Central Coast Watershed Studies

CCoWS

Garrapata Creek Lagoon, Central Coast, California: A Preliminary Assessment

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Preface

The following report is a preliminary investigation of seasonal water quality, macroinvertebrate communities, and habitat characteristics of the Garrapata Creek Lagoon and its potential use by juvenile steelhead. Lagoon conditions were monitored for six months (June–November). The conclusions presented here are preliminary and based only on the data collected during this study therefore no permanent conclusions should be drawn from this study; future monitoring will improve such conclusions.

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1. Executive Summary and Conclusions

Summary

In the summer and fall of 2005 (June 23rd to November 30th) the Watershed Institute conducted an assessment of the Garrapata Lagoon as part of the Garrapata Creek Watershed Assessment administered by the Garrapata Creek Watershed Council (GCWC). Funding for the Watershed Assessment was provided through an Adaptive Management Grant from the California Department of Fish and Game (CDFG).

Garrapata Lagoon is located at the southern end of Garrapata State Beach, approximately 16 km (10 mi) south of the town of Carmel on the Big Sur Coast of California. The lagoon is a small and shallow (maximum depth < 2 meters) embayment that forms at the mouth of Garrapata Creek in mid to late summer when sand replenishment is sufficient enough to form a partial sandbar. It is a dynamic system that is heavily influenced by ocean waves and tidal processes. The sandbar is not protected by an extensive beach or a northern headland and therefore receives direct impact from westerly and northwesterly swells.

The Garrapata Watershed supports a few federally listed species, most notably threatened steelhead trout (*Oncorhynchus mykiss*) and California red-legged frogs (*Rana aurora*). In many coastal watersheds, lagoons are important rearing areas for steelhead (Shapovalov and Taft, 1954; Smith, 1990; Martin, 1996; Cannata, 1998) and they are used as breeding habitats for red-legged frogs (Stebbins, 2003; Fellers and Guscio, 2004). As long as water quality conditions are suitable juvenile steelhead, rearing in lagoon habitats, can grow substantially and therefore increases their chance for survival in the ocean. Red-legged frogs, breed in early winter (typically December through March) and typically use calm, freshwater to mildly brackish (< 4.5 ppt) areas with abundant emergent vegetation (tules, cattails, etc).

To date, no studies have been conducted in the Garrapata Lagoon. In general, few studies have been conducted on Central Coast lagoons, especially smaller lagoons along the Big Sur Coast. The primary objectives of this study were to document general habitat characteristics of the lagoon including seasonal changes in water quality conditions, macroinvertebrate communities, and attempt to document the use of the lagoon by juvenile steelhead. The following summarizes the data collected to date and provides preliminary conclusions on the lagoon's potential use by juvenile steelhead. Finally, we discuss future studies that may be beneficial to the watershed with respect to the lagoon, invertebrate communities, and steelhead.

Water Quality

Water quality conditions were monitored at a total of six different sites, five in the lagoon area and one on lower Garrapata Creek. Monitoring occurred on eleven occasions between June 23rd and November 30th 2005. Surface to depth profiles were collected for the following parameters: water temperature, dissolved oxygen concentration, and salinity; secchi depth was also measured to the determine clarity of the water.

A partial sandbar formed in mid to late July thereby forming a small lagoon – on average less than 0.25 hectares (0.61 acres). Streamflow entering the lagoon was perennial and was partially responsible for maintaining an opened sandbar. The sandbar opening was to the south for most of the year, but shifted to the north in late November when wave action reduced the height of the sandbar on the north side.

Perennial streamflow maintained a freshwater lens throughout late summer and early fall. At depth, the water column remained brackish throughout the study period due to mixing of incoming streamflow with saltwater entering the lagoon through the opening in the sandbar and/or as wave overwash. Salinity levels in the lagoon gradually increased during high wave events in October and November, but never reached ocean concentrations due to incoming streamflow.

Stratification of the water column persisted throughout the year to some degree – especially in late summer and early fall. During this time, dissolved oxygen concentrations reached anoxic levels on the bottom of the deeper portions of the lagoon. This was exacerbated by the addition of significant amounts of kelp that washed into the lagoon area in early summer prior to partial sandbar formation. Kelp continued to wash into the lagoon from wave overwash during high tide and wave events, especially in mid to late fall.

Water temperatures remained cool throughout the study period. Warmer temperatures (nearly 20°C) occurred on the bottom of the lagoon, but only when the lagoon was stratified in late summer. As density stratification became less dominant, bottom temperatures decreased. This also coincided with slightly cooler inflow from Garrapata Creek and increased wave overwash (i.e. cooler ocean water) in mid to late fall.

Macroinvertebrates

Water column and epibenthic macroinvertebrates were sampled on four occasions from early August to late November. On all sampled dates, at least two sites, including the deepest, were assessed for presence and relative abundance of macroinvertebrate taxa. A 500µm D-net was used to spot check by sweeping through the water column several times per site and dragging lightly along the substrate of the lagoon at each site sampled.

A total of only four taxa were collected in the lagoon and creek inflow: two *Diptera taxa,* midge and fly larvae, *(Tipulidae* and *Chironomidae*), one *Polychaeta*, bristleworm (*Spionidae*), and an isopod, *Gnorimosphaeroma* (*Sphaeromatidae*).

Several macroinvertebrate taxa typical of Central Coast lagoon and estuarine habitats were consistently absent from Garrapata Lagoon. These include *Neomysis* (*Mysidae*) and two amphipods *Eogammarus* (*Anisogammaridae*) and *Corophium* (*Corophiidae*). In addition to *Gnorimosphaeroma* and *Chironomidae,* these three taxa are all common food resources for steelhead and other fish species in the lagoon/estuarine environment (Martin, 1996).

Reasons for their consistent absence in the lagoon are unclear. The methods used in this study to sample the macroinvertebrates were identical to those used in another recent lagoon study (Larson et al. 2005), in which these taxa were collected. Several abiotic factors may have (either individually or in combination) led to these results.

First, in winter and spring the entire lagoon area was lotic with no impounded water. The lack of a perennial embayment may be eliminating a source for colonization since these taxa generally do not use lotic environments.

Or, perhaps the lagoon is too dynamic. The relatively late lagoon formation, small size, and consistent interaction with wave and tidal processes create an unstable environment that could reduce the ability for these taxa to become established.

The lack of emergent vegetation could also be a factor. Robinson (1993) showed that *Eogammarus*, *Chironomus,* and *Gnorimosphaeroma* were positively correlated with the site abundance of pondweed (*Potamogeton*) in Pescadero Lagoon, Central California. Emergent aquatic plants were not present in Garrapata Lagoon at any time during this study.

Late summer and fall anoxia on the lagoon bottom may have also impacted benthic species such as *Corophium*.

Finally, we suggest food chain dynamics as a possible cause. *Neomysis* abundance has been positively correlated with turbidity (from phytoplankton) and algae abundance (Robinson, 1993). Although not sampled, abundance of phytoplankton appeared to be minimal. Water clarity was assessed in the lagoon with a secchi disk and by bank and underwater observations. Visibility in the lagoon was excellent throughout the study period, suggesting low abundance of phytoplankton, a critical food resource of *Neomysis*.

Steelhead Presence/Absence

On two visits to the lagoon, underwater cameras were used to detect the presence of juvenile steelhead. On all visits, bank observations with polarized sunglasses, were made prior to any other sampling. Observations for surface activity (i.e. feeding etc.) were also noted throughout the lagoon during each visit.

Steelhead were not observed at any time in the lagoon with any method. One juvenile coast-range sculpin (*Cottus aleuticus*) was collected in a D-net at the lagoon/creek confluence during invertebrate sampling.

Conclusions

Based on the data collected during the present study, it is likely that Garrapata Lagoon is not used by juvenile steelhead for rearing in most, if any, years. Habitat in the lagoon is limited due primarily to 1) a lack of impounded water for a large portion of the year (winter and spring), 2) a lack of diverse and abundant food resources, 3) lack of overhead cover (as depth and emergent aquatic plants), and 4) the overall unpredictable nature of the lagoon volume and water chemistry driven by random combinations of wave energy, tidal cycle, stream flow and sediment supply. The lagoon area may be used briefly by juvenile steelhead for acclimation to saltwater during spring out-migration, especially if a protected embayment exists. Continued monitoring of this lagoon and macroinvertebrates may improve our understanding on the role small dynamic lagoons, such as Garrapata, serve as potential habitat for steelhead and other estuarine species along the Big Sur Coast of California.

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2. Background and Study Area

Introduction

The Watershed Institute of California State University Monterey Bay (CSUMB) was contracted by the Garrapata Watershed Council (GWC) to assess water quality and general habitat conditions in the Garrapata Creek Lagoon (Garrapata Lagoon from here on). Collected data and field observations were also used to determine the degree to which steelhead trout (*Oncorhynchus mykiss*) use the lagoon as rearing habitat. Funding for this project was provided through an Adaptive Management Grant from the California Department of Fish and Game (CDFG).

Steelhead Use of Lagoons

Juvenile steelhead usually rear 1-2 years in freshwater before smolting and going to sea. Smolting is the physiologic transition juvenile steelhead undergo that enables them to adapt to saltwater conditions and life in the ocean (Shapovalov & Taff, 1954). Coastal estuaries, or lagoons, can be important habitat features for steelhead depending on a variety of key habitat components including, volume, overall depth, water chemistry (i.e. temperature, salinity, and dissolved oxygen), and ocean wave interaction.

In general, lagoons that maintain a thick freshwater layer throughout the summer usually maintain cool water temperatures, adequate dissolved oxygen levels, and healthy invertebrate populations, a critical food resource for rearing steelhead. Lagoons with deep-water habitat (> 1.5 meters) provide escape cover from avian predation and potentially provide thermal refuge during warm periods. However, deep portions of lagoons, especially off channel or scoured pools, can trap salt water and therefore become stratified. Stratification can lead to poor water quality and rearing conditions for juvenile steelhead. In the neighboring Carmel Lagoon, deep water exists in the off-channel south arm. Here saltwater persists at depth throughout the year resulting in both a thermally and density stratified water column. In turn this leads to minimal bottom dissolved oxygen concentrations during late summer and fall as water column mixing becomes negligible due to the density stratification (Casagrande & Watson, 2003; 2004). In the Carmel Lagoon, juvenile steelhead rear successfully using the upper layers of the water column and the main embayment, which usually remains fresh or slightly brackish and well mixed throughout summer and fall (Casagrande & Watson, 2003; 2004).

Smaller lagoons without deep off channel or scoured pools and with abundant freshwater inflow, will usually convert to freshwater by pushing saltwater through the bottom of the sandbar and thereby creating more favorable rearing conditions for steelhead (Smith, 1990). This is similar to the main, on-channel portion of the Carmel Lagoon near the sandbar.

If water quality and environmental conditions are favorable, juvenile steelhead can grow substantially in lagoons. Growth rate is critical because it can significantly improve the survival rate of juvenile steelhead in the ocean environment (Holtby et al. 1990). The combination of cool, well mixed waters with abundant macroinvertebrates allows steelhead to reach sizes more suitable for survival in the ocean after just one summer in a lagoon (Smith, 1990). Lagoons also

provide transitional brackish habitat where smolts can acclimate to saltwater prior to entering the ocean.

Lagoon use by adult steelhead is generally not as prolonged. During winter and spring, adult steelhead begin their upstream migration once flows increase and the sandbar is opened. If streamflow conditions are not conducive for upstream migration, adult salmonids may wait in deeper waters of the lagoon until streamflows improve. Unlike other salmonids most steelhead usually return to the ocean after spawning, and repeat the cycle the following year (Shapovalov & Taff, 1954). In drier watersheds, adults migrating out of the watershed late in the season can become trapped in the lagoon and holdover until the following winter.

Macroinvertebrates in lagoons

Lagoon macroinvertebrates are a critical component to the diet of steelhead (Fields, 1984; Robinson, 1993; Martin, 1995). In a lagoon, both the taxa composition and densities can change throughout the year depending on water quality conditions, vegetation, and sandbar conditions (Robinson, 1993; Larson et al. 2005). Common macroinvertebrate taxa found in lagoons of the Central California coast include the Gammarid amphipods *Corophium* and *Eogammarus*, a shrimp *Neomysis*, an isopod *Gnorimosphaeroma*, as well as some common freshwater inhabitants such as mayfly nymphs *Ephemeroptera*, midge larvae, *Chironomus*, and dragonfly/damselfly larvae, *Odonata* (Fields, 1984; Robinson, 1993).

Project Objectives

The primary objectives of this study were to:

- Assess seasonal water quality conditions in the lagoon
- Determine the extent of oceanic interactions with the lagoon (i.e. wave disturbance, salt water and kelp delivery and their impacts on the lagoon environment).
- Document the seasonal invertebrate communities and their relation to water quality and habitat conditions, and
- Assess the use of the lagoon by juvenile steelhead.

Study Area

Garrapata Creek Watershed

The Garrapata Creek Watershed is located in Monterey County, approximately 16 km (10 mi) south of Carmel, California (Fig. 2.1). The Watershed drains approximately 27.7 km^2 (10.7 mi^2) of primarily chaparral/scrub lands, canyon forests, and light residential development (PWA, 2003). The riparian vegetative community is dominated by redwood and tanoak in the mid to upper reaches of the watershed, with an alder/willow dominant community in the downstream reaches that extends to just below Highway 1. Below Highway 1 the channel is dominated by emergent aquatic vegetation.

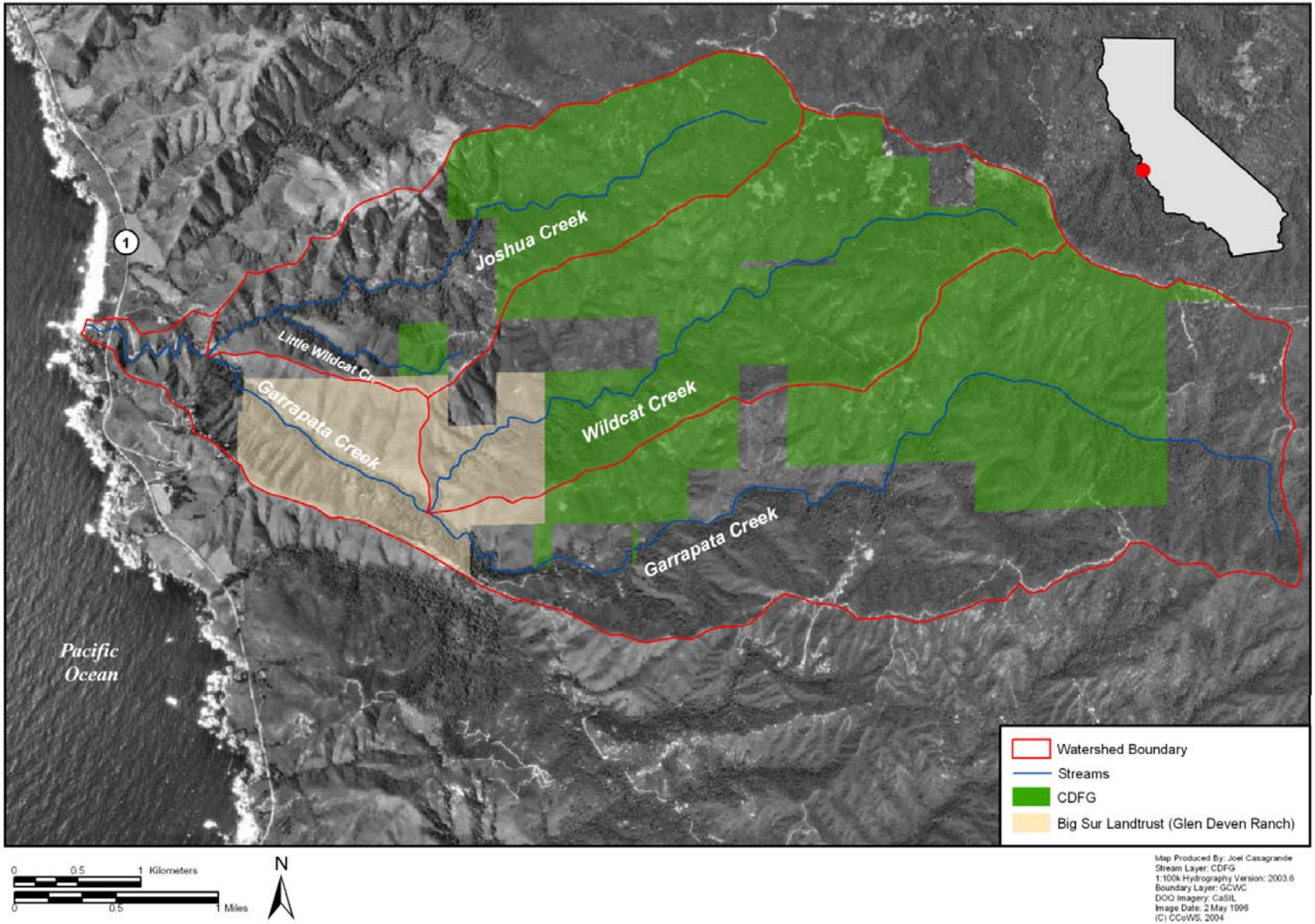

Figure 2.1. The Garrapata Creek Watershed. Public lands are shaded. (from Casagrande & Smith, 2005)

The Watershed consists of three major sub-basins, Garrapata Creek and two sub-watersheds Joshua and Wildcat Creeks, all of which are perennial. The watershed receives, on average, 71 cm (28 in) of rainfall a year based on a synthetic 82-year record (Smith et al. 2005). For a more detailed description of the hydrology in the Garrapata Creek Watershed, see Smith et al. (2005).

Garrapata Lagoon

Garrapata Lagoon is a small, narrow, often non-existent backwater located at the south end of Garrapata State Beach. Steep bedrock walls on both the northern and southern sides of the lagoon confine the total lagoon area to approximately 0.25 hectares (0.61 acres) (Fig. 2.2). Upstream near the Highway 1 Bridge, Garrapata Creek changes from a well-shaded, alder dominant stream, to a more exposed channel dominated by emergent aquatic vegetation (Fig. 2.3). A broad cobble riffle connects the creek with the main lagoon area. Substrate in the lagoon is predominantly sand with coarser substrate (cobbles and small boulders) closer to the creek inflow.

In winter, increased streamflows and significant wave action eventually remove the entire sandbar and drain any impounded water that may have existed. By early to mid summer decreased wave intensity and streamflow allow sand to accumulate at the mouth of Garrapata Creek, thereby forming a sandbar. In summer and fall, perennial streamflow entering the lagoon maintains a partial opening in the sandbar along the bar's southern end. The opening shifts to the northern end when wave action and increased streamflow reduced the sandbar height in winter.

The lagoon remains relatively shallow throughout the year. Depths in the lagoon are driven by the sandbar height. Typically, the deepest portions of the lagoon are found along the bedrock bluffs to the north (Figs 2.2 & 2.6). A maximum depth during the 2005 season was measured 1.6 m at the base of the northern bedrock. Overhead cover for steelhead is limited in part by the shallow nature of the lagoon, but also due to the lack of emergent vegetation (i.e. pondweed).

Garrapata Lagoon is dynamic, and its bathymetry can change rapidly. Wave and tidal interactions along with annual variability in streamflow affect the lagoon's shape, volume, and overall habitat suitability for steelhead. Various photos from the California Coastal Records Project[1] and photos taken during this project (See Appendix A) also show both annual and intra-annual variation in the size and shape of the Garrapata Lagoon.

[1] California Coastal Records Project: *Garrapata Lagoon Photo Summary*

http://www.californiacoastline.org/cgi-bin/timecompare.cgi?image=7223051&latdeg=36.421138&longdeg=121.925174&flags=0&year=1972&hidden=0&oneimage=current/200508582-2004/200402394-2002/1281-1987/8710043-1979/7934024-1972/7223051-

Figure 2.2 Garrapata Creek Lagoon. Photo: Doug Smith, 31Oct 04.

Figure 2.3 Upstream emergent vegetated reaches of Garrapata Creek near Highway 1. The main embayment of the lagoon is further downstream against the bluffs in the upper right corner of the photo. Photo: Joel Casagrande, 1 July 2004.

Figure 2.4 The cobble riffle separating the lower portion of Garrapata Creek from the lagoon embayment (looking upstream). Note the kelp accumulations in the foreground indicating the upstream extent of previous wave action. Photo: Joel Casagrande, 1 July 2004.

Figure 2.5 The eastern half of the main embayment with the downstream end of the cobble riffle shown in the lower right foreground. Photo: Joel Casagrande, 17 September 2005.

Figure 2.6 The western portion of the main embayment. Deeper water were located at the base of the bedrock bluffs in the upper right corner of the photo. Photo: Joel Casagrande, 04 August 2005.

Figure 2.7 The lagoon main embayment in early July 2004. Sand accumulations at mid lagoon nearly separated the lagoon into two halves. This same shape re-occurred in late fall 2005 (See Appendix). Photo: Joel Casagrande, 01 July 2004.

3. Methods

Monitoring Sites

Water quality conditions and macroinvertebrates were assessed at six sites (Figure 3.1) on several different days, although macroinvertebrates were not sampled at every site or on every sampling run. The sites were selected to represent all possible conditions with respect to depth, substrate conditions, and more importantly proximity to the ocean and creek inflow. Four sites were monitored in the main body of the lagoon (Sites 2-5), one in the outflow channel close to the ocean and one upstream in the inflowing creek.

Site 1 was located within the outflow channel of the lagoon against the southern bluff. This site consistently experienced direct wave interactions. Total depth averaged less than 0.5 m.

Site 2 was against the inside portion of the sandbar within the main embayment - just upstream from the outflow channel (Site 1). Wave interaction was limited to large wave overwash events. Depths were predominantly less than 0.5 m.

Site 3, usually the deepest point in the lagoon during summer and early fall monitoring, is located in the northwest corner (Fig. 2.6). A maximum depth at this site was measured at 1.30 m on September 16 2005. A staff plate was installed at this site on August 27th to assess relative changes in water elevation.

Site 4 is located against the northern bluffs at approximately the middle of the lagoon roughly 22 m upstream from Site 3. This site is generally the second deepest area in the lagoon, although it became the deepest in the lagoon by mid October.

Site 5 is located approximately 15-20 m upstream of Site 4 and just below the creek inflow. This site is typically the "freshest" in the lagoon embayment and substrate consists of a mixture of large cobbles and sand.

For reference, water quality measurements were also collected upstream in Garrapata Creek (RIV in Fig. 3.1). This site was purposely selected well upstream and away from any possible oceanic interactions.

Water Quality Measurements

Water quality surface to bottom profiles, for temperature, dissolved oxygen, and salinity, were measured using both a YSI 556 and a YSI 85 handheld meter (YSI Environmental®). Measurements were taken at quarter meter intervals at each monitoring site during each visit. Calibration of the YSI was conducted on a routine basis to ensure accuracy of all water quality parameters. Water column clarity was assessed using a secchi disk at each site, although the bottom was generally visible throughout the study.

Figure 3.1 Sampling locations in Garrapata Lagoon.

Macroinvertebrate Sampling

The presence and general abundance of both water column and epibenthic macroinvertebrate taxa were determined by spot-checking throughout the lagoon using a 500 µm D-net. For taxa present in the water column, the D-net was swiped through the water column several times in a side-to-side manner incorporating a variety of water elevations with the exception of the near bottom waters. The macroinvertebrates and any coarse matter (e.g. twigs, kelp, algae) were placed in a jar with 90% ethanol solution.

For epibenthic taxa, the D-net was lightly dragged along the bottom of the lagoon, starting away from and towards the person sampling. The macroinvertebrates and any coarse matter were placed in a jar with 90% ethanol solution.

In the lab, samples were sorted and all macroinvertebrates were identified to at least the Family Level. All samples were preserved in 90% ethanol.

The following documents were used to assist in the identification of the macroinvertebrates:

Merritt & Cummins (1996)
Harrington & Born (2000)

Steelhead Presence/Absence

A combination of bank observations and underwater camera surveillance was used to determine the presence/absence of steelhead in Garrapata Lagoon.

On each visit to the lagoon, bank observations were made using polarized sunglasses. In addition, an Aqua Vu® (Nature Vision Inc.) underwater camera system was used to survey the lagoon twice during the present study. The camera is attached to a 1.75-meter telescoping rod. A cable connects the camera to a viewing screen that is held by the observer. The observer can use the rod to point and maneuver the camera in any direction while viewing live underwater observations. Visibility for the camera is approximately equivalent to that of a submerged diver with a mask.

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4. Results: Hydrologic and Oceanic Data

Streamflow Data

Garrapata Lagoon receives perennial flow from the Garrapata, Joshua, and Wildcat creeks. There are two active stream gages in the watershed, one on Garrapata Creek near the Trout Farm and the other is located on Joshua Creek approximately 100 m upstream of the confluence with Garrapata Creek. The gage on Garrapata Creek is upstream from the Joshua Creek confluence and both are approximately 1.5 km upstream of the lagoon. Figures 4.1 and 4.2 show the hydrographs for both the Garrapata and the Joshua Creek gages during the project period. Figure 4.3 is a hydrograph of the sum of both Joshua and the Garrapata Creek gages. An error in the Garrapata gage precluded any data following October 1st 2005.

Ocean Wave Height and Tide Elevation Data

Hourly wave and tide levels are shown in Figure 4.4 & 4.5 respectively. Wave height data were retrieved from the NOAA/NWS moored buoy 46042, which is located in the center of Monterey Bay. Local (e.g. Garrapata Beach) wave and swell height patterns ultimately depend on a variety of factors including shore morphology, predominant wave direction, and the degree of wave refraction (Thorton, 2005). The predominant wave direction for the Central Coast is from the northwest. Beaches facing to the south and southwest are more protected from waves coming from the northwest and westerly direction (Thorton, 2005). Garrapata State Beach faces slightly to the southwest and thus is less protected, especially from common northwest and westerly swells. Because the lagoon mouth is at the southern end of the beach, there is no northern headland for protection against west and northwesterly swells. Figure (4.6) shows two examples of swell height for the Monterey Bay and Big Sur Coastal areas during smaller and larger wave events. Both images show that the Garrapata Beach area is not as protected as beaches near Santa Cruz and in Carmel Bay (northern headland protection) or Monterey Harbor (southern headland protection).

During the present study, significant wave events occurred in early June and more consistently from mid October through the end of the year (Fig. 4.4) Previous studies have shown that such wave events often result in significant wave overwash, which often leads to adverse water quality conditions in the lagoon (Smith, 1990; Casagrande & Watson, 2002, 2003; Watson & Casagrande, 2004). In addition to saltwater, waves often deliver copious amounts of kelp, which decay on the lagoon bottom often producing anoxic conditions.

Tide elevation data were retrieved from the NOAA/NOS station 9413450 located in Monterey Bay Harbor. Each day the Big Sur Coast has two high and two low tides of different elevations. Tide elevations peaked at 1.3 m (4.3 ft) on July 20th (Fig 4.5). Throughout the study period, the lower of low tides occurred predominantly in the early morning hours or at night and therefore were not monitored. All monitoring was conducted at or near high tides during daylight between 0900 and 1600 hours. On most visits to the lagoon, wave overwash or inflow through the opening of the sandbar was observed, in part due to high tide conditions and sporadic large surf.

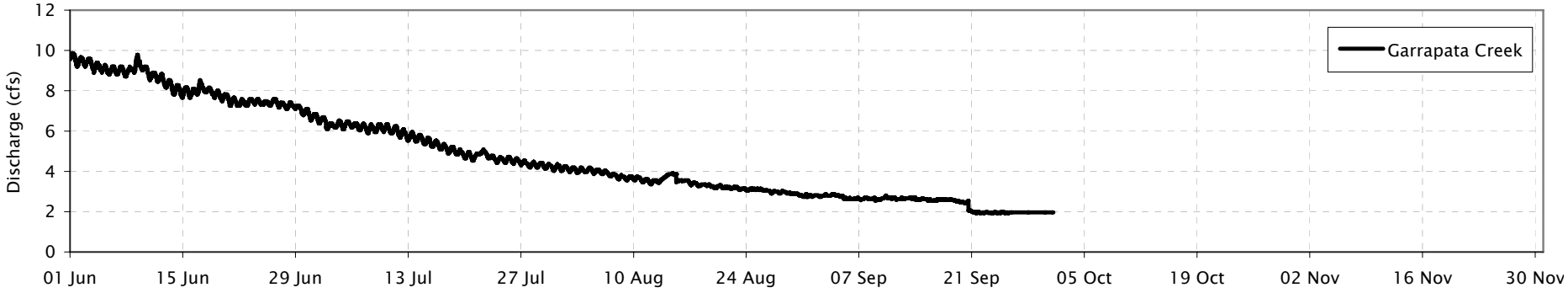

Figure 4.1 Garrapata creek hydrograph. Note gage error: record ends Sep. 30th.

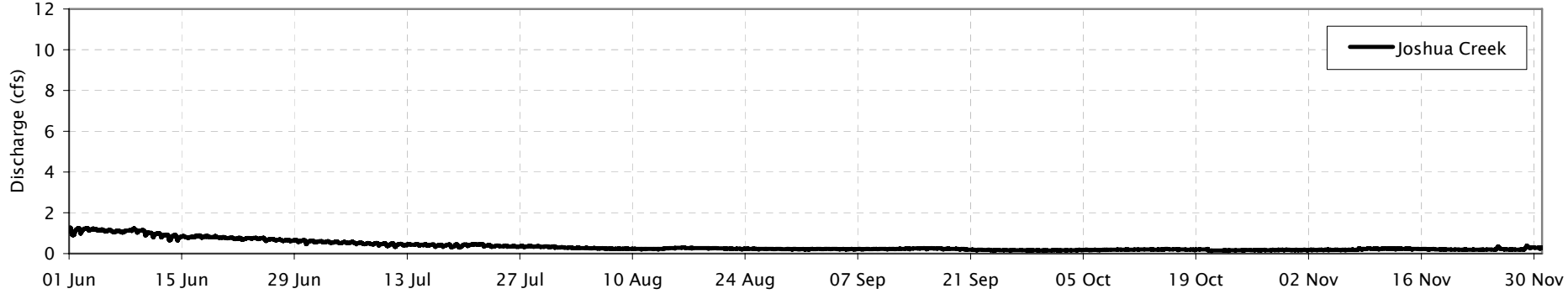

Figure 4.2 Joshua Creek hydrograph (June 1st to November 30th, 2005).

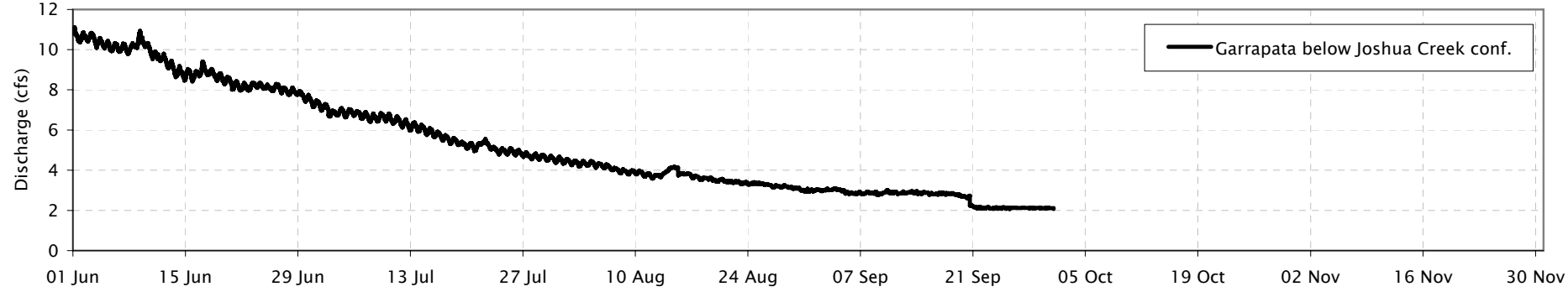

Figure 4.3 Hydrograph for Garrapata Creek below the Joshua Creek confluence. Note gage error: record ends Sep. 30th.

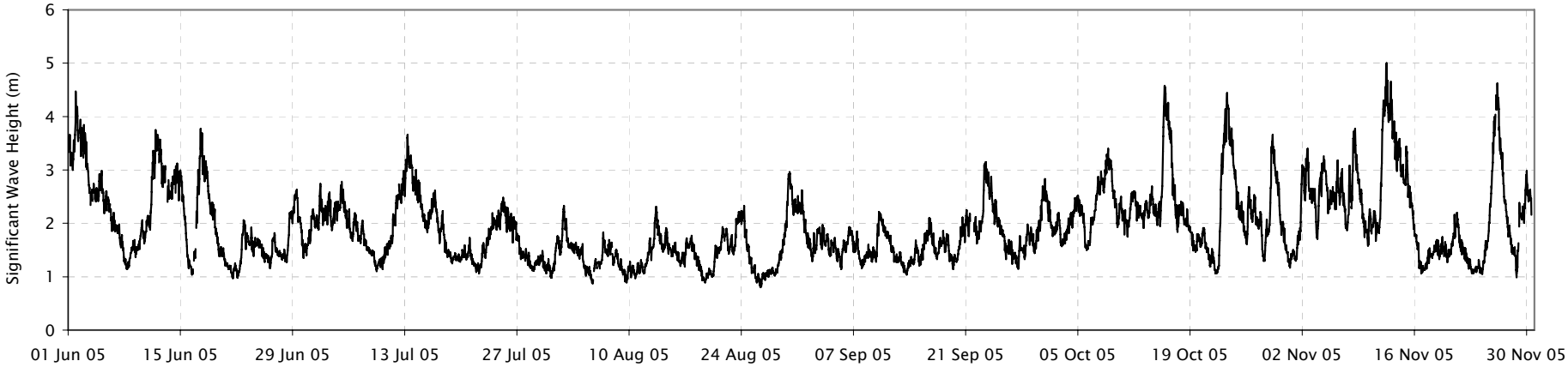

Figure 4.4 Significant wave height Monterey Bay. Data Source: National Data Buoy Center, NOAA/NWS Moor Buoy 46042

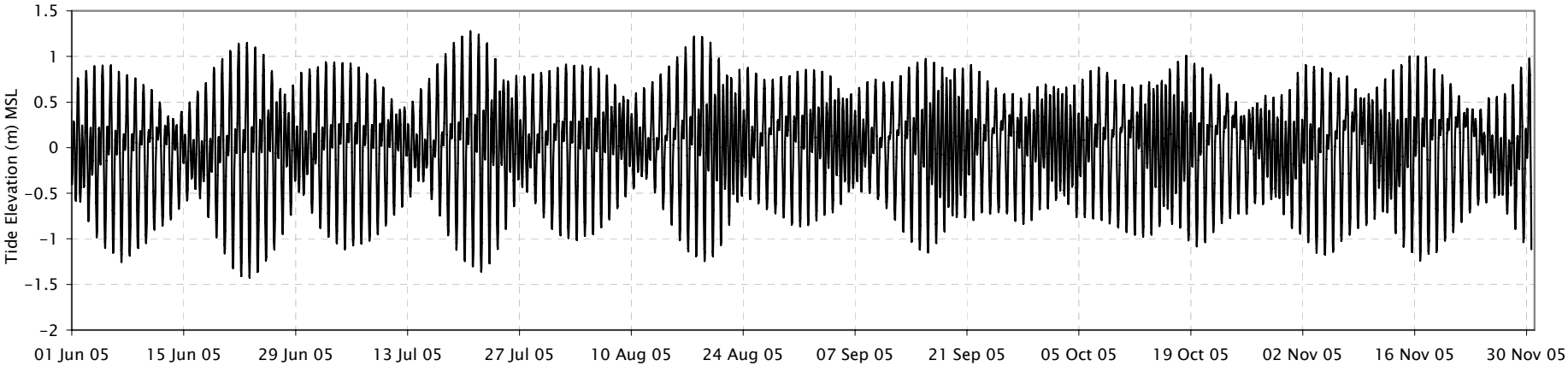

Figure 4.5 Tide elevations Monterey Harbor. Data Source: NOAA/NOS, Station 9413450.

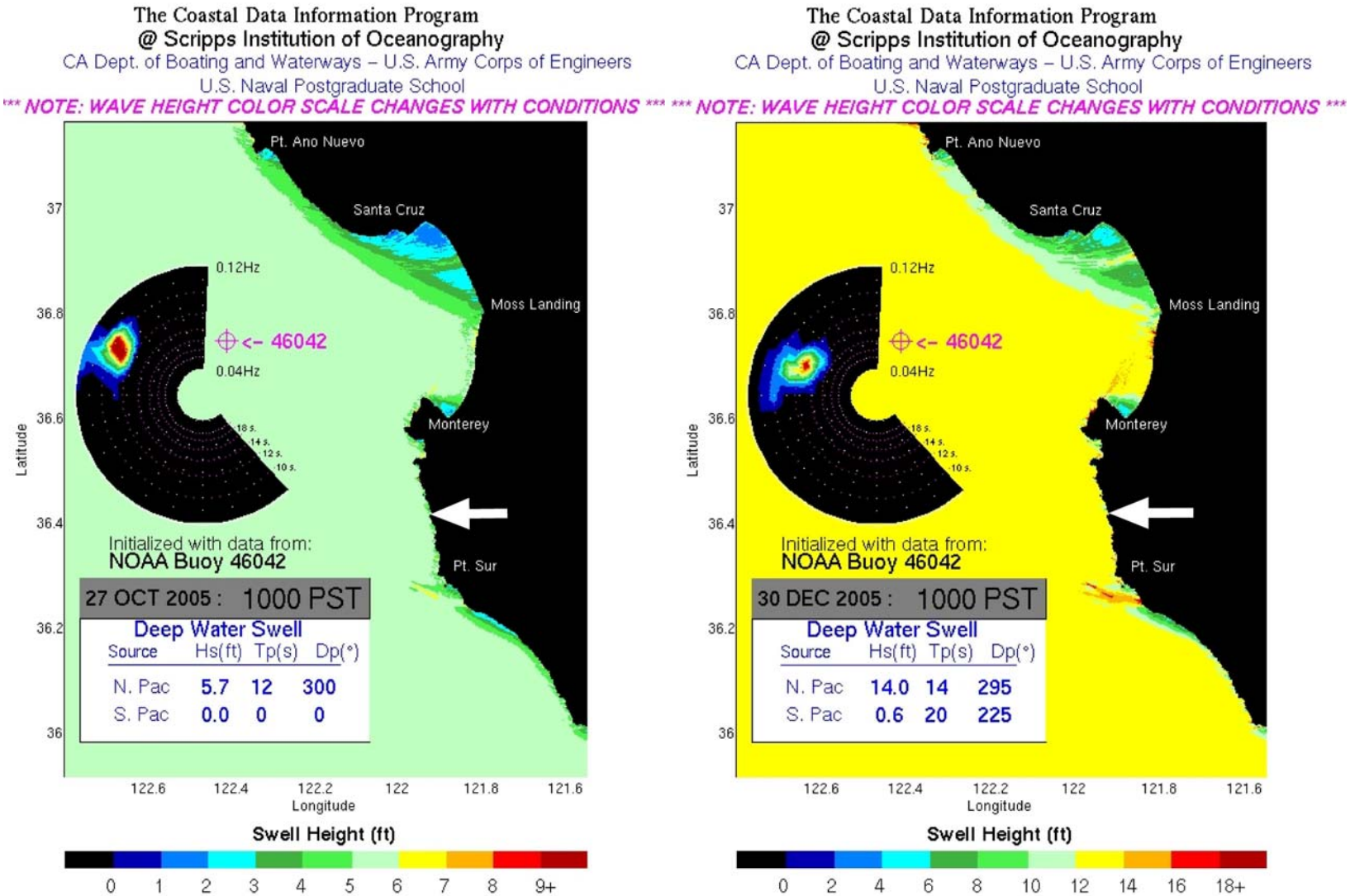

Figure 4.6 Deep water swell height for October 27th (smaller waves) and December 30th (larger waves) generated from NOAA Buoy 46042. White arrows show the approximate location of Garrapata Lagoon. Image Source: http://cdip.ucsd.edu/models/monterey.

5. Results: Monitoring Timeline

Water quality, macroinvertebrates and habitat conditions of Garrapata Lagoon were assessed throughout the summer and fall of 2005. Table 5.1 shows the dates, types of data collected, as well as weather and streamflow conditions at the lagoon.

Table 5.1 Sampling dates, data collected, weather and streamflow entering the lagoon.

Date/Time	Data Collected	Weather conditions	Estimated Streamflow (cfs)
23 Jun 2005 10:00	WQ, HAB	Overcast, slight breeze, cool	8.3
04 Aug 2005 13:30	WQ, HAB, INV	Overcast, slight breeze, cool	4.5
27 Aug 2005 12:20	WQ, HAB	Partly cloudy, windy, cool	3.6
16 Sep 2005 12:30	WQ, HAB, INV	Clear, windy, mild (overcast in the morning)	3.3
27 Sep 2005 10:00	WQ, HAB	Clear, slight breeze, warm	2.1
06 Oct 2005 15:23	WQ, HAB	Partly cloudy, windy, mild	*< 2.0
12 Oct 2005 14:52	WQ, HAB	Overcast, breezy, cold	*< 2.0
22 Oct 2005 11:51	WQ, HAB, INV	Overcast, windy, cold	*< 2.0
02 Nov 2005 10:26	WQ, HAB, INV, FISH	Partly cloudy, breezy, cool	*< 2.0
18 Nov 2005 10:40	WQ, HAB, FISH	Clear, calm, warm	*< 2.0
30 Nov 2005 10:00	WQ, HAB, INV	Partly cloudy/hazy, cool, slight breeze	*< 2.0

WQ = water quality

INV = macroinvertebrates

HAB = general habitat observations

FISH = Direct fish observations (i.e. snorkeling, underwater camera, or CDFG sampling). Bank observations for steelhead were made on all visits and are not noted specifically here.

* Streamflow records after September 30th are not available for Garrapata Creek. With the possible exception of November 30, which followed a moderate rain event, streamflow for all other monitoring dates post September 30th was likely < 2 cfs.

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6. Results: Summer Conditions (June 23rd – Sep 16th 2005)

June 23, 2005

Water Quality

On June 23, the lagoon was completely open to the sea with no impounded water present. Streamflow entering the lagoon was approximately 8.3 cfs and flowing out to the ocean along the northern bluff (Figs 4.3 & 4.5 and Table 5.1). Fresh kelp was abundant in the lagoon area indicating the extent of the tidal influence (Fig 6.1).

Streamflows were cool (13°C), well oxygenated (11 mg/L), and fresh (0.13 ppt) all the way down to the mouth. Maximum depths were less than 0.25 m throughout the lagoon area. Pools were found upstream of the main embayment in the lowest reaches of Garrapata Creek (Fig. 6.2). Several small fish were observed here that appeared to be juvenile steelhead, although this was not positively confirmed by sampling.

Figure 6.1. Fresh kelp at the lower end of the Garrapata Lagoon. Photo: Joel Casagrande 23 June 2005.

Figure 6.2 The lower reach of Garrapata Creek with emergent vegetation just upstream of the main embayments. Photo: Joel Casagrande 23 Jun 2005.

August 4, 2005

Weekly observations made from the Highway 1 Bridge revealed that a sandbar formed at the lagoon's mouth sometime in mid to late July forming a small and mostly shallow embayment (Fig. 6.5 and Appendix A).

Water Quality

Streamflow had declined substantially since June 23rd (Fig. 4.3 & Table 5.1). Water quality conditions were well mixed with cool temperatures (15°C) and oxygenated waters to depth, fresh waters at the surface, and more saline waters on the bottom (Figs 6.3 & 6.4). Kelp was abundant on the bottom of the lagoon at sites 3 and 4, however anoxic conditions were not present. Streamflow entering the lagoon was enough to maintain adequate dissolved oxygen levels. Maximum depth in the lagoon was slightly greater than 1 meter along the bedrock bluffs in the northwest corner. Ocean wave heights around this time were not significant, thus allowing a modest freshwater lens to develop in the lagoon. Water quality conditions were suitable for steelhead at this time, although none were observed.

Macroinvertebrates

Both water column and epibenthic macroinvertebrates were spot-checked at Sites 2, 3, 5. With the exception of only a few *Chironomid* near the creek entrance (Site 5), no macroinvertebrates were observed in the lagoon. Because of the recent closure of the lagoon, it is likely that invertebrate populations had not established themselves in such a short period of time.

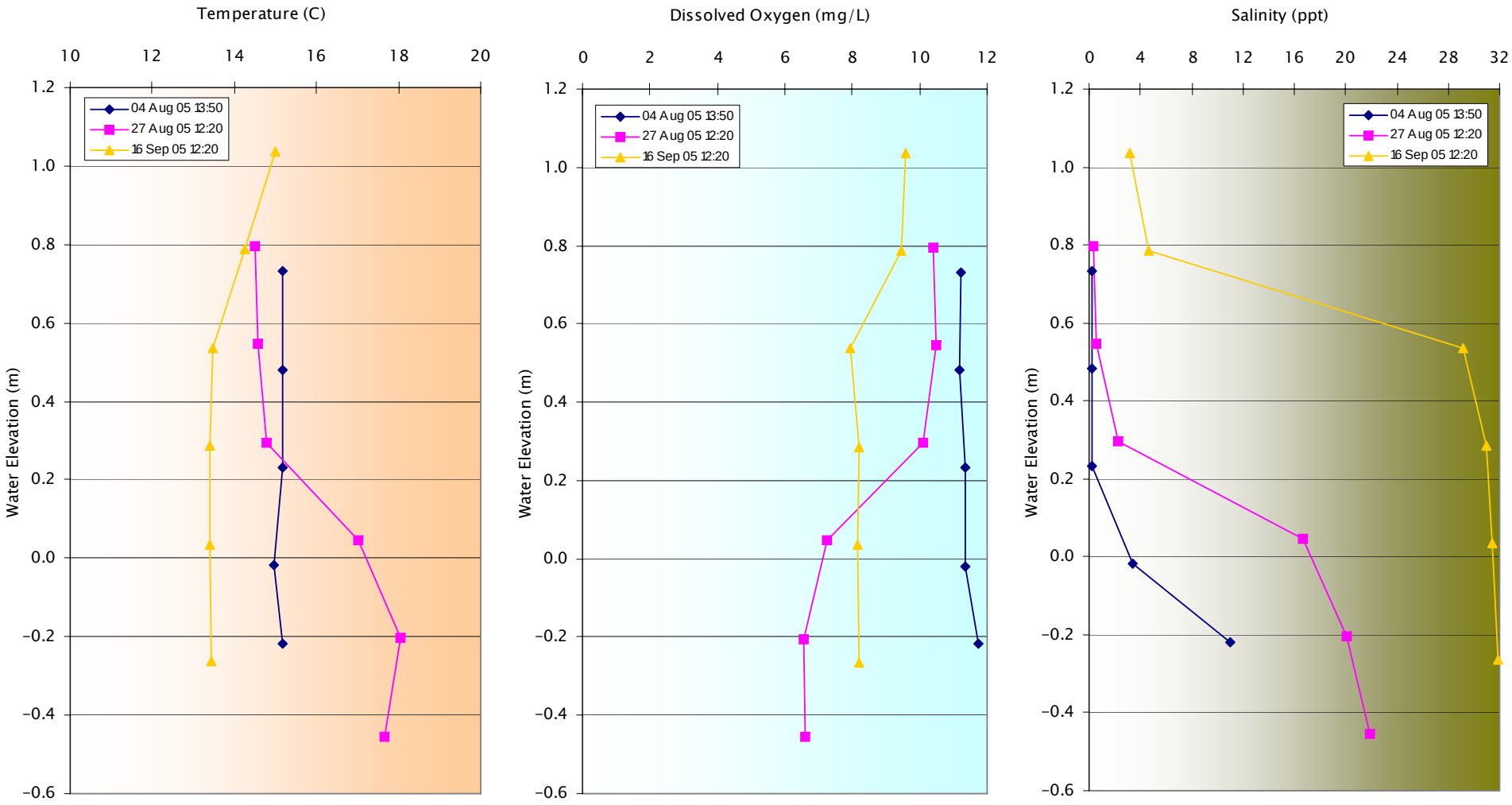

Figure 6.3 Summer water quality profiles (temperature, dissolved oxygen, and salinity) from Site 3 in the Garrapata Lagoon.

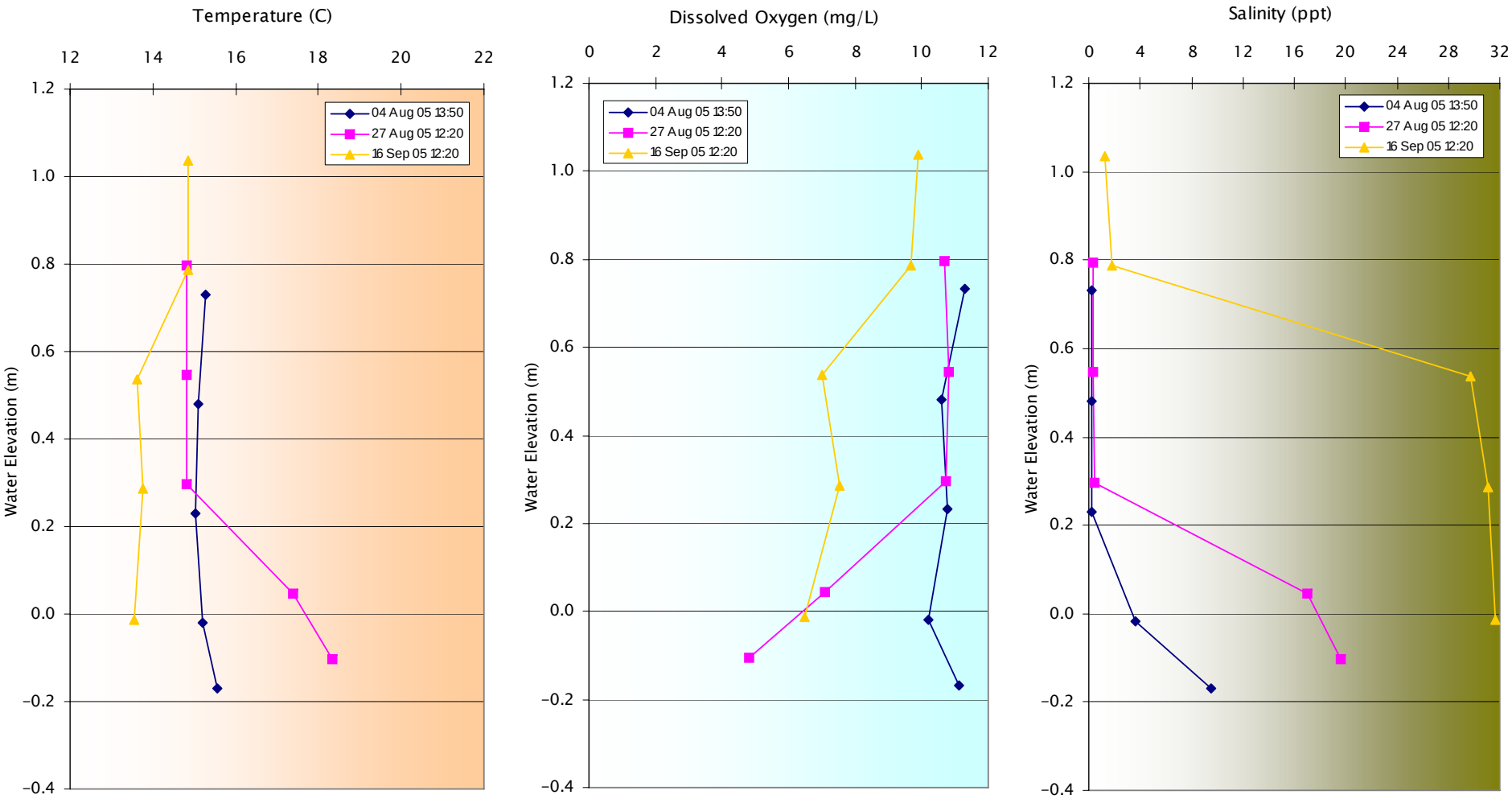

Figure 6.4 Summer water quality profiles (temperature, dissolved oxygen, and salinity) from Site 4 in the Garrapata Lagoon.

Figure 6.5 Garrapata Lagoon looking upstream. Note kelp floating on surface. Photo: Joel Casagrande, 04 August 2005

August 27, 2005

Water Quality

On August 27, afternoon water quality conditions were measured throughout the lagoon. Streamflow was still entering the lagoon and a small opening in the sandbar remained in the southwest corner (Fig. 6.6). Morning weather conditions were overcast, windy and cool, and by afternoon, skies were partly cloudy, but remained windy and cool (Table 5.1). There were noticeable changes in the sandbar condition and the outflow channel between the lagoon and the ocean when compared to the previous visits to the lagoon (Fig. 6.7). Although wave heights appear to have been minimal prior to the 27th (Fig. 4.4), high tides were near peak levels between August 16th and 20th (Fig. 4.5), which may explain the significant changes in the sandbar.

The water column in the lagoon was thermally stratified with an apparent halocline (Figs 6.3 & 6.4). This can have adverse consequences for water quality conditions. In general, saltwater on the lagoon bottom traps incoming solar energy, thus warming the bottom waters. Also, because of the density differences between salt- and freshwater, complete water column mixing is reduced substantially resulting in the inability for heavier saltwater to lose heat to the atmosphere. Warmer water temperatures then increase the depletion of oxygen along the bottom due to more rapid decomposition of organic matter (e.g. kelp). Although water quality conditions were suitable, no steelhead were observed in the lagoon,.

Figure 6.6 The mouth of the Garrapata Lagoon along the southern bluffs. Photo: Joel Casagrande 27 August 2005

Figure 6.7 The outflow channel connecting the lagoon and the ocean (looking northwest). On August 4th, the channel was straight out along the southern bluff as opposed to the sinuous pattern shown here. Photo: Joel Casagrande, 27 August2005

September 16, 2005

Water Quality

Increased wave action coupled with high tides had increased the volume of saltwater in the lagoon. This is evident by the substantial change in the volume of saltwater throughout the lagoon (Figs 6.3 & 6.4) and the abundance of fresh kelp on both the surface (Fig. 6.8) and bottom of the lagoon as well as on the sandbar (Fig. 6.9).

Weather conditions were windy with clear skies and mild air temperatures. Water temperature in the lagoon had cooled at depth, also a result of the recent addition of cooler salt water to the bottom. Suitable dissolved oxygen concentrations to depth also reflect the recent mixing of ocean wave inputs.

Water quality conditions were suitable for steelhead in the lagoon, especially in the upper layers of the water column. However, no steelhead were observed in the lagoon at this time.

Macroinvertebrates

Macroinvertebrates from both the water column and epibenthic habitats were sampled at Sites 3, 4, & 5 and from the inflowing creek. No taxa were collected from the water column at any site (Sites 3, 4, 5). At each site, three sets of three repeated swipes (each swipe equals both a back and forth motion of about 2 meters) with the D-net were taken at each site, all resulting in no taxa. Water quality conditions (brackish, cool, and well oxygenated) were suitable for a host of invertebrate taxa typically present in local lagoons at this time of year (Larson et al. 2005).

Epibenthic habitats were sampled at each of the three sites with three sets of three swipes along the bottom. At Site 3, a few *Dipteran*s (*Tipulidae*) were found. It is likely that they were washed in from the cobble riffle upstream where there numbers were much higher. At Site 4, Dipterans (*Tipulidae* and *Chironomidae*) were the only taxa present, but again in low numbers. Further upstream, at Site 5, only the isopod, *Gnorimospherma* (*Sphaeromatidae*) was collected, but in low numbers. Also, two 60 sec samples were taken with a D-net from the middle of the cobble riffle just upstream of the lagoon. Here *Gnorimospherma* and three Dipteran taxa (*Tipulidae*, *Chironomidae,* & *Simuliidae*) were found and in relatively higher numbers.

It is unclear why macroinvertebrates are consistently in such low abundance in the lagoon and why typical lagoon taxa such as *Corophium* and *Neomysis* are absent all together, especially when water quality conditions have been suitable. Several factors may have contributed to this. First, the late closure of the lagoon could have limited colonization time. Second, the lack of emergent vegetation present in the lagoon (with the exception of decomposing kelp) and finally, both recent and constant changes in water quality (especially salinity) may have disturbed the overall colonization of macroinvertebrates in the lagoon.

Figure 6.8 The main embayment of the Garrapata Lagoon on September 17, 2005. Note both the presence of kelp accumulated at the base of the bluff in the background and the inundation of the cobble riffle, showing the increasing in water elevation. Photo: Joel Casagrande 17 Sep 2005.

Figure 6.9 The inland side of the sandbar, or back beach, showing kelp deposits from recent waves overtopping the bar at high tide. Photo: Joel Casagrande, 17 Sep 2005.

7. Results: Fall Conditions (Sep 27th – Nov 30th 2005)

September 27, 2005

Water Quality

Water elevation in the lagoon was much lower (Fig. 7.1) since the previous visit on September 17th, although the water column remained stratified. Streamflow entering the lagoon had declined by approximately 1.2 cfs. Temperatures were cool at the surface but warm at depth (Figs 7.2 & 7.3). Dissolved oxygen concentrations were suitable in the upper layers but anoxic along the bottom of the deeper sites (Sites 3 & 4). The increase in bottom water temperatures likely led to an increase in the rate of decomposition of the accumulating kelp along the bottom of the lagoon, thus contributing to the lack of oxygen at depth.

Overall, suitable water quality conditions for rearing steelhead were present in the lagoon, but only in the upper layers of the water column. Emergent vegetation had not colonized therefore overhead cover remained limited in the lagoon. The shallow depths in the lagoon coupled with a flat, calm water surface, created ideal conditions for observing juvenile steelhead. However, no steelhead were observed at this time.

Figure 7.1 Main body of the lagoon. Photo: Joel Casagrande, 27 Sep 05.

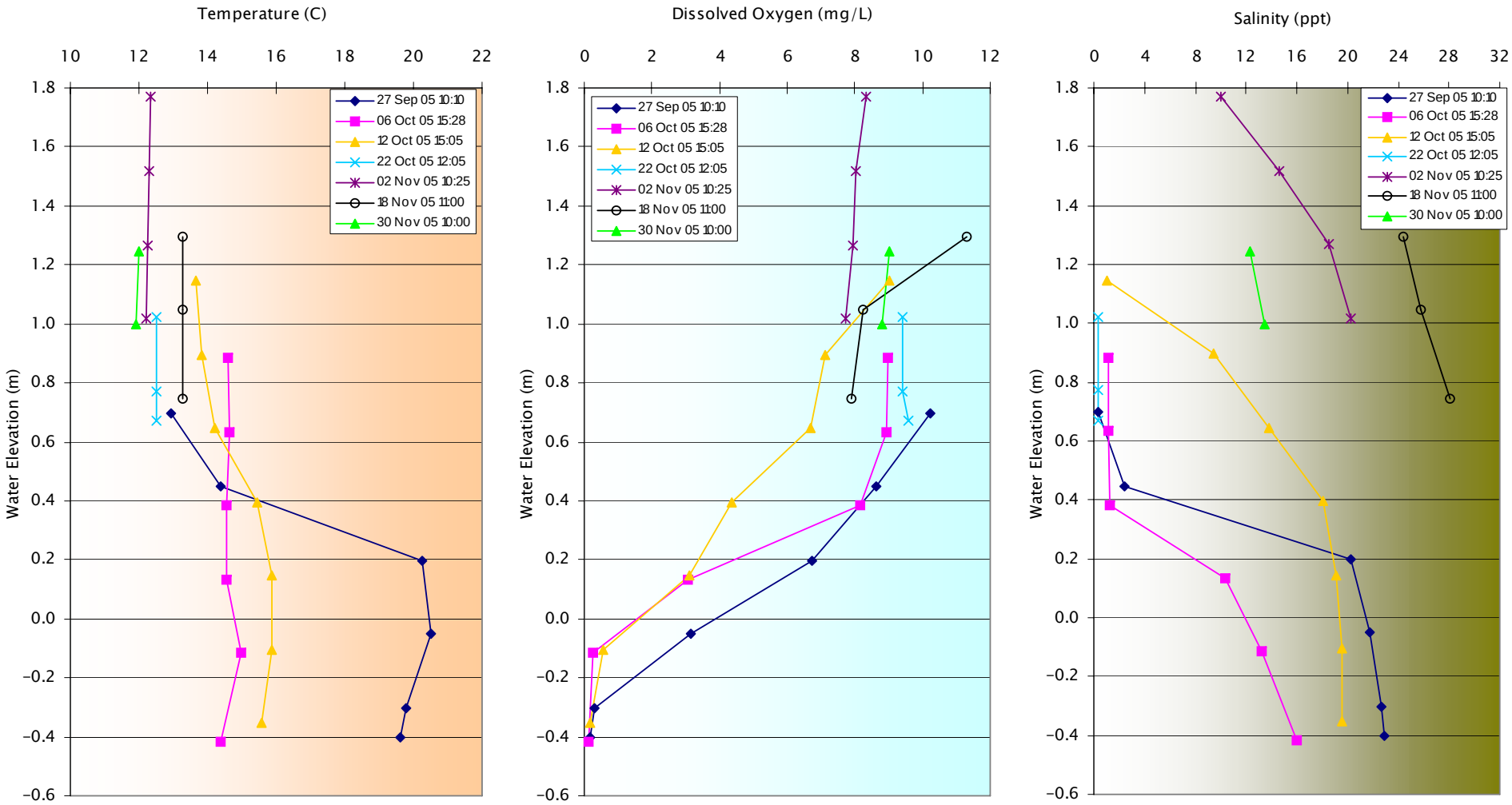

Figure 7.2 Fall water quality profiles (temperature, dissolved oxygen, and salinity) from Site 3 in the Garrapata Lagoon.

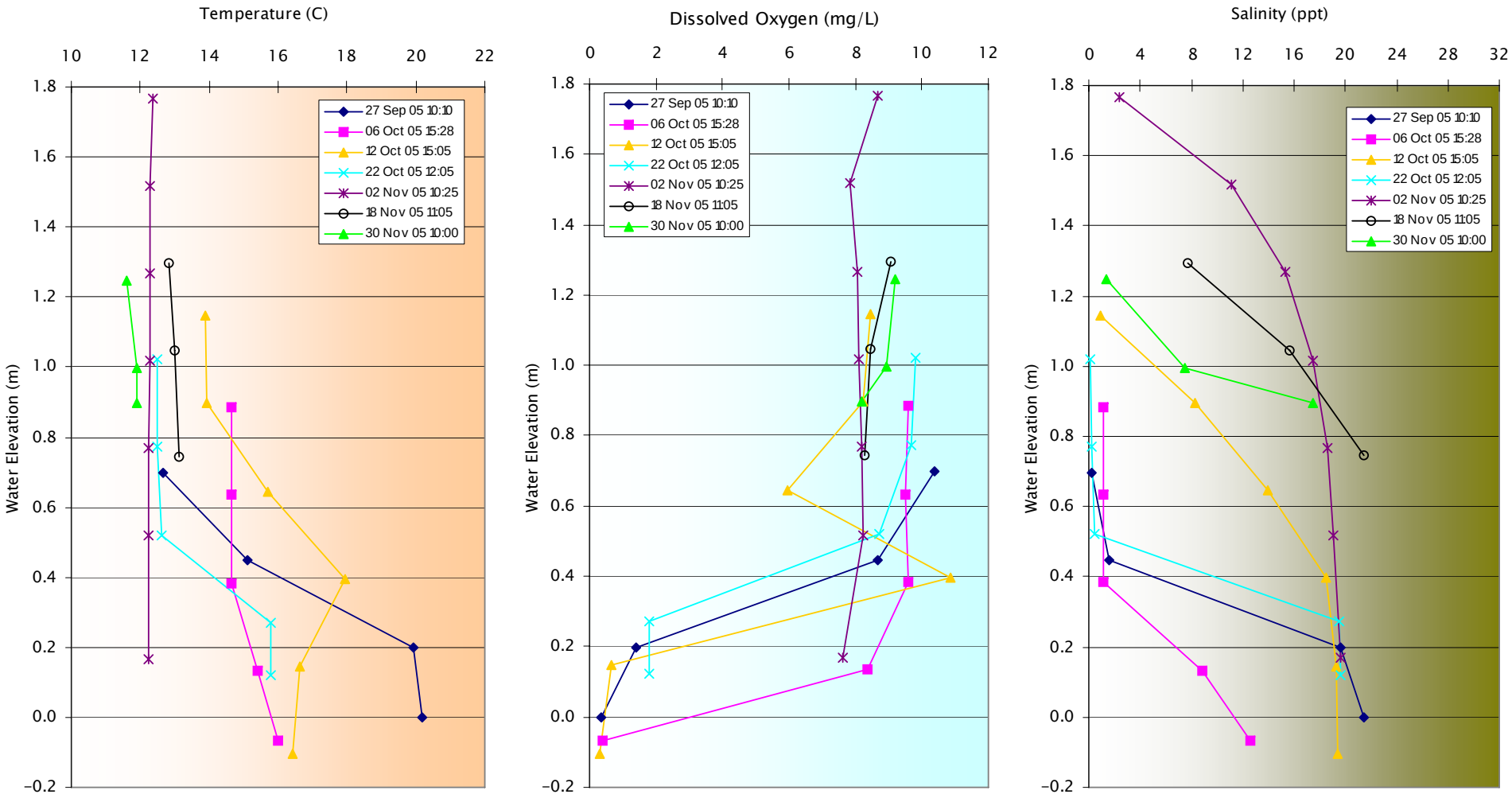

Figure 7.3 Fall water quality profiles (temperature, dissolved oxygen, and salinity) from Site 4 in Garrapata Lagoon.

Figure 7.5 Looking downstream at the backside of the sandbar. Photo: Joel Casagrande, 27 Sep 2005.

Figure 7.4 The outflow channel of the lagoon. Note the degree of down cutting through the sandbar. This did not exist 10 days prior and suggests a "filling/breaching" event in between the 17th and 27th of September. Photo: Joel Casagrande, 27 Sep 2005.

October 6, 2005

Water Quality

At this time the lagoon water elevation increased by approximately 0.2 m (0.6 ft) since September 27th. The salinity profiles (Figs 7.2 & 7.3) show an increase in the freshwater lens in the lagoon indicating increased retention of incoming freshwater and due to reduced seawater inputs. No waves were observed washing over the sandbar at this time, although an occasional wave did surge up the outflow channel and fresh kelp on the backside of the sandbar suggests that ocean waves recently had reached the lagoon over the bar.

The lagoon waters were cool from top to bottom, however salinity stratification persisted (Figs 7.2 & 7.3). Dissolved oxygen concentrations continued to decrease at all depths, likely a result of continued decomposition of the large amounts of kelp on the lagoon bottom and a lack of mechanical mixing throughout most of the lagoon. Oxygen concentrations at depth were higher closer to the creek inflow.

Water quality conditions were suitable for steelhead, especially in the upper 0.75 m of the water column and closer to the creek inflow. However, steelhead were not observed in the lagoon at this time.

October 12, 2005

Water Quality

Less than a week later, the lagoon water elevation was 0.25 m (0.9 ft) higher (Fig. 7.6). This change was likely due to high tidal conditions and wave overwash, which increased the amount of saltwater in the lagoon (Figs 7.2 & 7.3). Days prior to this monitoring, a wave event (> 3.0 m) had occurred (Fig. 7.2). Fresh kelp was present on the sandbar and throughout the lagoon area up to the cobble riffle (Fig. 7.7).

Dissolved oxygen concentrations were slightly lower than the previous visit. This was likely a result of continued kelp decomposition. At Site 4, a peak dissolved oxygen concentration (> 10.0 mg/L) was present at the halocline (0.75 m depth). Such phenomena are common in Central Coast lagoons (Smith, 1990; Casagrande & Watson, 2002, 2003; Watson & Casagrande, 2004). The halocline typically has higher water temperatures (Figs 7.2 & 7.3) which induce higher rates of photosynthetic activity, thus creating localized increases of dissolved oxygen at these depths.

Figure 7.6 A fuller Garrapata Lagoon on October 12, 2005. Compare with Figure 7.1. Photo: Joel Casagrande 12 Oct 2005.

Figure 7.7 Kelp accumulations at the eastern edge of the lagoon near the cobble riffle. Photo: Joel Casagrande 12 Oct 2005.

October 22, 2005

Water Quality

Large waves had significantly altered the lagoon days prior to the 22nd of October (Fig. 4.4). Sand deposits had filled approximately one-quarter of the lower lagoon area including Site 3, the deepest location in the lagoon (Figs 7.8 & 7.9). The sandbar elevation was reduced substantially by the waves. This allowed ocean waves to enter the lagoon more frequently, although during this monitoring ocean wave inputs were minimal.

Water quality in the lagoon was measured at Sites 3, 4 & 5, as well as the creek inflow. – Sites 1 and 2 were now only sheet flows (< 0.10 m) exiting the lagoon. Site 3 was mainly flowing water with a maximum depth of only 0.35 m. At this site, water quality conditions were cool, well oxygenated and fresh – essentially creek water flowing at the surface (Fig. 7.2). Upstream at Site 4, moderate depths (0.95 m) were still available. The water column remained stratified – warm, less oxygenated and salty water at depth with cooler, oxygenated fresher waters at the surface (Fig. 7.3). Salt concentrations at Site 4 and 5 were diluted by incoming fresh water from Garrapata Creek. At Sites 4 & 5, decomposing kelp was resulting in anoxic conditions on the bottom of the lagoon.

Macroinvertebrates

Water column and epibenthic macroinvertebrates were sampled at Sites 4 & 5. No taxa were present in all water column attempts at both sites. At Site 4, epibenthic taxa were few, only the isopod (*Gnorimospherma*) and bloodworms (*Chironomidae*) were found but in low abundance. At Site 5, a greater variety of substrate types were present including purely sand, sand with large cobbles, and decomposing kelp over sand. Samples taken over the decomposing kelp had some *Chironomidae*. Over the purely sandy substrate, both *Gnorimospherma* and *Chironomidae* were present and slightly more abundant. The cobble dominant substrate had some *Chironomidae* and two aquatic bristleworms, (*Polychaeta*) were found, although these are not typically taken by steelhead (Martin, 1996).

In general, invertebrate populations in the lagoon were again low and restricted to only a few taxa. While both *Chironomidae* and *Gnorimospherma* are consumed by juvenile steelhead (Martin, 1996), their relatively low abundance suggests that there was likely not enough food in the lagoon for steelhead. Further, overhead cover continued to be limited in the lagoon.

Figure 7.8 Sand deposition due to high surf in the lower half of the Garrapata Lagoon. Note: Compare with Figures 7.1 & 7.6. Photo: Joel Casagrande, 22 Oct. 2005

Figure 7.9 Loss of deeper water habitat at Site 3 due to sand deposition. Photo: Joel Casagrande, 22 Oct. 2005.

November 2, 2005

Water Quality

On Saturday October 29th large waves were observed crashing into the lagoon reaching upstream to a point approximately half way to the large cobble riffle (Fig. 4.4). Large waves (> 3.0 m) began at Garrapata Beach on Friday morning (Oct. 28th) (Ken Ekelund, pers. comm.). On November 2nd ocean waves were frequently entering the lagoon (Fig. 7.10). The water elevation in the lagoon had increased substantially. This was a result of large volumes of sand that filled in the lower half of the lagoon. Sites 1, 2, remained completely filled with only a sheet of water flowing out to sea while Site 3 regained some depth due to increased water elevations (Fig. 7.11). The increased water elevations in the lagoon completely inundated the cobble riffle upstream (Fig. 7.12).

Water quality in the lagoon was cool and mostly saline due to the wave event, although bottom waters were still diluted from incoming freshwater (Figs 7.2 & 7.3). Surface and subsurface salt concentrations were lower closer to the creek inflow. Mechanical mixing from ocean waves created well-mixed temperature and dissolved oxygen profiles.

Figure 7.10 Ocean waves breaking on what used to be the sandbar separating the lagoon from the ocean. Photo: Joel Casagrande, 02 Nov. 2005

Steelhead Presence/Absence

A handheld underwater camera mounted on a rod was used to look for and potentially detect steelhead in the lagoon (Fig. 7.13). The lagoon was checked in a systematic manner walking from side to side (north to south) in an upstream progression. Visibility was approximately 1.5 m. No steelhead, or any other species of fish, were observed after approximately 45 minutes of viewing and no steelhead were observed during bank observations.

Figure 7.11 The front half of the Garrapata Lagoon. Water depths here were now reduced to inches although Site 3 (just out of view to the right) did re-scour some. Photo: Joel Casagrande, 02 Nov. 2005

Figure 7.12 The cobble riffle (looking upstream) submerged – a result of significant sand delivery and accumulation in the lower lagoon. Compare with Figure 2.4. Photo: Joel Casagrande, 02 Nov. 2005.

Figure 7.13 Using underwater cameras in an attempt to determining the presence of steelhead and other fish species. Photo: Julie Casagrande, 02 Nov. 2005.

November 18, 2005

Water Quality

Over the past month, episodes of large waves occurred along the Central Coast of California. These recent wave events continued to alter the lagoon's shape, bathymetry and reduced the volume substantially (Figs 7.14, & 7.15). Sand accumulated in the center of the lagoon (near Site 4) forming a bar that nearly separates the lagoon into two (Fig. 7.14). The same pattern was observed in July of 2004. The lagoon depths had declined significantly especially at Site 4 (See and compare total profile depths in Figs 7.2 & 7.3).

Kelp accumulations were also substantial (Fig. 7.16), however suitable dissolved oxygen concentrations were maintained due to continued mechanical mixing from wave and tidal action (Figs 7.2 & 7.3). Recent daily air temperatures were above normal for several days, although this had little effect on lagoon water temperatures. Temperatures remained cold especially upstream near the inflow of Garrapata Creek, which was 11.7 ºC at 11:00am. The lagoon, especially the downstream two-thirds, was salty (> 20ppt throughout) with only a minimal freshwater lens near the creek inflow.

Steelhead Presence/Absence

The shallow depths of the lagoon and relatively clear water conditions created ideal conditions for detecting steelhead in the lagoon. Both bank and underwater observations were made throughout the entire lagoon working in an upstream direction. No steelhead were observed after approximately 35 minutes.

Figure 7.14 The lower half of the Garrapata Lagoon. Compare with earlier Figures especially Figures 7.1 & 7.8. Photo: Joel Casagrande, 18 Nov 2005.

Figure 7.15 Consistent wave overwash into Garrapata Lagoon was observed during high tide. By mid-November, the sandbar height was minimal, a result of recent large surf. Photo: Joel Casagrande 18 Nov 05.

Figure 7.16 Extensive kelp accumulations within the lagoon area on November 18th, also a result of high surf conditions along the Big Sur Coast. Photo: Joel Casagrande, 18 Nov 05.

November 30, 2005

Water Quality

On November 30th, the lagoon was shallow throughout with a maximum depth of 0.55 m measured near the inflow (Fig. 7.17). Sand accumulation continued in the lagoon and along the southern end of the sandbar. As a result, the lagoon was now draining along the north side of the sandbar. Based on previous "winter" photos of the lagoon (See Appendix: January and early March 2005 photos) the north drainage may be typical during winter conditions.

Water quality conditions were cold, well mixed, and brackish (Figs 7.2 & 7.3). Rainfall days prior to this monitoring resulted in noticeable increases in streamflow, which helped to dilute the large volumes of saltwater entering the lagoon (Fig. 7.18).

Macroinvertebrates

Water column and epibenthic macroinvertebrates were sampled as well. Again, no macroinvertebrates were found in the water column samples from Sites 4 and 5. Epibenthic samples at both sites had abundant bloodworms *(Chironomidae)* and isopods *(Gnorimosphaeroma)* were found as well; although the isopods were noticeably less abundant than previous occasions.

Figure 7.17 Garrapata Lagoon on November 30th 2005. Photo: Joel Casagrande, 30 Nov. 2005.

Figure 7.18 Ocean waves continuously entered the lagoon along the north side of the sandbar, often sending surge waves up the lagoon to the cobble riffle area. Photo: Joel Casagrande, 30 Nov. 2005.

Figure 7.19 A shallow remnant of the Garrapata lagoon looking downstream. Photo: Joel Casagrande, 30 Nov 2005.

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9. Appendix

Photo Timeline of Garrapata Lagoon (January 2005– January, 2006)

The following series of pictures were taken from the southern end of the Highway 1 Bridge throughout 2005. The pictures illustrate the dynamic seasonal changes and in some cases, the weekly changes, in the lagoon and near lagoon areas. For example, compare April 8th and April 27th. Note the sandbar present along the north side of the lagoon on April 27th that was not present on April 8th. Then compare both with May 27th.

The photos also show that the first significant amount of impounded water occurred near July 29th 2005, although earlier photos in July do show some impounded water. Finally, the photos clearly document that by early November sand delivery by ocean waves had reduced the lagoon's volume substantially. The November 30th photo shows large waves in the background. The December 18 photo was taken just before dark at the end of the first big storm event of the 2005/06 winter. On December 20th, an early morning photo shows that the remnants of the lagoon embayment were nearly gone and after the next storm, December 30th, the lagoon area was entirely lotic and against the northern bluffs. Photos from early January 2006 were taken during a significant storm. The January 3rd photo illustrates the considerable impact large waves have on the lagoon.

January 9th 2005 (Photo: Ken Ekelund)

Mar 2nd 2005 (Photo: Ken Ekelund)

Mar 9th 2005 (Photo: Ken Ekelund)

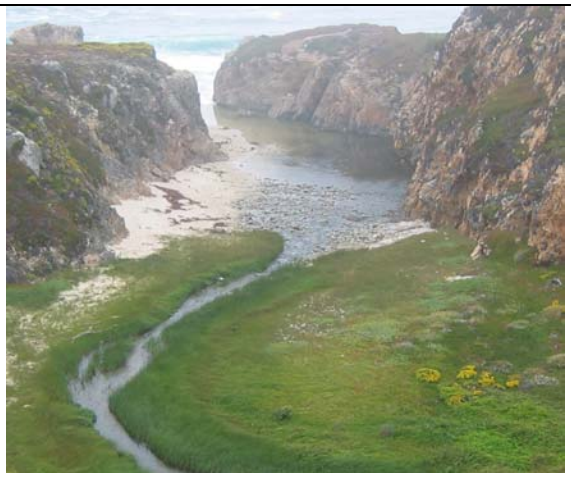
April 8th 2005 (Photo: Joel Casagrande)

April 27th 2005 (Photo: Ken Ekelund)

May 27th 2005 (Photo: Ken Ekelund)

June 21st 2005 (Photo: Ken Ekelund)

July 1st 2005 (Photo: Ken Ekelund)



July 14th 2005 (Photo: Ken Ekelund)

July 19th 2005 (Photo: Ken Ekelund)

July 29th 2005 (Photo: Ken Ekelund)

August 23rd 2005 (Photo: Ken Ekelund)

September 19th 2005 (Photo: Ken Ekelund)

November 2nd 2005 (Photo: Ken Ekelund)

November 30th 2005 (Photo: Joel Casagrande)

December 9th 2005 (Photo: Ken Ekelund)

December 18th 2005 (Photo: Ken Ekelund)

December 20th 2005 (Photo: Ken Ekelund)

 December 30th 2005 (Photo: Ken Ekelund)	 January 3rd 2006 (Photo: Ken Ekelund)