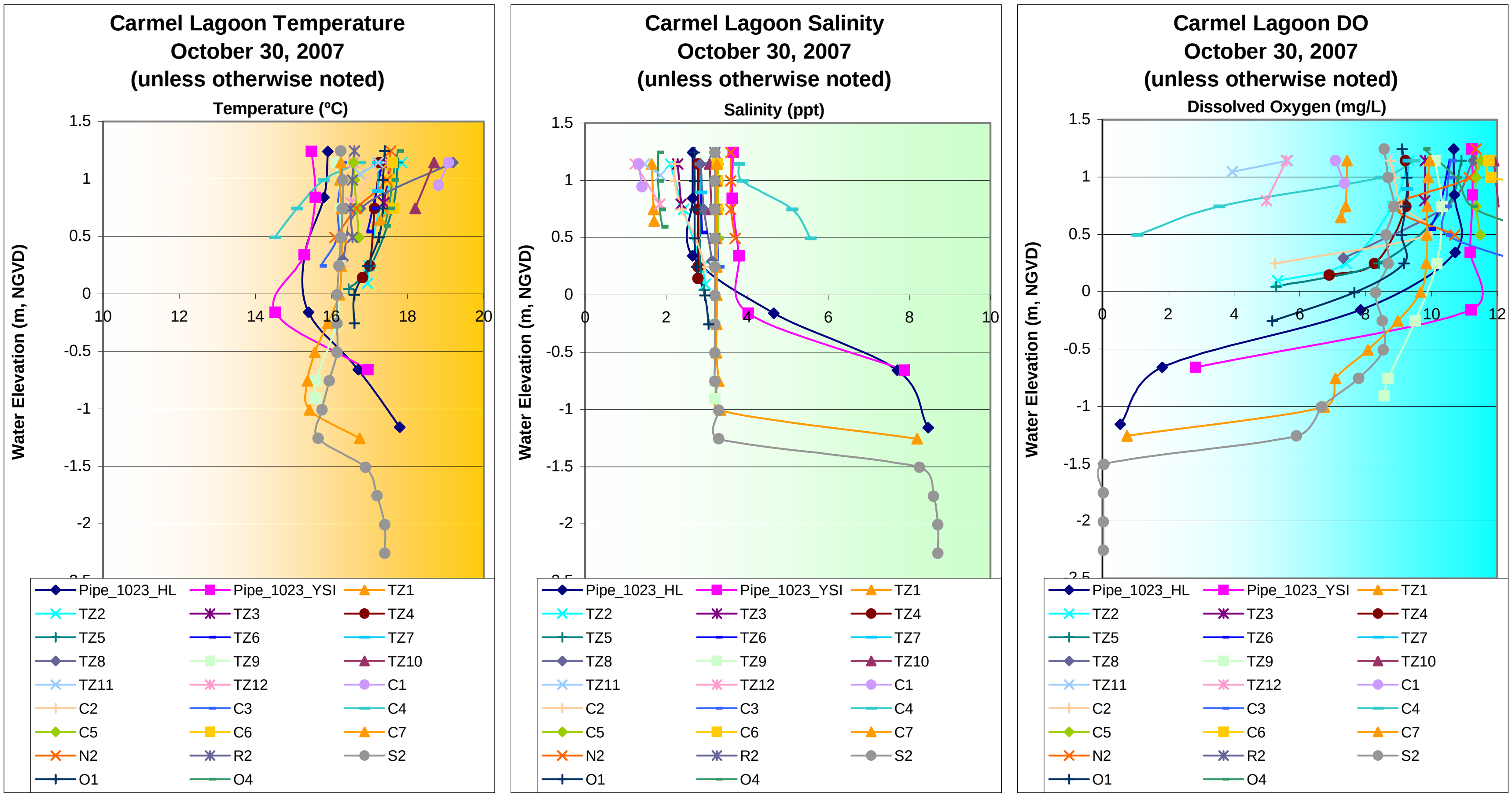

Figure 4. Water quality profiles from various sites in the Carmel Lagoon: October 23rd and 30th, 2007.

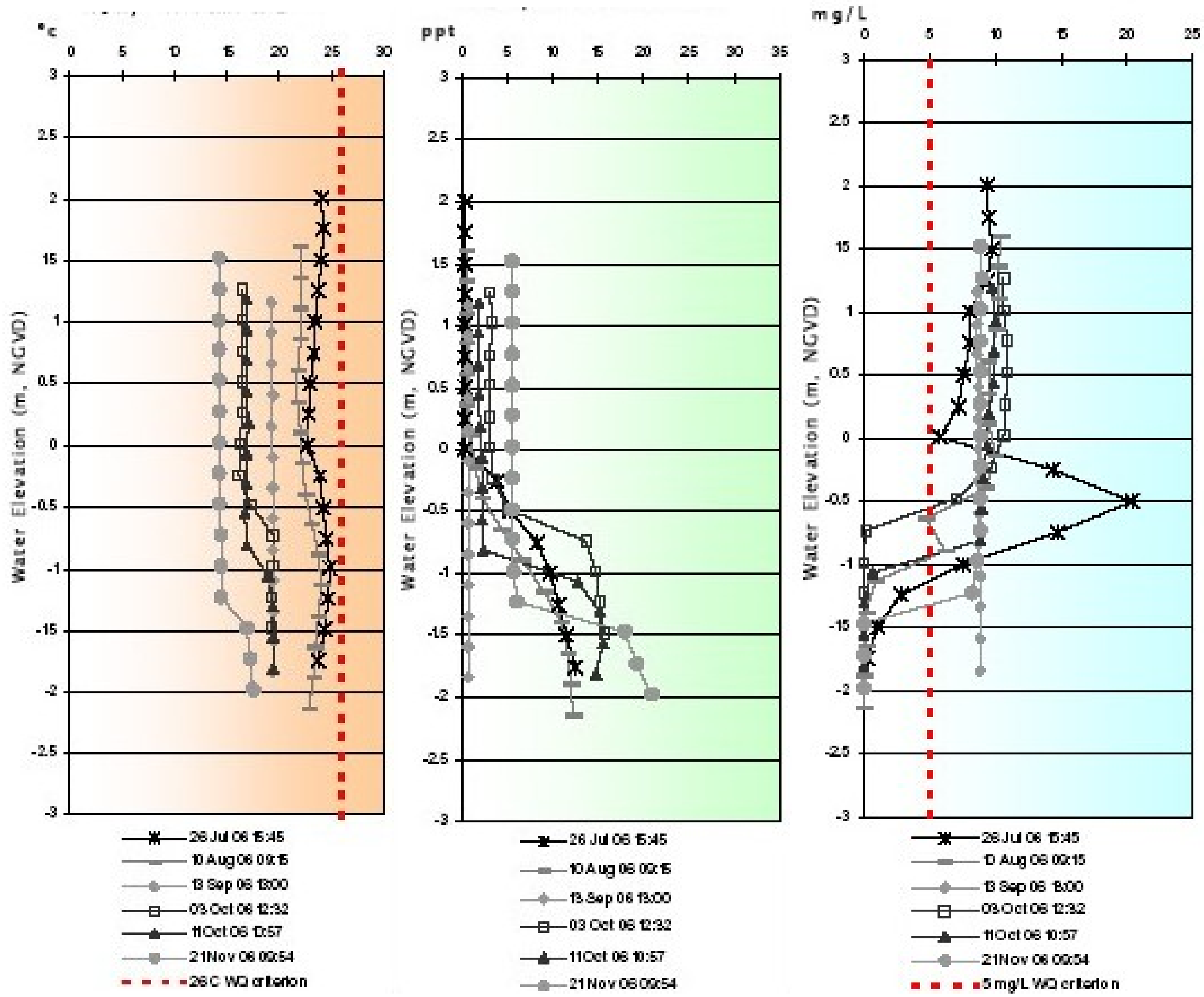

Figure 5. Water quality profiles from the South Arm (S2) in the Carmel Lagoon, Fall 2006, reproduced from Perry et al. (2007).

3 Sonar survey for steelhead trout

3.1 Goal

Steelhead population estimates provide important data for federal agencies involved in steelhead recovery efforts. By using sonar survey methods we sought to detect and, if present, make approximate counts of individual steelhead along transects in locations that we predicted they would prefer based on physical (depth and volume) and water quality (temperature, dissolved oxygen, salinity) characteristics. Additionally, we aimed to test sonar as a method for estimating steelhead populations in the lagoon.

3.2 Methods

Seining has been used in the past at Carmel Lagoon as a method for estimating populations of steelhead rearing in the lagoon. However, because Central Coast steelhead are listed as threatened under the federal ESA, the permits needed to seine steelhead in the lagoon are extremely difficult to obtain, creating a need for alternative methods. Counting steelhead by using sonar “fish-finders” is one such alternative method that we used on November 6th 2007 to estimate steelhead presence and abundance in the South Arm and Odello Extension of Carmel Lagoon.

An Eagle Ultra 3D sonar was mounted to the bow of a kayak that was then slowly paddled along longitudinal transects. Objects interpreted as “fish” by the fish-finder were counted along each transect. Only distinct objects appearing as fish in the water column with the fish-finder were counted; non-distinct objects appearing along the bottom were not counted due to the likelihood they could be aquatic vegetation or other debris. The counts observed along each transect can be divided by transect length to obtain a rough estimate of fish density (fish per meter) in these reaches. Figure 6 shows the locations and lengths of transects. Note that we also tested a Piranha Max 15 sonar, which gave qualitatively similar responses, but that we did not use for the transect survey described here.

Using sonar as a method to estimate steelhead abundance is potentially fraught with a high degree of uncertainty. The sonar interprets any sufficiently dense object as a fish, making it possible to count fish as clumps of plants or other debris in the water column (i.e. submerged wood debris). Sonar also does not distinguish between fish species, making it impossible to differentiate steelhead from other species present in the lagoon such as hitch (Lavinia exilicauda) and occasionally stripped bass (Morone saxatilis) both of which have recently been found during seining events in the lagoon (Casagrande pers comm.). In addition when the lagoon is open to the ocean several other open water species could be present. However, the convenience and time efficiency of using sonar to document the presence of juvenile steelhead and estimate relative steelhead abundance, make this a potentially useful method, especially when considering that much more sophisticated sonar units are available than the ones we were able to use during this study.

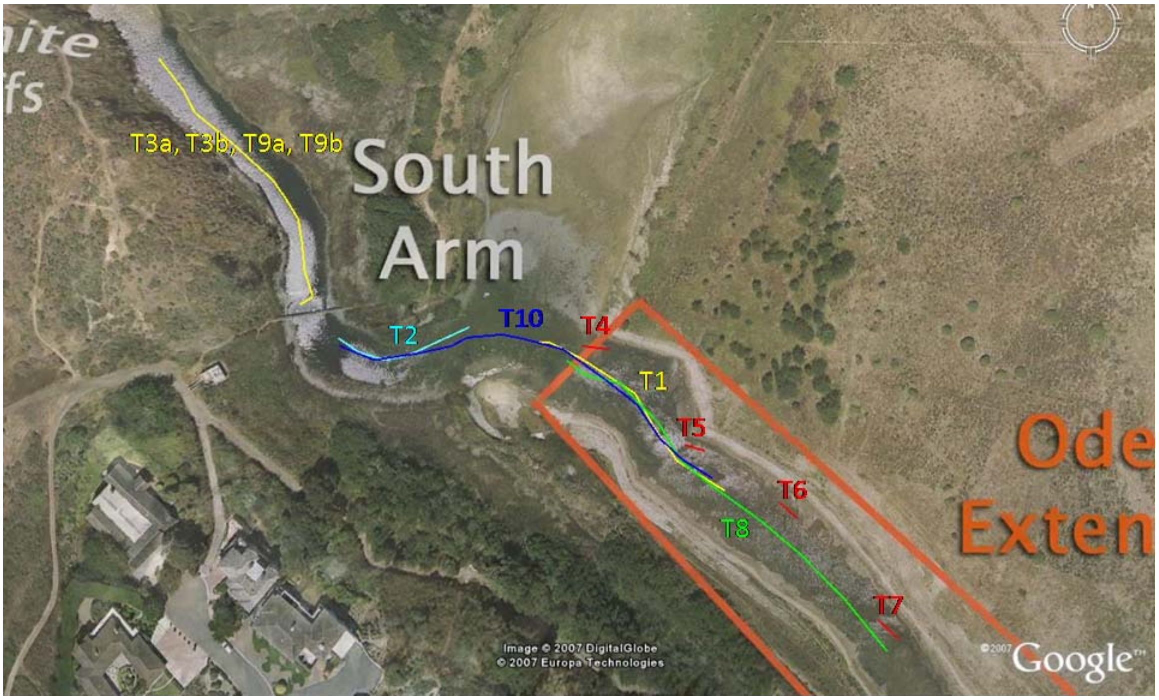

Figure 6. Location of sonar transects for locating Steelhead Trout in Carmel Lagoon.

3.3 Results

Table 3 shows sounding results from 12 transects, including transect length and the number of fish estimated to have been detected. Transects T3a, T3b, T9a and T9b were over the same 120 meter reach of the South Arm of the lagoon where a range of 56-80 fish were observed for each pass. Transects T4, T5, T6 and T7 were all about 10 meter transects adjacent to logs in the Odello Extension of the lagoon where a range of 0-6 fish were observed per log. Transects T1, T2, T8 and T10 were long transects 60-200 meters long near the middle of the lagoon between the South Arm and the beginning portions of the Odello Extension of the lagoon and had an observed range of 4-24 fish per transect.

Table 3. Number of fish estimated to have been detected using single-beam sonar along several transects in Carmel Lagoon, Fall 2007.

Transect Name	Estimated Length (m)	Number of fish observed
T1	130	8
T2	60	9
T3a	150	80
T3b	150	76
T4	10	5
T5	10	1
T6	10	0
T7	10	1
T8	180	4
T9a	150	64
T9b	150	56
T10	200	24

3.4 Discussion

Due to the limitations of our survey (i.e. limited extent, low resolution, little time), it is difficult to draw definitive conclusions about the abundance of steelhead in the southern part of Carmel Lagoon during our study. However, one clear pattern was consistently observed in the South Arm (Transects T3a, T3b, T9a, T9b) immediately north of the pipe. These sites had the highest numbers of fish (sonar echoes classified as) , where channel depth was greatest (total depth was approximately 3.5 m) among all areas surveyed. This indicates that conditions in the South Arm north of the pipe were more favorable to those in the Odello Extension which was shallower. We observed a thick layer of cool, relatively fresh and oxygenated water in the South Arm where the greatest density of fish-detects was recorded. Surface cover in the Odello Extension consists primarily of artificially placed logs along the channel margins. Our survey was not comprehensive, focused primarily on open water areas, and did not adequately investigate the use of cover (i.e. logs) by steelhead. However, sampling along four of these logs detected the presence of fish (or sonar echoes classified as such). . With the narrow width of the sonar beam and its angle of orientation when paddling along a log, it is difficult to accurately detect fish directly beneath logs, making it possible more fish could have been present than were detected. These Transects (T4, T5, T6, T7) as well as T1, T2, T8, and T10 were in a much wider part of lagoon, making it more unlikely that fish present will be detected, given that the sonar covers only a small fraction of channel and that the fish are likely scared by the kayak overhead.

The accuracy of these methods for assessing relative fish abundance could be greatly improved by using both higher resolution sonar and different systematic techniques including more thoroughly surveying different areas of the lagoon.

A different approach could be to use stationary sonar positions (i.e. fixed to a log or an immobile kayak) to record the number of sonar echoes at a site per unit of time. This could reduce some error by eliminating the use of kayaks which could be scaring the fish to safer areas away from the detection limit of the sonar unit.

4 Macroinvertebrates

We had the opportunity to do a brief invertebrate survey on November 6th, 2007 in the Odello Extension of the lagoon. We performed two D-net sweeps with a 500 μm mesh D-net following the protocols outlined in Larson et al. 2005. We observed the presence of eight invertebrate taxa in our two samples. See Table **Error! Reference source not found.** for the species list.

Table 4. Invertebrate taxa observed in the Odello Extension of the South Arm, November 2007.

Phylum	Class	Order	Family	Genus	Common Name
Arthropoda (Subphylum Crustacea)	Malacostraca (Subclass Eumalacostraca)	Mysidacea (Superorder Peracarida)	Mysidae	Neomysis	Opossum shrimp
Arthropoda (Subphylum Crustacea)	Malacostraca (Subclass Eumalacostraca)	Amphipoda (Superorder Peracarida)	Anisogammaridae (Suborder Gammaridae)	Eogammarus	Scud
Arthropoda (Subphylum Crustacea)	Malacostraca (Subclass Eumalacostraca)	(Superorder Peracarida) Isopoda	Sphaeromatidae	Gnorimosphaeroma	Isopod
Arthropoda	Insecta	Diptera	Chironomidae (pupa)		Midge larvae
Arthropoda	Insecta	Ephemeroptera	Baetidae		Mayfly larvae
Arthropoda	Arachnida (Subclass Acari)				Water mite
Arthropoda	Maxillopoda				Copepod
Mollusca	Gastropoda	Pulmonata	Physidae or Gyraulus		Aquatic snail

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