# NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM
# 2009 RECEIVING WATER MONITORING REPORT
# RRI ENERGY MANDALAY GENERATING STATION
# VENTURA COUNTY, CALIFORNIA

## 2009 Survey

**Prepared for:**

**RRI Energy Mandalay, Inc.**

**Prepared by:**

**MBC *Applied Environmental Sciences***
**3000 Red Hill Avenue**
**Costa Mesa, California 92626**

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**March 2010**

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# EXECUTIVE SUMMARY

The 2009 National Pollutant Discharge Elimination System (NPDES) marine monitoring program for the RRI Energy Mandalay Generating Station was conducted in accordance with specifications set forth by the California Regional Water Quality Control Board, Los Angeles Region (LARWQCB) in NPDES Permit No. CA0001180 dated 26 April 2001. The 2009 studies included physical monitoring of the receiving waters and underlying sediments, and biological sampling of the benthic infaunal, fish, and macroinvertebrate assemblages. Results of the 2009 surveys were compared among stations and with previous studies to determine if the beneficial uses of the receiving waters continue to be protected.

## WATER COLUMN MONITORING

In winter 2009, slightly warmer surface temperatures in the surf zone and at some offshore stations suggested the influence of a warm water thermal discharge from the generating station during both tides. In summer, temperatures at the surf zone stations were comparable to offshore temperatures during flood tide, though temperatures indicated the presence of warm water from the discharge throughout the surf zone on ebb tide. Thermal influences on the offshore stations in summer were not observed in summer. However, even at stations influenced by the thermal field, surface temperatures were typical of the area and similar to values reported during previous surveys. All dissolved oxygen values found during both winter and summer sampling were typical of the area, and though slightly depressed in the surf zone compared to offshore stations in winter, well above the level of biological concern. In both winter and summer, pH was consistent throughout the water column at the offshore stations, though values were slightly less stable in winter. At the discharge, pH values were slightly lower than those found up- and downcoast on flood tide in winter and during both tides during summer, likely related to slight differences in water quality characteristics such as salinity between surf-zone receiving waters and the cooling water source. Still, pH varied relatively narrowly during both seasons, and values were similar to levels found in previous sampling. During both seasons, salinity was somewhat variable in surface waters, but increased slightly and became more stable with depth. At the surf-zone stations, lower values at the discharge in winter suggested some local freshwater influence from the discharge plume, likely from urban and agricultural runoff into the harbor and intake canal that supply cooling water to the generating station. Otherwise salinity along the shoreline was similar to, though slightly higher than, levels reported in surface waters at the offshore stations. All values reported in 2009 were typical of the nearshore waters of southern California and within values found previously in the area.

In 2009, water quality parameters were relatively consistent among stations and between tides during both winter and summer. During both seasons, warmer surface water was observed near the discharge during at least one tide, with variations in water quality parameters among nearby stations attributable to tidal influences on the thermal discharge from the generating station. These patterns have been observed in the area in previous surveys and the resulting parameters were similar to natural conditions found commonly throughout the study area. While water quality measurements indicated the presence of a thermal discharge from the Mandalay Generating Station in 2009, the influence was localized did not appear to have an adverse effect on receiving waters in the study area.

## SEDIMENT CHARACTERISTICS

### Sediment Grain Size

In 2009, sediments were analyzed from five stations offshore the Mandalay Generating Station. Sediments were generally composed of about 93% sand with lesser amounts of fine material (silt and clay) and mean grain sizes in the very fine to fine sand categories. Sediment distribution characteristics were similar among all stations, though mean grain size increased and percent contribution of fine sediments decreased with distance from the Santa Clara River. Sediments at

Station B5, nearest the river and farthest upcoast of the discharge were comprised of about 87% sand, while farthest downcoast of the discharge (Station B4) sediments were coarsest, comprised of 96% sand. The degree of influence of the discharge on local sediments varies from year to year, and the localized and transitory influence near the discharge noted in some previous surveys was not observed in 2009. Sediment characteristics offshore of the Mandalay Generating Station discharge in 2009 were similar to those found previously in the area and appear to be affected primarily by natural causes.

**Sediment Chemistry**

In 2009 metal concentrations were lowest farthest downcoast or offshore of the discharge, though levels were similar among all stations Although higher than levels reported since 2006, metal concentrations in 2009 were similar to results found commonly in previous surveys. Sediment metal concentrations have remained relatively consistent in the area since 1990 and have been consistently lower than mean metal concentrations found in sediments at shallow (5-30 m) coastal stations throughout southern California. While metal levels typically vary slightly from year to year, no long-term patterns of metal concentrations relative to the discharge were apparent. As in previous surveys, sediment metal levels were well below concentrations determined to be potentially toxic to marine organisms. Concentrations of sediment metals in 2009 did not appear to be influenced by the operation of the Mandalay Generating Station.

## MUSSEL BIOACCUMULATION

Since 2001 it has been necessary to transplant mussels for tissue analysis to an offshore mooring maintained in the area for that purpose. In 2009, live bay mussels (*Mytilus galloprovincialis*) were purchased from a commercial supplier in Carlsbad, California and transplanted to the mooring near the Mandalay discharge where the mussels were allowed to acclimate for a period of 133 days, after which they were retrieved and returned to the laboratory for chemical analysis. Results were compared with those from mussels collected at the source site at the time of the transplant and to mussels collected from the Manhattan Beach Pier in Santa Monica Bay, which served as a reference site.

In 2009, concentrations of metals decreased from levels reported commonly in previous surveys and were among the lowest reported in mussels from the Mandalay discharge area. Metal levels were also reduced in source mussels and in mussels from the reference site. In general, levels were comparable among the sites. However, chromium at the discharge and at the reference site exceeded values considered elevated by the State Mussel Watch Program, while copper was found to be highly elevated at the reference site. The similarity of tissue metal levels among sites to previous studies, and to other areas in southern California suggests that the operation of the Mandalay Generating Station is not elevating metal concentrations above background levels.

## BENTHIC INFAUNA

The infaunal community in 2009 was comprised primarily of small annelid worms, burrowing sea anemones, arthropods, and mollusks. Abundance averaged 910 individuals per station (22,745 individuals/$m^2$), which, based on density of organisms, was about eight times that in 2008 and was the second highest recorded for summer surveys conducted in the study area since 1978. A total of 91 species was taken, the highest number ever found in the area; richness averaged 48 species per station. Mean species diversity (H') was 2.64, the second highest diversity value seen. The Southern California Benthic Response Index (BRI), an abundance-weighted average pollution tolerance of species occurring in a sample, indicated that the communities at most of the stations were healthy. The value for the community at the station farthest upcoast was slightly elevated, suggesting the influence of a minor, undetermined source of disturbance at that location. Values for all five stations were higher than in previous surveys since 2006, the first year that the index was used. Infaunal parameters such as abundance and species richness showed some relationship to sediment characteristics, as values were lowest where sediments were coarsest, farthest downcoast, and abundance was highest immediately upcoast of the generating station, where sediments were moderately fine and poorly sorted. The high abundance at that location was due to a large number of the burrowing sea anemone *Zaolutus actius*. Several other species were also most abundant there. However, species diversity was lowest for that community, due to the numerical dominance of *Z. actius*. Species diversity was highest farthest downcoast, as no single species dominated the community. Infaunal values for the community near the generating station discharge were near or only slightly below the study-area means.

Infaunal community composition was somewhat similar throughout the study area. The communities immediately upcoast and downcoast of the generating station were most alike, while the community farthest upcoast was least similar to those elsewhere. Although *Zaolutus actius* was the most abundant species overall, it was found primarily at the three stations near and immediately adjacent to the discharge, as were a few of the other abundant species, such as the annelids *Owenia collaris*, *Armandia brevis*, and *Ampharete labrops*. The polychaete annelid *Apoprionospio pygmaea* and the clam *Tellina modesta* were second and fifth most abundant overall, respectively. Unlike many of the other abundant species, however, they were fairly evenly distributed among the five stations. Many of the common constituents of the communities in 2009, such as *A. brevis*, *T. modesta*, the cumacean *Diastylopsis tenuis*, and the amphipod *Rhepoxynius menziesi*, are efficient burrowers, well adapted to the sandy, nearshore environment found offshore of the generating station. *Apoprionospio pygmaea* has usually been the most abundant species in the area, while *Z. actius* has occurred infrequently and has never been particularly abundant before. Overall, the communities found in 2009 were similar to those encountered previously in the study area and are typical of the shallow subtidal habitat in the Southern California Bight. The high abundance and species richness seen in 2009 may be part of an local phenomenon, as a similar pattern was observed offshore of another generating station nearby, but not at other locations farther south. Infaunal community parameters and composition appeared to be somewhat related to sediment characteristics, and no adverse effects from the generating station discharge were found.

**DEMERSAL FISH AND MACROINVERTEBRATES**

In 2009, 2,694 fish weighing 35 kg representing 30 species were taken during summer and winter trawl sampling. The winter survey caught 769 fish representing 19 species weighing 15 kg, eight species of which were unique to the winter survey. Summer trawling caught 1,925 fish from 22 species, five of which were unique to the season, with a combined weight of 20 kg. White croaker (*Genyonemus lineatus*) was the most abundant species, followed by speckled sanddab (*Citharichthy stigmaeus*). Combined, these two species accounted for 74% of the total abundance. Uncommon but large elasmobranchs, spiny dogfish (*Squalus acanthias*) and bat ray (*Myliobatis californica*) substantially affected the total biomass, accounting for 44% of the total. Spatially, the fewest fish were taken at Station T4, farthest downcoast, where bottom water temperature was lowest in winter and highest in summer, with the highest abundance recorded farthest upcoast at Station T1, which had the highest or second highest bottom temperature. The majority of white croaker were taken at Station T1.

A total of 10,145 macroinvertebrates weighing 34 kg representing 17 species was collected during the 2009 monitoring year. More species (14) but fewer individuals were taken in winter than in summer when 6,708 individuals from nine species were caught. Pacific sand dollar (*Dendraster excentricus*) and blackspotted bay shrimp (*Crangon nigromaculata*) accounted for 85% of the total abundance with 94% of all Pacific sand dollars taken in summer. Similar to the results for fish, the majority of all macroinvertebrates were taken upcoast of the discharge in both seasons, with nearly all Pacific sand dollars and most blackspotted bay shrimp caught at Station T1.

With the exception of queenfish (*Seriphus politus*), the core species groups that have regularly dominated the fish and macroinvertebrate assemblages were taken in 2009. The macroinvertebrate community was more robust than found in recent years while the fish community appeared to be in a slight decline compared to recent surveys. Both communities continued a general trend of greater abundance upcoast of the discharge, which is typically warmer near the sea floor and closer to the Santa Clara River. Therefore, this spatial pattern may be an indication of habitat differences caused by proximity to the river with finer sediments typically found closer to the river mouth than farther downcoast. There is, however, no indication that plant operations have adversely affected the fish or macroinvertebrate populations offshore of the Mandalay Generating Station.

**IMPINGEMENT**

To evaluate fish loss at the Mandalay Generating Station, fish impingement was monitored during six normal operation surveys during the 2009 monitoring year. No heat treatments occurred in 2009. Based on these surveys, an estimated total fish abundance of 11,525 individuals representing 14 species and weighing more than 162 kg were impinged at the generating station. Overall, fish abundance in 2009 was greater than that in 2008, but less than recorded in four out of the eight prior monitoring years since 2001. In addition, an estimated 574 individuals representing four macroinvertebrate species and weighing more than 119 kg were impinged during the study year, the second highest total since data was first reported in 2001.

Species reported in 2009 were similar to those collected in previous surveys, suggesting that a core group of species remains in the area despite differences in abundance from year to year. Over time, abundances have fluctuated independently of the cooling water flow volumes which suggests that natural variability in the local populations was the most important factor influencing the observed interannual variability. There is no indication that plant operations have adversely affected the fish or macroinvertebrate populations in the vicinity of the Mandalay Generating Station intake canal.

**CONCLUSIONS**

The overall results of the 2009 NPDES monitoring program indicated that operation of the Mandalay Generating Station had no detectable adverse effects on the beneficial uses of the receiving waters.

# CHAPTER 1 — INTRODUCTION

This report presents and discusses the results of the 2009 receiving water monitoring studies conducted for the Mandalay Generating Station which is owned and operated by RRI Energy. The 2009 monitoring program was conducted in accordance with specifications set forth in National Pollutant Discharge Elimination System (NPDES) Monitoring and Reporting Program No. 2093 (Permit No. CA0001180) issued by the California Regional Water Quality Control Board, Los Angeles Region (LARWQCB) on 26 April 2001 (Appendix A). Results of the 2009 surveys were compared among stations and with past physical and biological studies to determine if the generating station discharge is having an adverse effect on the marine environment, and if the beneficial uses of the receiving waters are being protected. Sampling included physical and chemical monitoring of receiving waters and sediments, and biological monitoring of infaunal, fish, and macroinvertebrate assemblages.

## DESCRIPTION OF THE GENERATING STATION

The Mandalay Generating Station is located on the California coast, approximately 4.8 kilometers (km) west of the City of Oxnard in Ventura County. The generating station consists of two steam-electric generating units, each rated at 215 megawatts (Mw), and one gas turbine unit rated at 147 Mw. Steam is supplied to the steam-electric units by two gas-fired boilers, each rated at 707,600 kilograms (kg) of steam per hour.

Cooling water is supplied to the station from the ocean via the Edison Canal from Channel Islands Harbor, 4.8 km downcoast, at a rate of approximately 176,000 gallons per minute (gpm). Water enters the station through a screening facility which removes large marine organisms, trash, and other debris. Cooling water is pumped to the two steam condensers where its temperature is elevated approximately 12.2°C when the units are operating at full capacity. The warmed effluent is returned to the ocean across the beach via a rock-lined canal (Figure 1-1).

Approximately 9,800 gpm (6%) of the main cooling water is diverted before it reaches the steam condensers and is directed to an auxiliary heat exchanger which is used to cool distilled water used in auxiliary station equipment. The temperature of this seawater is elevated approximately 5°C before it joins the main cooling-water flow in the discharge conduit. An additional 3,200 gpm (2%) is diverted to an auxiliary cooling-water heat exchanger for the gas turbine unit where its temperature is raised a maximum of 9°C. The turbine unit is operated only when needed and does not use cooling water.

Two of four circulator pumps were operating during the winter survey on 11 March 2009, discharging 121.2 mgd. The intake temperature was 15.6°C and the discharge temperature was 25.0°C, a difference of 9.4°C. All circulator pumps were operating during the summer survey on 21 July 2009, discharging 226.1 mgd. The intake temperature was 20.0°C and the discharge temperature was 28.9°C, a difference of 8.9°C. During 2009, the Mandalay Generating Station operated at 12.14% of their total operating capacity (Siekiel-Zdzienicki 2009, pers. comm.).

## DESCRIPTION OF THE STUDY AREA

The physiography, climate, and hydrography of the southern California coastal region contribute to the character of the study area and, therefore, affect the influence of thermal discharges in coastal waters. Oceanographic, biological, and meteorological elements are all characterized by short- and long-period cyclical variations as well as non-periodic trends. Winds, tides, and currents are particularly important since they have the greatest impact on the fate of the thermal plume itself.

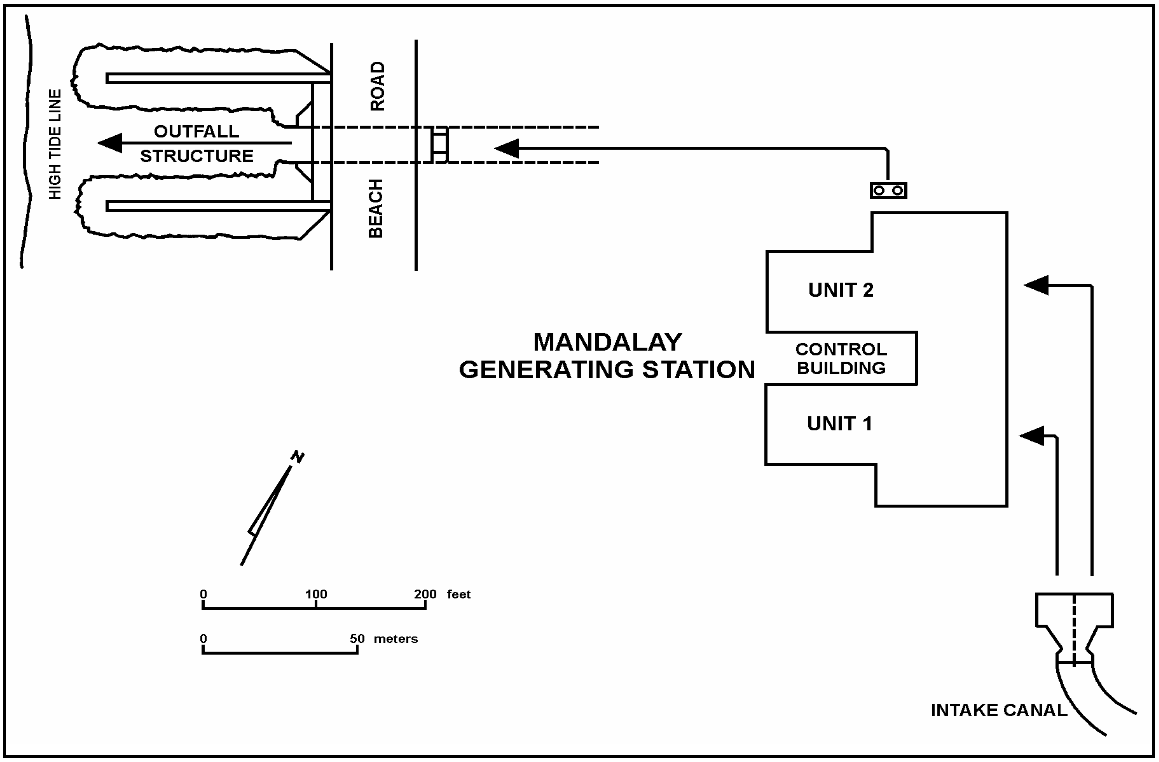



**Figure 1-1. Diagram of the Mandalay Generating Station cooling water system. Mandalay Generating Station NPDES, 2009.**

## Physiography

The general orientation of the coastline between Point Conception and the Mexican border is from northwest to southeast. The continental margin has been slowly emerging over time, resulting in a predominantly cliffed coastline, broken by coastal plains in the Oxnard-Ventura, Los Angeles, and San Diego areas. Drainage of the coastal region is by many relatively short streams which normally flow only during rain storms. Only a small part of the storm drainage actually reaches the ocean because most is impounded by dams and diverted for other uses.

The Mandalay Generating Station is situated on the coastal plain of the Ventura Basin, approximately 30 km northwest of Point Mugu and 3 km south of the mouth of the Santa Clara River (Figure 1-2). The Ventura Basin is defined by the Ventura River delta to the north and the barrier beaches at Point Mugu to the south. Prominent natural features of this stretch of coast include straight sandy beaches, the dunes along Mandalay Beach, and the marshes and lagoon in the naval reservation near Point Mugu.

The eight islands offshore southern California strongly influence water circulation and general oceanographic characteristics of the entire Southern California Bight. The mainland shelf is narrow along the coast, ranging in width from less than 1.6 to more than 19 km, averaging approximately 7 km. Seaward of the shelf is an irregular and geologically complex region known as the continental borderland, which consists of numerous ridges and basins extending from near the surface to depths in excess of 2,400 meters (m).

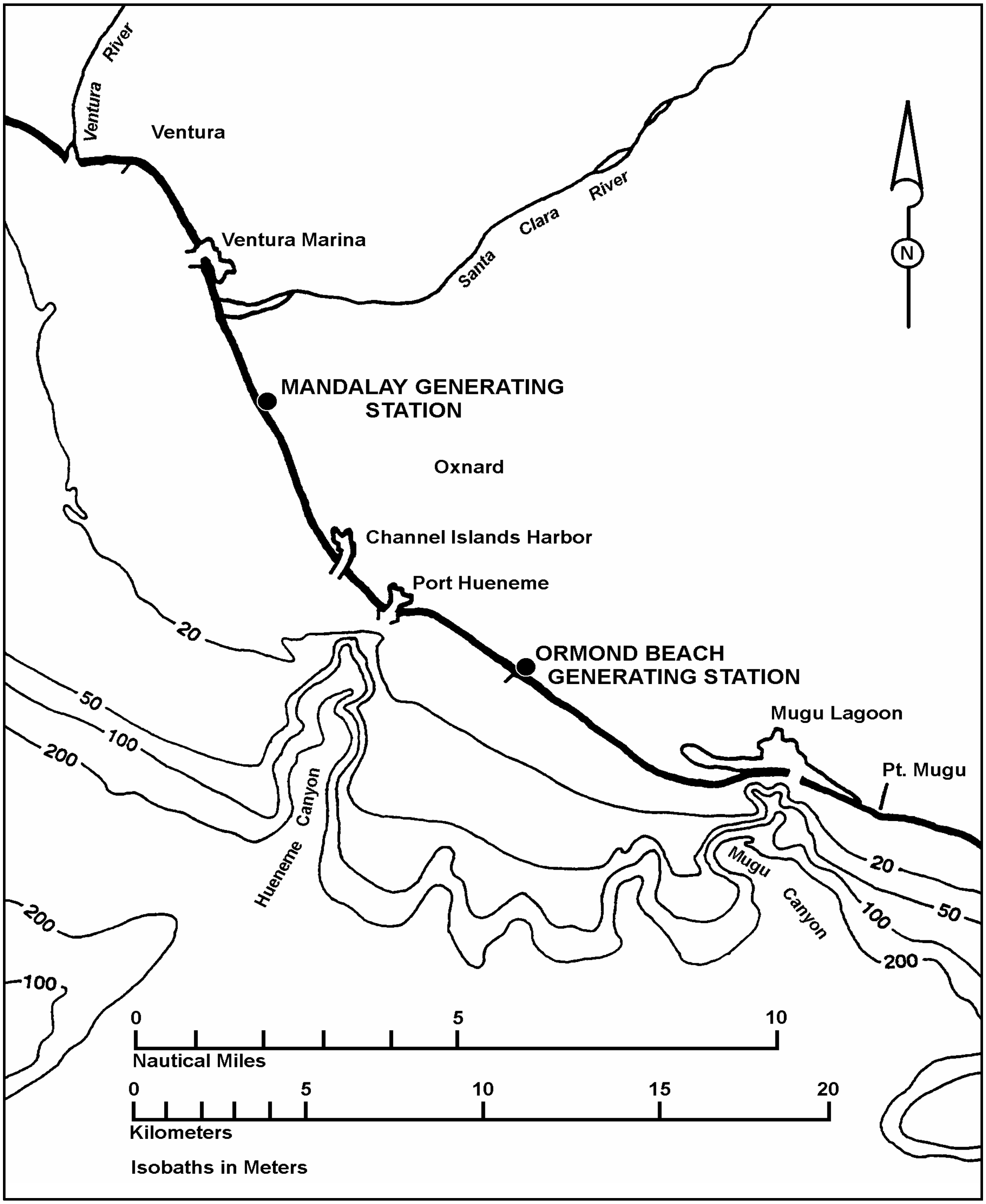



**Figure 1-2. Location of the study area. Mandalay Generating Station NPDES, 2009.**

## Submarine Physiography

The submarine physiography of the Ventura Basin is characterized by two distinct areas divided by the Hueneme Canyon (IRC 1973). To the northwest of the Hueneme Canyon is a broad gently sloping sea floor and to the southeast a narrower, steeper slope (Figure 1-2). Mugu Canyon cuts into the slope near the southeastern boundary of the basin.

Offshore at Mandalay Beach, the 20 fathom (fm) (36 m) contour is 12.8 to 16.0 km from shore while further south in the basin, it is closer (3.2 to 6.4 km) to shore. The head of Hueneme Submarine Canyon approaches the shoreline so closely that the 20 fm isobath is within 100 m of the jetties at Port Hueneme. There are no major irregularities in bathymetry between Hueneme Canyon and the mouth of the Ventura River.

Marked changes in bottom topography close to shore can result in irregular current patterns and variable current velocities. Nearshore circulation in the study area is affected by Hueneme and Mugu Canyons, Port Hueneme, Channel Islands Harbor, the Ventura Marina, and the mouth of the Santa Clara River. None of the studies conducted at the Mandalay Generating Station indicated that the tidal prism from the harbors and marinas in the area significantly influence current speed and direction near the generating station (IRC 1973).

**Climate**

Southern California is in a climatic regime broadly defined as Mediterranean, which is characterized by short, mild winters and warm, dry summers. Long-term annual precipitation near the coast averages about 46 centimeters (cm), of which 90% occurs between November and April. Monthly mean air temperatures along the coast range from 8.3°C in winter to 20.6°C in summer, with daily minima dropping slightly below freezing and maxima reaching above 37°C.

Sea breezes, which develop from differential heating between land and sea masses, combine with the prevailing winds from the northwest during summer months to produce strong onshore winds. Summer sea breezes typically start at about noon and may continue through late afternoon, with speeds reaching 37 km/hour (hr). In late fall and winter, reverse pressure systems frequently develop; coastal winds tend to be from the southeast and the sea breezes typically blow from 1300 hr to as late as 2000 hr.

**Ocean Currents**

Water in the northern Pacific Ocean is driven eastward by prevailing winds until it impinges on the western coast of North America where it divides and flows both north and south. The southern component comprises the California Current, a diffuse and meandering water mass which generally flows to the southeast, following the coast. There is no fixed western boundary to this current, but more than 90% of its transport is within 725 km of the California coast. South of Point Conception, the California Current generally flows along the Patton Escarpment (160 km offshore) and approaches the coast again near Cape Colnett, Baja California (Figure 1-3). Off Baja California part of the California Current turns north forming a counter-current in the Southern California Bight known as the Southern California Countercurrent. Part of this countercurrent flows through the Santa Barbara Channel and then rejoins the California Current while the rest turns and flows south

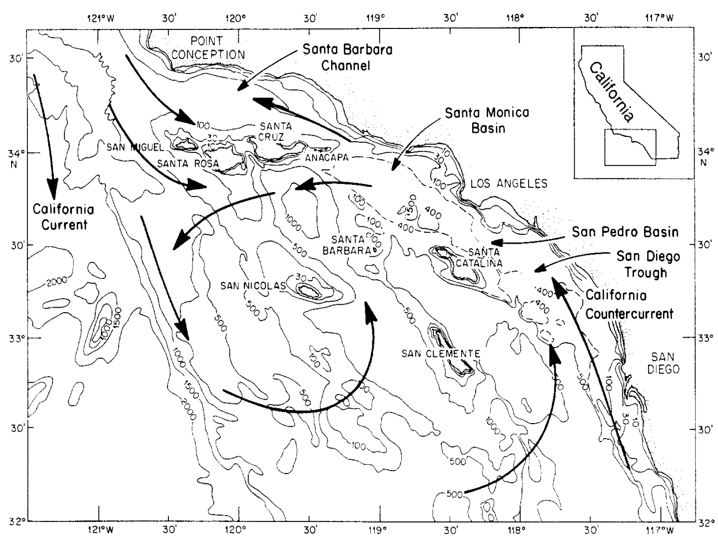



**Figure 1-3. Surface circulation in the Southern California Bight (from Hickey 1992). Mandalay Generating Station NPDES, 2009.**

nearshore. Nearshore, coastal currents are strongly influenced by a combination of wind, tides, and local physiography. Therefore, short-term observations of currents near the coast often vary in both direction and speed.

Surface speed in the countercurrent ranges between 5.5 and 11 centimeters per second (cm/s). The general flow pattern is complicated by eddies in the Channel Islands region and fluctuates seasonally, being more strongly developed in summer and autumn, and weak or occasionally absent in winter and spring.

**Longshore Drift**

Longshore currents typically move sand parallel to shore and thus toward the heads of submarine canyons either upcoast or downcoast. In the Hueneme area southeast of Mandalay, the net littoral sediment transport, or longshore drift, is downcoast at the rate of 600,000 to 900,000 $m^3$ per year. When the entrance to Port Hueneme was constructed, the upcoast jetty effectively trapped or diverted the natural sand supply that was formerly available to beaches in the Ormond Beach area. That portion of sediment not trapped by the jetty was lost into deep water at the head of the Hueneme Canyon. Approximately 900,000 $m^3$ per year are eroded downcoast of the jetties. Slightly more than 1,500,000 $m^3$ of sediment are dredged and bypassed biannually around the trap. Erosion southeast of the harbor continues, however, at a rate of approximately 1,500,000 $m^3$ per year.

Channel Islands Harbor was designed to prevent sediment loss into Hueneme Canyon. The detached breakwater at the harbor entrance provides a shadow zone which traps sediment upcoast of the northwest jetty. In 1960-61, dredging of the sand trap, the entrance channel, and the first phase of development at Channel Islands Harbor provided about 4,120,000 $m^3$ of sand which were used for beach nourishment (IRC 1973). To the northwest of the Mandalay Generating Station the normal southeasterly movement of sediment from the Ventura River area is interrupted by the trap effect of Ventura Marina breakwater and jetties.

**Tides**

Tides along the California coast are mixed, semidiurnal, with two unequal highs and two unequal lows during each 25 hr period. The tide is a long-period wave that is a combination of semidiurnal components (each having nearly 12 hr periods) and diurnal components with nearly 25 hr periods. In the eastern North Pacific Ocean, the tide wave rotates in a counterclockwise direction so that tidal extremes occur progressively later in the day northwards along the coast. As a result, flood tide currents flow upcoast and ebb tide currents flow downcoast.

**Upwelling**

The predominant northwesterly winds are responsible for large scale upwelling along the California coast. From about February to October, these winds induce offshore movement of surface water which is replaced by the upwelling of deeper ocean waters. The upwelled water is colder, more saline, lower in oxygen, and higher in nutrient concentrations than surface waters. Thus, upwelling not only alters the physical properties of the surface waters but also enhances biological productivity.

**RECEIVING WATER CHARACTERISTICS**

The capacity of the marine environment to assimilate heated cooling water depends on its ability to dilute and disperse the thermal discharge. The extent to which these functions are accomplished depends on the quantity and temperature of the thermal effluent relative to normal ocean temperatures and ocean current patterns as well as other characteristics of the receiving waters. These factors are the primary determinants of the fate and effect of thermal effluent discharge. The following discussion focuses on natural physical and chemical oceanographic characteristics that influence the local marine biota.

**Temperature**

Natural water temperatures fluctuate throughout the year in response to seasonal and diurnal variations in currents; meteorological conditions such as wind, air temperature, relative humidity, and cloud cover; and parameters such as ocean waves and turbulence. Natural temperature is defined by the California State Water Resources Control Board (SWRCB 1972) as "the temperature of the receiving water at locations, depths, and times which represent conditions unaffected by any elevated temperature waste discharge or irrigation return waters."

Daily surface water temperatures may be expected to vary 1°C to 2°C in summer and 0.3°C to 1°C in winter on the average. Factors contributing to rapid daytime warming of the sea surface are weak winds, clear skies, and warm air temperatures; factors that limit diurnal temperature ranges are overcast skies, moderate air temperatures, and mixing of the surface waters by winds and waves.

Between July 1970 and January 1973 natural surface water temperatures at nearby Ormond Beach ranged from 11.4°C in December 1971 to 22.0°C in August of the same year. During 1971-1972 minimum and maximum surface water temperatures at a control station offshore from the Mandalay Generating Station were 11.6°C and 22.7°C, respectively (IRC 1973).

When there is a large difference between surface and bottom water temperatures, a steep temperature gradient between adjacent water layers of different temperatures (i.e., a thermocline) may develop. Natural thermoclines are formed when absorption of solar radiation at the sea surface develops a stable stratification, separating surface from subsurface layers. Off southern California, a reasonably sharp thermocline is normally found in summer in the upper 30 m of the water column; in winter thermoclines are weakly defined. Artificial thermoclines may result when warm water from a thermal discharge overlies cooler receiving waters.

**Salinity**

Salinity is a measure of the concentration of salts in water which can be expressed as a weight of salts dissolved in a volume of water. Typically, the concentration of salts in the ocean is roughly 35 grams per kilogram of water and can be expressed as 35 parts per thousand (ppt). Although relatively constant in the open ocean, salinity fluctuates in coastal environments as a result of the introduction of freshwater runoff and direct rainfall, and through the evaporation of freshwater. Between 1965 and 1971 surface salinity at the Ventura Marina ranged from a minimum of 24.1 ppt, which was associated with rainfall runoff, to a maximum of approximately 33.9 ppt (IRC 1973).

**Dissolved Oxygen**

Dissolved oxygen (DO) is utilized by aquatic plants and animals in their metabolic processes; it is replenished by gaseous exchange with the atmosphere and as a byproduct of photosynthesis. High values generally result from photosynthetic activity and low values from mixing of surface waters with oxygen-depleted subsurface waters. Between July 1970 and January 1973, concentrations in surface waters offshore Ormond Beach ranged from 7.3 milligrams per liter (mg/l) to 11.0 mg/l (IRC 1973).

**Hydrogen Ion Concentration**

The hydrogen ion concentration (pH) in southern California surface waters varies narrowly around a mean of approximately 8.1 and decreases slightly with depth. However, values will naturally approach 8.6 during phytoplankton blooms, which rapidly metabolize carbonates in the surface waters. Values can also drop below 7.9, although this generally occurs in waters below 100 meters, or in confined water ways such as harbors, where organic decomposition and reduced circulation will lead to an accumulation of acidic byproducts. In annual and semiannual monitoring conducted offshore of the Mandalay Generating Station between 1986 and 2006, pH was found to range from 7.32 to 8.56 (MBC 1986, 1988, 1990, 1994-2005, 2006a-2008a; Ogden 1991-1993).

**BENEFICIAL USES OF RECEIVING WATERS**

The Water Quality Control Plan for the Santa Clara River Basin (California Regional Water Quality Control Board 1994) lists beneficial uses of waters in the nearshore and offshore zones of the Santa Clara-Calleguas Hydrographic Unit, which includes Mandalay and the study area. These uses are:

**Industrial Service Supply (IND)** - Uses of water for industrial activities that do not depend primarily on water quality including, but not limited to, mining, cooling water supply, hydraulic conveyance, gravel washing, fire protection, or oil well re-pressurization.

**Navigation (NAV) -** Uses of water for shipping, travel, or other transportation by private, military, or commercial vessels.

**Water Contact Recreation (REC-1)** - Uses of water for recreational activities involving body contact with water, where ingestion of water is reasonably possible. These uses include, but are not limited to, swimming, wading, water-skiing, skin and scuba diving, surfing, white water activities, fishing, or use of natural hot springs.

**Non-contact Water Recreation (REC-2)** - Uses of water for recreational activities involving proximity to water, but not normally involving body contact with water, where ingestion of water is reasonably possible. These uses include, but are not limited to, picnicking, sunbathing, hiking, beachcombing, camping, boating, tidepool and marine life study, hunting, sightseeing, or aesthetic enjoyment in conjunction with the above activities.

**Commercial and Sport Fishing (COMM)** - Uses of water for commercial or recreational collection of fish, shellfish, or other organisms including, but not limited to, uses involving organisms intended for human consumption or bait purposes.

**Marine Habitat (MAR) -** Uses of water that support marine ecosystems including, but not limited to, preservation or enhancement of marine habitats, vegetation such as kelp, fish, shellfish, or wildlife (e.g., marine mammals, shorebirds).

**Wildlife Habitat (WILD)** - Uses of water that support terrestrial ecosystems including, but not limited to, preservation and enhancement of terrestrial habitats, vegetation, wildlife (e.g., mammals, birds, reptiles, amphibians, invertebrates), or wildlife water and food sources.

**Preservation of Biological Habitats (BIOL)** - Uses of water that support designated areas or habitats, such as Areas of Special Biological Significance (ASBS), established refuges, parks, sanctuaries, ecological reserves, or other areas where the preservation or enhancement of natural resources requires special protection.

**Rare, Threatened, or Endangered Species (RARE)** - Uses of water that support habitats necessary, at least in part, for the survival and successful maintenance of plant or animal species established under state or federal law as rare, threatened, or endangered.

**Migration of Aquatic Organisms (MIGR)** - Uses of water that support habitats necessary for migration, acclimatization between fresh and salt water, or other temporary activities by aquatic organisms.

**Spawning, Reproduction, and/or Early Development (SPWN)** - Uses of water that support high quality aquatic habitats suitable for reproduction and early development of fish.

**Shellfish Harvesting (SHELL)** - Uses of water that support habitats suitable for the collection of filter-feeding shellfish (e.g., clams, oysters, and mussels) for human consumption, commercial, or sports purposes.

Although all of the above uses may not directly apply to the generating station's receiving waters at all times, they may be reasonably assumed to constitute occasional beneficial uses of nearshore waters in the study area.

## SCOPE OF THE MONITORING PROGRAM

The 2009 monitoring program for the Mandalay Generating Station was conducted by MBC Applied Environmental Sciences (MBC) in accordance with specifications set forth in the NPDES Monitoring and Reporting Program (Appendix A). The monitoring program included winter and summer water column profiling, summer sediment sampling for grain size and chemistry, mussel sampling for bioaccumulation, summer biological sampling for benthic infauna, and winter and summer trawling for fish and macroinvertebrates. In addition, the impingement of fish and invertebrate species on the intake screens were monitored periodically and total yearly impingement estimated from monitoring results and plant operations.

## STATION LOCATIONS

The locations of the monitoring stations are described in Appendix A and shown on Figure 1-4. The 2009 monitoring program included 17 water quality (RW) stations, five sediment and benthic infauna (B) stations, and four trawl (T) stations.

## FIELD OBSERVATIONS

The NPDES water quality monitoring surveys were conducted on 11 March and 21 July, the demersal fish and invertebrate trawl surveys were conducted on 12 March and 23 July, and benthic sampling was conducted on 22 July 2009. Latitude and longitude coordinates for all receiving water (RW), trawl (T), and benthic (B) stations are listed in Table 1-1.

During the winter surveys, no oil sheens, grease or apparent red tide (plankton bloom) were observed at any of the receiving water or trawl stations. The water appeared moderately turbid at all offshore stations during both water quality monitoring and the trawl survey. Slight turbidity was noted at the surf-zone stations located at and downcoast of the discharge, while moderate turbidity was noted at surf-zone stations upcoast of the discharge. Drift kelp (*Macrocystis pyrifera*) and terrestrial vegetation was seen at most of the trawl stations and at receiving water Station RW17. Floating plastic trash was noted at trawl Stations T2 and T4, while drift wood was noted at Stations T2, T3, and surf-zone receiving water Stations RW1 and RW5. California sea lions (*Zalophus californianus*) were observed swimming during water quality monitoring at Station RW11 and a small pod of bottlenose dolphins (*Tursiops truncatus*) was observed during the trawl survey at Stations T1 and T3. Western gulls (*Larus occidentalis*) were seen throughout the trawl survey area, at all surf-zone receiving water stations, and at offshore receiving water Stations RW6, RW12, RW13, RW15, and RW16, while western grebes (*Aechmophorus occidentalis*) were observed at most of trawl stations and at Stations RW1, RW10, RW11, RW13, and RW15 through RW17, and cormorants (*Phalacrocorax* sp) were seen at Stations T3 and T4. At the surf-zone stations, sanderlings (*Calidris alba*) were observed at Stations RW3 and RW4, willets (*Tringa semipalmatus*) were seen at Stations RW2 and RW5, and

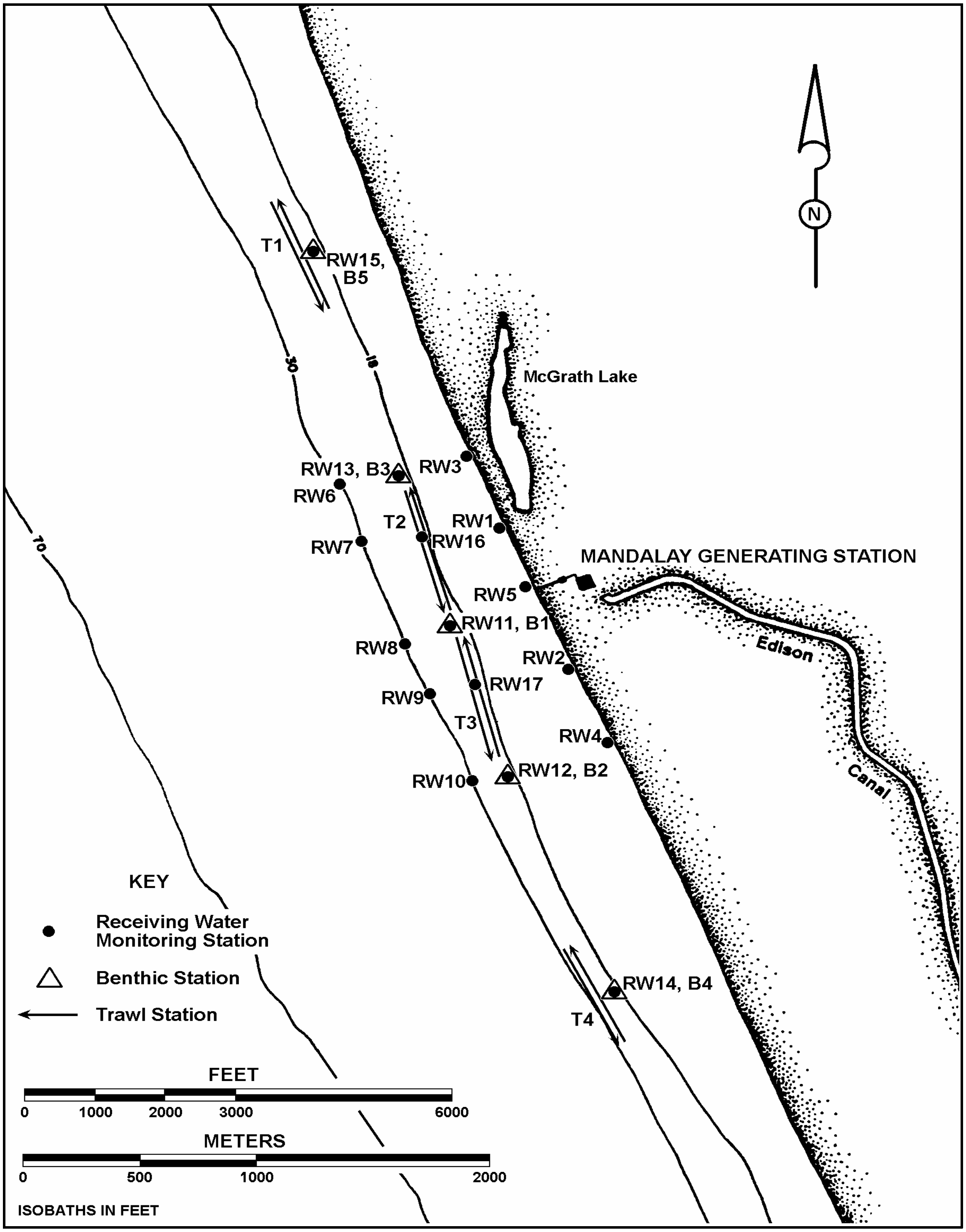



**Figure 1-4. Location of the monitoring stations. Mandalay Generating Station NPDES, 2009.**

a marbled godwit (*Limosa fedoa*) was observed at Station RW5. California brown pelicans (*Pelecanus occidentalis californicus*) were seen at all surf-zone stations, offshore receiving water Stations RW8, RW9, RW11, and RW15 through RW17, and trawl Stations T3 and T4. No California least terns (*Sternula antillarum browni*) were observed during the winter surveys.

During the summer surveys, no oil sheens, grease or red tide were observed at any of the stations. The water appeared slightly turbid at all stations during water quality monitoring (21 July), benthic sampling (22 July) with the exception of Station B4 where the turbidity was noted as moderate, and trawl survey (23 July). Drift kelp was noted at most of the benthic stations, trawl Stations T2 and T3, and receiving water Stations RW5, RW11, RW13, and RW17, other drift algae was observed at Station B1, drift surfgrass (*Phyllospadix* sp) was noted at Station RW4, and terrestrial vegetation was seen throughout the surf-zone stations. Floating plastic trash was noted at Stations RW5, RW11, and T2, while wood debris was observed at Stations RW2 and RW5. California sea lions were observed swimming during water quality monitoring at Station RW16, at benthic Station B4, and trawl Stations T2 through T4, while small pods of bottlenose dolphins were observed at Station RW12, RW15, B4, and during the trawl survey at Stations T1 through T3. Western gulls were seen throughout the entire survey area during the demersal fish trawls and water quality monitoring as well as at benthic Stations B1 through B3, while Heermann's gulls (*Larus heermanni*) were observed at Stations RW3, RW4, B3, T1, and T2. Cormorants were noted at most of the benthic and trawl stations and at receiving water Stations RW3, RW9, RW12, RW16. Caspian terns (*Hydroprogne caspia*) were observed at trawl Station T2, other tern species (Laridae) were seen at trawl Stations T1 through T3 and receiving water Stations RW8, RW10, and RW13, and western grebes were noted at Station RW15. Marbled godwits were observed at most of the surf-zone stations, while sanderlings were seen at Stations RW3 and RW4, willets were observed at Station RW1, and a shearwater (*Puffinus* sp) was seen at Station RW5. California brown pelicans were observed throughout the trawl survey area, at benthic Stations B3 and B4, surf-zone water quality monitoring Stations RW1, RW2, RW3, and RW5, and offshore Stations RW7 through RW9, RW11 through RW14, and RW17. No California least terns were observed during any of the surveys.

**Table 1-1. Latitude/longitude coordinates of sampling stations. Mandalay Generating Station NPDES, 2009.**

| Stations | | | |
|---|---|---|---|
| Water Quality | Benthic | Latitude | Longitude |
| RW1 | | 34°12.54' | 119°15.29' |
| RW2 | | 34°12.19' | 119°15.10' |
| RW3 | | 34°12.69' | 119°15.36' |
| RW4 | | 34°12.01' | 119°14.99' |
| RW5 | | 34°12.36' | 119°15.19' |
| RW6 | | 34°12.58' | 119°15.81' |
| RW7 | | 34°12.40' | 119°15.73' |
| RW8 | | 34°12.22' | 119°15.59' |
| RW9 | | 34°12.06' | 119°15.50' |
| RW10 | | 34°11.88' | 119°15.35' |
| RW11 | B1 | 34°12.30' | 119°15.40' |
| RW12 | B2 | 34°11.94' | 119°15.20' |
| RW13 | B3 | 34°12.65' | 119°15.58' |
| RW14 | B4 | 34°11.40' | 119°14.92' |
| RW15 | B5 | 34°13.17' | 119°15.93' |
| RW16 | | 34°12.47' | 119°15.51' |
| RW17 | | 34°12.11' | 119°15.31' |
| Trawl Stations | Heading | Latitude | Longitude |
| T1 | 130° | 34°13.37' | 119°15.98' |
| T2 | 138° | 34°12.62' | 119°15.61' |
| T3 | 130° | 34°12.12' | 119°15.33' |
| T4 | 150° | 34°11.52' | 119°15.05' |

## STATISTICAL ANALYSES

Summary statistics developed from the biological data included the number of individuals (expressed as both trawl and per standard area), number of species and Shannon-Wiener (Shannon and Weaver 1962) species diversity (H') index. The diversity equation is as follows:

Shannon-Wiener

$$H' = -\sum_{j=1}^{s} \frac{n_j}{N} \ln \frac{n_j}{N}$$

where: $H'$ = species diversity
$n_j$ = number of individuals in the $j^{th}$ species
$S$ = total number of species
$N$ = number of individuals

The Southern California Benthic Response Index (BRI) is an abundance-weighted average pollution tolerance of species occurring in a sample, and is a measure of the condition of marine and estuarine benthic communities (Smith et al. 2003). It classifies benthic communities as "reference" (i.e., undisturbed) or one of four levels of response to increased disturbance. The index formula is:

Benthic Response

$$BRI_S = \frac{\sum_{i=1}^{n} \sqrt[4]{a_{si}\, p_i}}{\sum_{i=1}^{n} \sqrt[4]{a_{si}}}$$

where: $BRI_s$ = BRI value for sampling unit $s_i$
n = number of species with pollution tolerance scores in $s_i$
$p_i$ = pollution tolerance of species *I*
$a_{si}$ = abundance of species *I* in *s*

Species pollution tolerances $p_i$ were determined during BRI development as the position of the abundance distribution of species *I* on a gradient between the most and least disturbed sites. Species without pollution tolerance values are not included in the calculation. Pollution tolerance values were not assigned to species if the data were insufficient to assign a value. The index was developed for benthic samples that were sieved through a 1-mm mesh screen. Pollution tolerance scores were derived for coastal shelf samples for shallow (10-30 m deep), mid-depth (>30-120 m deep), and deep (>120-324 m deep) habitats, and for bay and harbor habitat samples, northern (Point Conception to Newport Bay) and southern (Dana Point to the U.S.-Mexico border). The species names for which scores are available are based on Edition 5 of the Southern California Association of Marine Invertebrate Taxonomists (SCAMIT) list of invertebrate species (SCAMIT 2008).

Evenness (J') is a measure of the degree to which a sampled community is dominated by one or a few species. Values of evenness range from 1.0 (all species with identical abundances) to 0 (Pielou 1977). The evenness equation is as follows:

$$J' = \frac{H'}{\ln S}$$

where: J' = Evenness
H' = Shannon-Wiener Index
S = number of species within the community

Biological data were subjected to log transformations (when necessary) and classified (clustered) using NCSS 2000 Hierarchial Clustering (Hintze 1998). Cluster analysis provides a graphic representation of the relationship between species, their individual abundance, and spatial occurrence among the stations sampled. In theory, if physical conditions were identical at all stations, the biological community would be expected to be identical as well. In practice this is never the case, but it is expected that the characteristics of adjacent stations would be more similar than those distant from one another. The dendrogram shows graphically the degree of similarity (and dissimilarity) between observed characteristics and the expected average. The two-way analysis utilized in this study illustrates groupings of species and stations, as well as their relative abundance, expressed as a percent of the overall mean. Two classification analyses are performed on each set; in one (normal analysis) the sites are grouped on the basis of the species which occurred in each, and in the other (inverse analysis) the species are grouped according to their distribution among the sites. Each analysis involves three steps. The first is the calculation of an inter-entity distance (dissimilarity) matrix using Euclidean distance (Clifford and Stephenson 1975) as the measure of dissimilarity.

Euclidean distance

$$D = \left[ \sum_{1}^{n} \left( x_1 - x_2 \right) \right]^{1/2}$$

where: D = Euclidean distance between two entities
$x_1$ = score for one entity
$x_2$ = score for other entity
n = number of attributes

The second procedure, referred to as sorting, clusters the entities into a dendrogram based on their dissimilarity. The group average sorting strategy is used in construction of the dendrogram (Boesch 1977). In step three, the dendrograms from both the site and species classifications are combined into a two-way coincidence table. The relative abundance values of each species are replaced by symbols (Smith 1976) and entered into the table. In the event of extreme high abundance of a single species, abundance data are transformed using a natural log transformation [ln(x)].

Community importance for benthic infaunal species and trawled fish and macroinvertebrates was tested using the Index of Relative Importance (IRI): IRI = Rank (Rank of abundance + Rank of Frequency of Occurrence) (Stephens and Zerba 1981, Stephens et al. 1994). Spearman's rank correlation was used to test for similarities in the distribution of IRI ranks between the annual surveys.

Estimates of historic community importance were calculated for the ten most abundant fish species and the five most abundant macroinvertebrate species. The annual Index of Community Importance (ICI) was calculated as described by Allen et al. (2002): ICI = (% Number + % Biomass) X % Frequency of Occurrence. Annual rank order of ICI was determined. Spearman's rank correlation was used to determine potential similarities between the years based on the rank of ICI by species.

**DETECTION / REPORTING LIMITS**

Detection/reporting limits used in reporting chemistry results are interpreted as the smallest amount of a given analyte that can be measured above the random noise inherent in any analytical tool. Thus, any value below the detection/reporting limits cannot be considered a reliable estimate of analyte concentration. Therefore, where a test for a given analyte results in a level below the detection/reporting limit, a "none detected" (ND) value has been assigned. The complication of what numerical value to substitute for ND in statistical calculations is addressed by the Environmental Protection Agency (EPA 1989, Section 5.3.3). When values for a given analyte are ND for all stations, then means and standard deviations will also be considered ND. However, when an analyte is detected at some stations and not at others, statistical calculations can be made by substituting ND values with either (a) zero, (b) one-half the average detection limit, or (c) the average detection limit (EPA 1989). Determining which substitution to use is based on whether or not substantial information exists to support the historical presence or absence of a given analyte at the station location. Since chemistry analyses have repeatedly resulted in ND values at the same stations through past surveys, ND values have been replaced with zeros in performing statistical calculations. As the ability to detect chemicals in increasingly smaller concentrations has improved greatly with time, detection/reporting limits differ in virtually all past surveys; this would confound any yearly comparison if options (b) or (c) from above were used.

# CHAPTER 2 — WATER COLUMN MONITORING

Water column measurements of physical and chemical characteristics such as water temperature, dissolved oxygen concentration, hydrogen ion concentration, and salinity are important components of a discharge monitoring program. Because biological communities exist in equilibrium within the marine environment, changes in the properties of these characteristics can result in potentially adverse impacts to these communities. As the properties within the receiving waters can vary naturally on a relatively small scale, water quality monitoring is designed to assess these parameters in a way that helps determine the scale of seasonal and tidally driven oceanographic influences with respect to the point of discharge. Long-term monitoring of these parameters can help determine whether deviations from expected patterns exist that may indicate impacts from the discharge on local biological communities and to determine whether the beneficial uses of the receiving waters remain protected.

## MATERIALS AND METHODS

Water quality monitoring was conducted during winter and summer at 17 receiving water (RW) stations located within the surrounding waters of the Mandalay Generating Station discharge channel (Figure 2-1). Stations RW1 through RW5 are positioned along the beach within the surf zone, centered on the discharge location. Stations RW6 through RW10 are positioned along the 30-foot (ft) isobath and Stations RW11 through RW17 are positioned along the 20-ft isobath. Water temperature, dissolved oxygen (DO) concentration, hydrogen ion concentration (pH), and salinity were recorded during ebbing and flooding tides, during the winter and summer surveys.

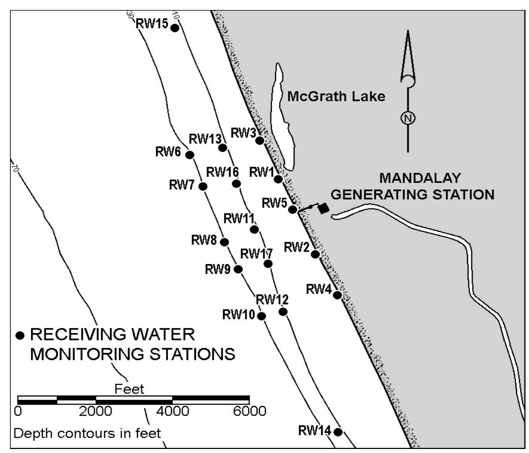



**Figure 2-1. Location of the water column sampling stations. Mandalay Generating Station NPDES, 2009.**

Winter water quality was monitored at Stations RW1 through RW17 on 11 March 2009 during flood and ebb tides. At surf-zone Stations RW1 through RW5, flood tide was sampled between 0700 and 0845 hours (hr) and ebb tide was sampled between 1200 and 1330 hr. At offshore Stations RW6 through RW17, flood tide was sampled between 0700 and 0815 hr and ebb tide was sampled between 1230 and 1345 hr (Figure 2-2). On the day of sampling, the tide rose from a low of +0.1 ft Mean Lower Low Water (MLLW) at 0416 hr to a high of +5.4 ft MLLW at 1018 hr, then fell to a low of -0.2 ft MLLW 1632 hr. Skies at surf-zone stations were overcast to mostly cloudy (75 to 100% cloud coverage) with winds that changed from west at 5 to 7 knots during the morning to northeast at 5 to 7 knots by the afternoon. At offshore stations, skies were mostly cloudy (80 to 95% coverage) with winds from the northeast at 3 to 5 knots during the flood tide sampling and changed to west at 2 to 3 knots by the afternoon ebb tide sampling. Seas were west at 2 to 3 ft.

Summer water quality was monitored at Stations RW1 through RW17 on 21 July 2009 during flood and ebb tides. At surf-zone Stations RW1 through RW5, flood tide was sampled between 0630 and 0800 hr and ebb tide was sampled between 1145 and 1315 hr. At offshore Stations RW6 through RW17, flood tide was sampled between 0600 and 0715 hr and ebb tide was sampled between 1145 and 1245 hr (Figure 2-2). On the day of sampling, the tide rose from a low of -1.5 ft MLLW at 0358 hr to a high of +4.2 ft MLLW at 1025 hr, then fell to a low of +1.9 ft MLLW at 1513 hr. Skies at surf-zone stations were clear with winds from the west at 1 to 3 knots in the morning and increased to 5 to 7 knots by the afternoon. At offshore stations, skies were overcast to cloudy (60 to 100% coverage) with winds from the southwest at 3 to 5 knots in the morning. By the afternoon, skies were mostly clear (15% coverage) to clear with winds from west at 5 to 7 knots. Seas were southwest at 2 to 3 ft during morning sampling and changed to west at 2 to 3 ft by the afternoon sampling.

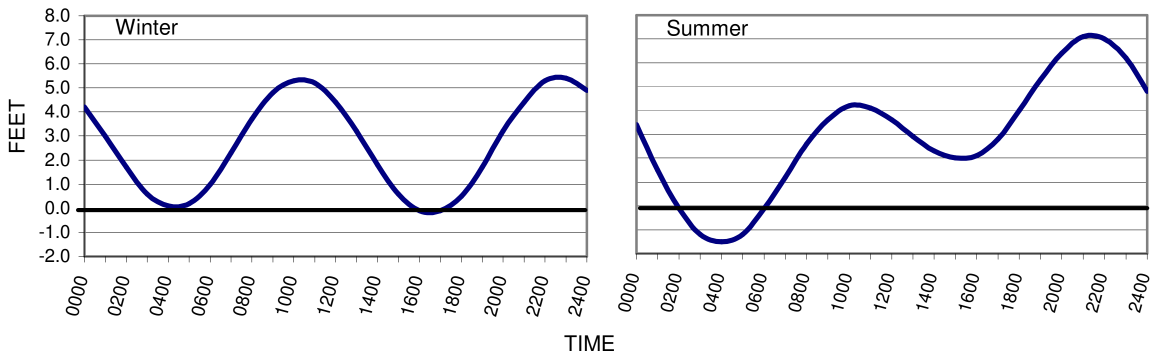



**Figure 2-2. Tidal rhythms during water column sampling, winter and summer surveys. Mandalay Generating Station NPDES, 2009.**

Water quality sampling at surf-zone stations was conducted by collecting surface water samples from the surf zone. Water samples were analyzed in the field using a Eureka Manta water quality analyzer. Sampling at offshore stations was conducted using a Sea-Bird Water Quality Monitoring System (SBE 25). Sea-Bird data were processed using Sea-Bird proprietary software (SeaSoft). The resulting data, along with field readings from the surf-zone stations, were imported into Microsoft Office Excel 2000 spreadsheets for further reduction and analysis. Vertical water quality profiles were constructed with SigmaPlot version 9. Color contour images depicting sea surface temperatures were constructed with TecPlot version 9.

## RESULTS

Water quality monitoring was conducted during flood and ebb tides, in winter and summer, offshore and alongshore of the Mandalay Generating Station to determine potential effects of the generating station discharge on receiving waters. Receiving water monitoring stations are shown in Figure 2-1. During both seasons, flood tide was sampled in the early morning, while ebb tide was sampled late morning or early afternoon. During the winter sampling two of four circulating pumps were operating with a flow of 121.2 mgd and a discharge temperature of 25.0℃, approximately 9.4℃ above ambient intake temperature (Siekiel-Zdzienicki 2009, pers. comm.). On the day of the summer sampling all four circulating pumps were in operation with a flow of 226.1 mgd and a discharge temperature of 28.9℃, about 8.9℃ above the intake temperature. Seasonal water quality data for flood and ebb tides are presented in Figures 2-3 through 2-6 and summarized in Tables 2-1 and 2-2. Raw data are presented in Appendix B-1 and B-2.

### Water Temperature

During winter monitoring, offshore surface water temperatures during the morning flood tide averaged 13.57℃ and ranged from 13.26℃ at Station RW14, 5,910 ft downcoast of the discharge on the 20-ft isobath, to 13.79℃ at Station RW17, 1,180 ft downcoast of the discharge channel on the 20-ft isobath (Table 2-1, Figure 2-3 and Appendix B-1). Surface water temperatures during ebb tide averaged 14.22℃ and ranged from 13.75℃ at Station RW14 to 14.47℃ at Station RW9, 1,180 ft downcoast of the discharge channel on the 30-ft isobath. At all stations, surface temperatures were higher during the later ebb tide by an average of almost 0.7℃ compared to the morning flood tide. The greatest increase between tides (1℃) was found at Station RW6, 2,360 ft upcoast of the discharge channel at 30 ft. Temperature decreased from surface to bottom at all stations during both tides. Average bottom water temperatures were 12.71°C during flood tide and 13.14°C on ebb tide. Coolest bottom water temperatures were recorded at stations along the 30-ft isobath and warmest bottom temperature was recorded at stations on the 20-ft isobath, at Station RW15, 5,910 ft upcoast of the discharge, on flood tide and at Station RW13, 2,360 ft upcoast of the discharge, on ebb tide.

**Table 2-1. Summary of water quality parameters during flood and ebb tides at offshore stations. Mandalay Generating Station NPDES, 2009.**

| | Winter | | | | | | | | Summer | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Temp. (°C) | | D.O. (mg/l) | | pH | | Salinity (psu) | | Temp. (°C) | | D.O. (mg/l) | | pH | | Salinity (psu) | |
| | Surface | | | | | | | | Surface | | | | | | | |
| | flood | ebb | flood | ebb | flood | ebb | flood | ebb | flood | ebb | flood | ebb | flood | ebb | flood | ebb |
| Mean | 13.57 | 14.22 | 8.52 | 9.06 | 7.93 | 8.00 | 33.40 | 33.37 | 16.02 | 16.67 | 7.43 | 7.92 | 7.87 | 7.93 | 33.44 | 33.49 |
| Minimum | 13.26 | 13.75 | 8.21 | 8.59 | 7.86 | 7.96 | 33.38 | 33.30 | 15.48 | 16.33 | 7.24 | 7.75 | 7.84 | 7.92 | 33.36 | 33.46 |
| Maximum | 13.79 | 14.47 | 9.15 | 9.71 | 7.98 | 8.05 | 33.42 | 33.43 | 16.51 | 16.93 | 7.55 | 8.22 | 7.88 | 7.96 | 33.48 | 33.50 |
| | Bottom | | | | | | | | Bottom | | | | | | | |
| | flood | ebb | flood | ebb | flood | ebb | flood | ebb | flood | ebb | flood | ebb | flood | ebb | flood | ebb |
| Mean | 12.71 | 13.14 | 7.20 | 8.20 | 7.80 | 7.91 | 33.48 | 33.45 | 14.61 | 14.66 | 7.44 | 7.65 | 7.86 | 7.89 | 33.51 | 33.50 |
| Minimum | 12.46 | 12.62 | 6.47 | 7.04 | 7.76 | 7.83 | 33.43 | 33.39 | 14.11 | 14.18 | 6.97 | 7.39 | 7.83 | 7.87 | 33.51 | 33.49 |
| Maximum | 13.40 | 13.74 | 8.42 | 9.00 | 7.91 | 7.98 | 33.50 | 33.48 | 15.33 | 15.61 | 7.86 | 8.04 | 7.89 | 7.92 | 33.52 | 33.52 |

At surf-zone stations in winter, surface water temperatures during flood tide averaged 14.12°C and ranged from 13.03°C at Station RW4, 2,360 ft downcoast of the discharge channel to 16.91°C at Station RW5, at the discharge channel (Table 2-2, Figure 2-3 and Appendix B-1). Surface water temperatures during ebb tide averaged 15.15°C and ranged from 14.16°C at Station RW3, 2,360 ft upcoast of the discharge channel, to 17.67°C at Station RW5. Water temperatures at all stations increased by about 1°C between tides, with temperatures at Station RW5 higher than those at the other surf zone stations.

**Table 2-2. Summary of water quality parameters during flood and ebb tides at surf-zone stations. Mandalay Generating Station NPDES, 2009.**

| | Temp. (°C) | | D.O. (mg/l) | | pH | | Salinity (psu) | | Temp. (°C) | | D.O. (mg/l) | | pH | | Salinity (psu) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Winter | | | | | | | | Summer | | | | | | | |
| | flood | ebb | flood | ebb | flood | ebb | flood | ebb | flood | ebb | flood | ebb | flood | ebb | flood | ebb |
| Mean | 14.12 | 15.15 | 6.49 | 6.48 | 8.05 | 8.15 | 33.3 | 33.5 | 16.36 | 18.50 | 6.98 | 7.10 | 8.00 | 8.09 | 33.7 | 33.7 |
| Minimum | 13.03 | 14.16 | 6.30 | 6.28 | 7.99 | 8.12 | 32.7 | 33.2 | 15.50 | 17.85 | 6.74 | 6.69 | 7.96 | 8.04 | 33.6 | 33.6 |
| Maximum | 16.91 | 17.67 | 7.04 | 6.96 | 8.08 | 8.17 | 33.5 | 33.7 | 17.00 | 19.21 | 7.13 | 8.17 | 8.05 | 8.14 | 33.7 | 33.7 |

During summer monitoring, surface water temperature during flood tide averaged 16.02°C and ranged from 15.48°C at Station RW15 to 16.51°C at Station RW9 (Table 2-1, Figure 2-4 and Appendix B-2). Surface water temperatures during ebb tide averaged 16.67°C and ranged from 16.33°C at Station RW14 to 16.93°C at Station RW15. Although average surface temperatures increased by less than 0.7°C between tides, surface temperature increases of 1°C or more were noted at the three stations offshore and upcoast of the discharge on the 20-ft isobath between tides. The greatest difference between tides (1.5°C) found at Station RW15. Temperature decreased from surface to bottom at all stations during both tides, with near-bottom temperatures similar at most stations on both tides. During flood tide, temperatures declined steadily with depth at all stations with moderate mid-depth thermal gradients observed at some stations. During the later ebb tide surface water warming resulted in stronger thermal gradients, with thermoclines of 1°C or more change within one meter of depth found between 3 and 5 m at all stations except RW10 and RW12, both 2,360 ft downcoast of the discharge, on the 30-ft and 20-ft isobaths, respectively. Average bottom

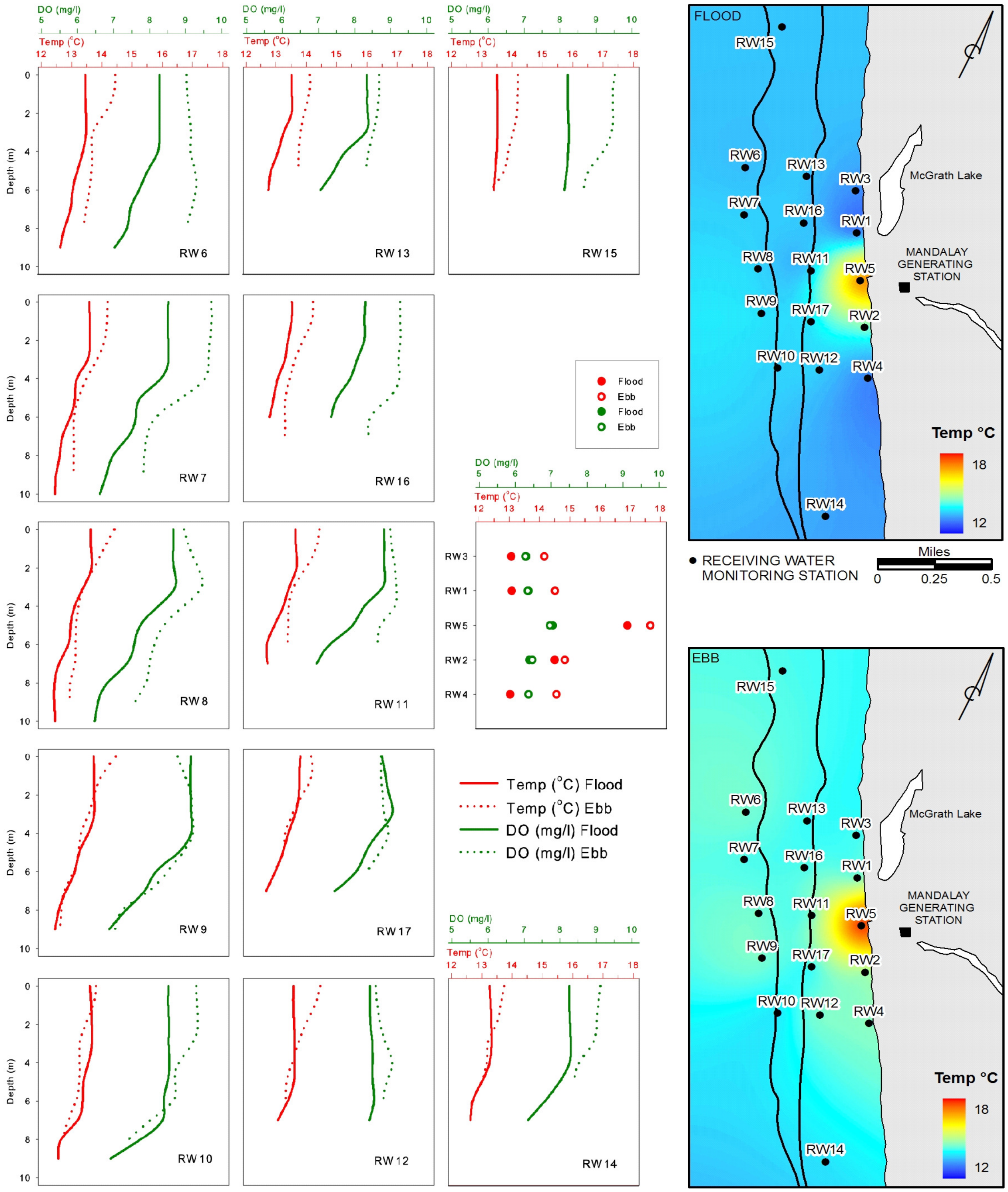



**Figure 2-3. False color surface temperature contour plots, surf-zone water quality, and temperature and dissolved oxygen vertical profiles during flood and ebb tides, winter survey. Mandalay Generating Station NPDES, 2009.**

water temperatures were 14.61 °C during flood tide and 14.66 °C on ebb tide. Coolest bottom water temperatures were recorded at stations along the 30-ft isobath and warmest bottom temperature was recorded at Station RW14 on flood tide and at Station RW12 on ebb tide, both stations on the 20-ft isobath.

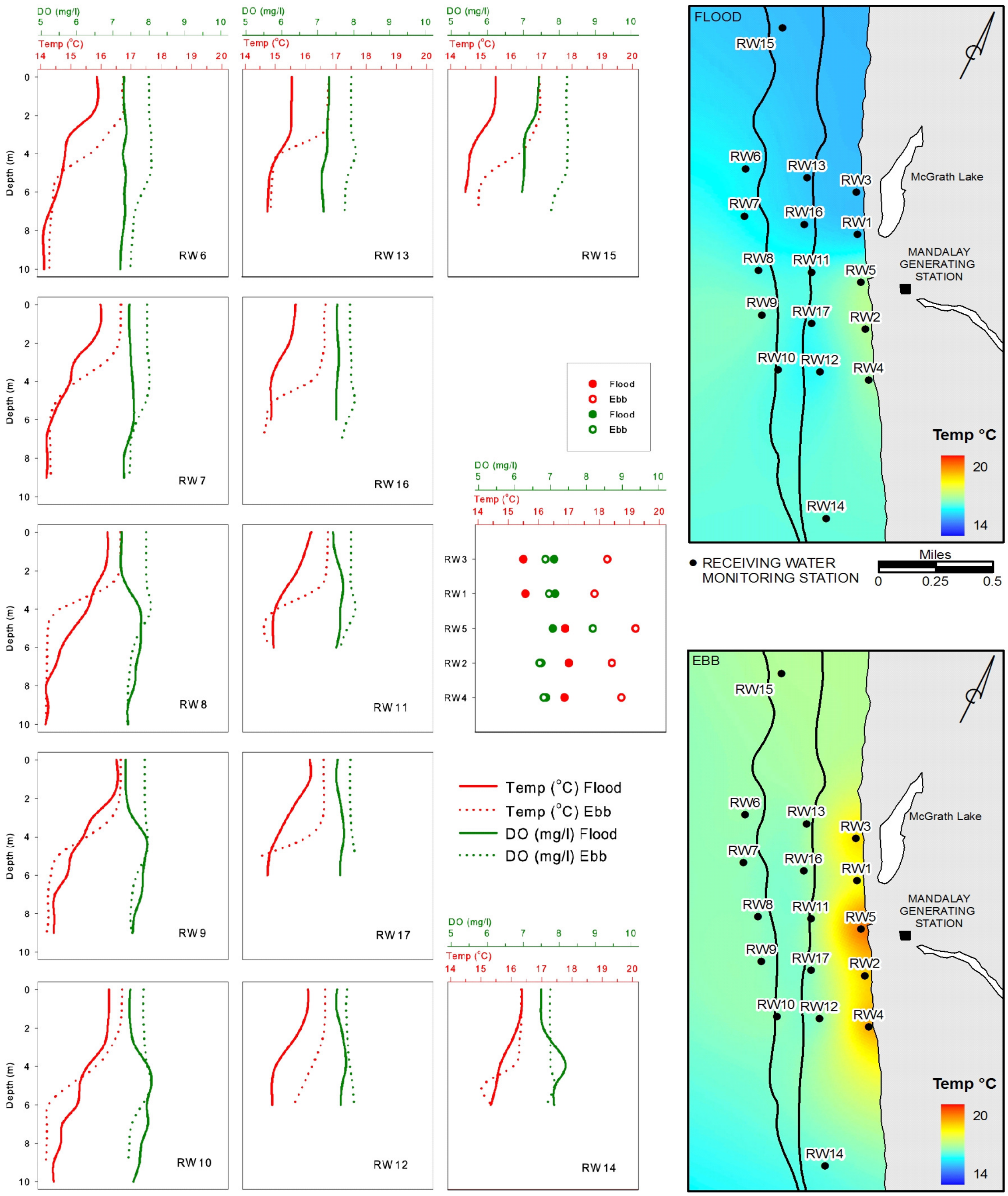



**Figure 2-4. False color surface temperature contour plots, surf-zone water quality, and temperature and dissolved oxygen vertical profiles during flood and ebb tides, summer survey. Mandalay Generating Station NPDES, 2009.**

At surf-zone stations, surface water temperatures during flood tide averaged 16.36°C and ranged from 15.50°C at Station RW3 to 17.00°C at Station RW2, 1,180 ft downcoast of the discharge channel (Table 2-2, Figure 2-4 and Appendix B-2). Surface water temperatures during ebb tide averaged 18.50°C and ranged from 17.85°C at Station RW1, 1,180 ft upcoast of the discharge to 19.21°C at Station RW5. Water temperatures increased all stations by more than 2°C between tides on average, with temperatures at Station RW5 slightly warmer than those reported at the other surf-zone stations during both tides.

**Dissolved Oxygen**

During winter monitoring, offshore surface dissolved oxygen (DO) concentration during flood tide averaged 8.52 mg/l and ranged from 8.21 mg/l at Station RW15 to 9.15 mg/l at Station RW9 (Table 2-1, Figure 2-3 and Appendix B-1). Surface DO concentrations during ebb tide averaged 9.06 mg/l and ranged from 8.59 mg/l at Station RW12 to 9.71 mg/l at Station RW7, 1,180 ft upcoast of the discharge channel on the 30-ft isobath. Surface DO values averaged more than 0.5 mg/l higher on ebb tide than during flood tide and in general DO concentrations at stations offshore and upcoast of the discharge were higher throughout the water column during the later tide. Downcoast of the discharge, ebb tide values were similar to flood values throughout the water column, particularly near bottom, with DO concentrations at Stations RW9 and RW17 decreasing slightly between tides in the upper water column. During both tides, DO concentrations at most stations remained consistent or increased slightly with depth to about 4 or 5 m, then decreased more rapidly with continued depth to the bottom. Maximum surface-to-bottom DO differentials, reductions of 2.27 mg/l and 1.87 mg/l, were found at Stations RW9 and RW7 on flood and ebb tides, respectively. Average bottom DO values were 7.20 mg/l during flood tide and 8.20 mg/l during ebb tide. On flood tide bottom DO concentrations ranged from 6.47 mg/l at Station RW8, offshore of the discharge channel on the 30-ft isobath, to 8.42 mg/l at Station RW12. On ebb tide bottom DO values ranged from 7.04 mg/l at Station RW9 to 9.00 mg/l at Station RW6.

At surf-zone stations in winter, surface DO concentrations during flood tide averaged 6.49 mg/l and ranged from 6.30 mg/l at Station RW3 to 7.04 mg/l at Station RW5 (Table 2-2, Figure 2-3 and Appendix B-1). Surface DO concentrations during ebb tide averaged 6.48 mg/l and ranged from 6.28 mg/l at Station RW3 to 6.96 mg/l at Station RW5.

During summer, offshore surface DO concentration during flood tide averaged 7.43 mg/l and ranged from 7.24 mg/l at Station RW8 to 7.55 mg/l at Station RW17 (Table 2-1, Figure 2-4 and Appendix B-2). Surface DO concentrations during ebb tide averaged 7.92 mg/l and ranged from 7.75 mg/l at Station RW14 to 8.22 mg/l at Station RW15. Surface DO values averaged about 0.5 mg/l higher on ebb tide than during flood tide. In general DO concentrations were higher in the upper water on ebb tide at all stations, though at most stations near-bottom DO values were similar between the tides. At Stations RW13 and RW15, farthest upcoast at 20 ft, DO concentrations decreased with depth to the bottom on flood tide. At the remaining offshore stations, DO concentrations increased slightly with depth to 4 or 5 m, then decreased more rapidly and variably with continued depth to the bottom on both tides. Maximum surface-to-bottom DO differentials were reductions of about 0.5 mg/l at Stations RW15 and RW8 on flood and ebb tides, respectively. Average bottom DO values were 7.44 mg/l during flood tide and 7.65 mg/l during ebb tide. On flood tide, bottom DO concentrations ranged from 6.97 mg/l at Station RW15 to 7.86 mg/l at Station RW14. On ebb tide, bottom DO values ranged from 7.39 mg/l at Station RW8 to 8.04 mg/l at Station RW17.

At surf-zone stations in summer, surface DO concentrations during flood tide averaged 6.98 mg/l and ranged from 6.74 mg/l at Station RW2 to 7.13 mg/l at Station RW1 (Table 2-2, Figure 2-4 and Appendix B-2). Surface DO concentrations during ebb tide averaged 7.10 mg/l and ranged from 6.69 mg/l at Station RW2 to 8.17 mg/l at Station RW5.

**Hydrogen Ion Concentration**

During winter monitoring, offshore surface hydrogen ion concentrations (pH) averaged 7.93 during flood tide and 8.00 during ebb tide (Table 2-1, Figure 2-5 and Appendix B-1). In general, pH

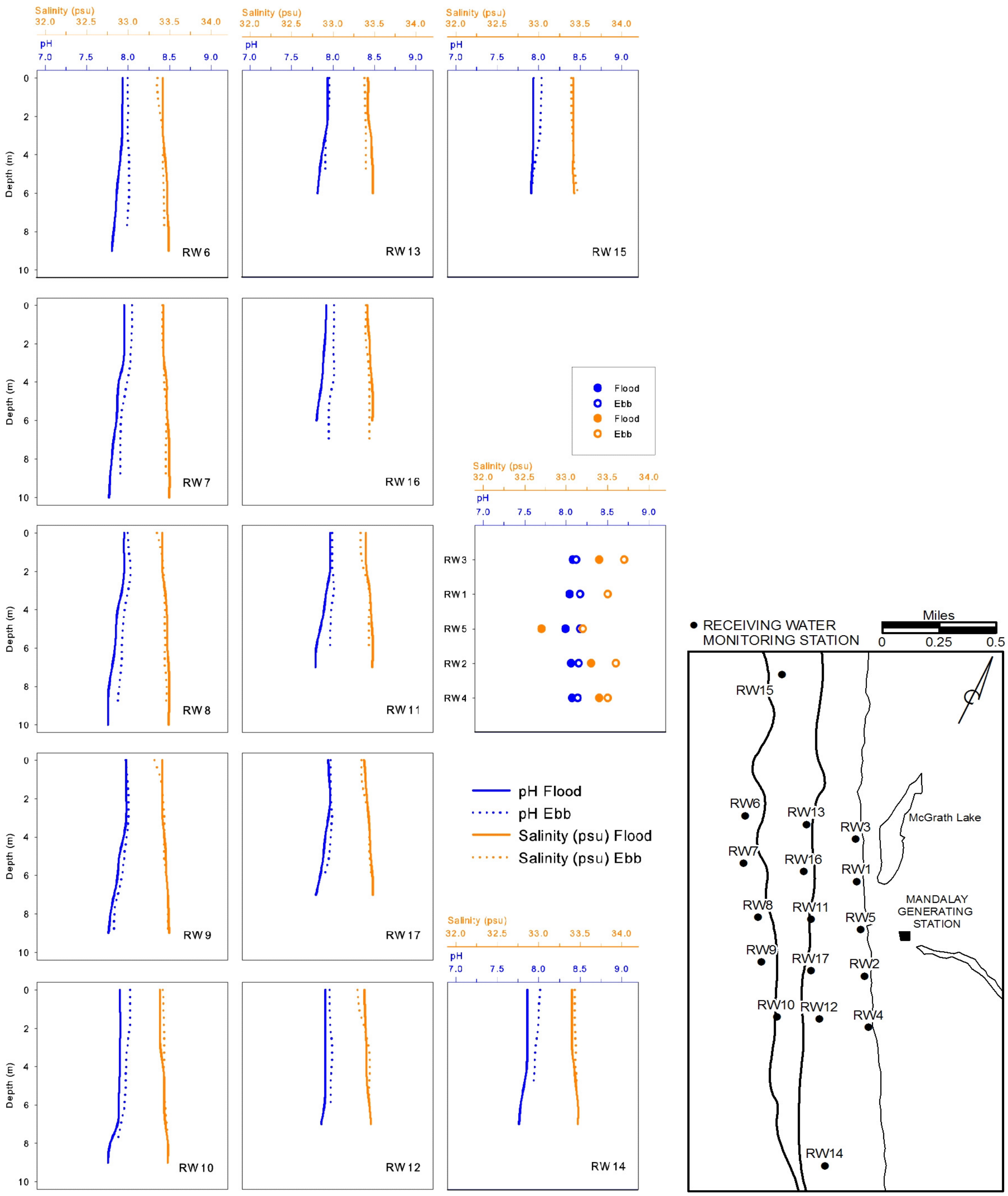



**Figure 2-5. Surf-zone water quality, and hydrogen ion concentration (pH) and salinity vertical profiles during flood and ebb tides, winter survey. Mandalay Generating Station NPDES, 2009.**

was slightly higher throughout the water column on ebb tide. During both tides, pH was consistent with depth at all stations, with a maximum surface-to-bottom differentials of 0.21 units at Station RW9 on flood tide and 0.15 units at Station RW10 on ebb tide, with an overall range of less than 0.3 units between tides and among stations and depths. Near-bottom pH values averaged 7.80 on flood tide and 7.91 during ebb tide.

At surf-zone stations in winter, surface pH values averaged 8.05 during flood tide and 8.15 during ebb tide (Table 2-2, Figure 2-5 and Appendix B-1). Hydrogen ion concentrations varied by less than 0.2 units among stations and between tides. Highest pH values were recorded at Station RW3 on flood tide and at Stations RW1 and RW5 on ebb tide.

In summer, surface pH values at offshore stations averaged 7.87 during flood tide and 7.93 during ebb tide (Table 2-1, Figure 2-6 and Appendix B-2). During the flood survey pH increased slightly with depth to a depth of about 3 m at most stations, then remained consistent with depth to the bottom. On ebb tide, near surface pH values were slightly higher than values reported during flood tide sampling. At most stations, mid and bottom pH levels were similar to those found during flood sampling, though at several stations on the 20-ft isobath higher pH values were reported throughout the water column. On both tides surface-to-bottom differentials of less than 0.1 units were reported at each station, with a total range of 0.13 units between tides and among stations and depths. Near-bottom pH values averaged 7.86 on flood tide and 7.89 during ebb tide.

At surf-zone stations, surface pH values averaged 8.00 during flood tide and 8.09 during ebb tide (Table 2-2, Figure 2-6 and Appendix B-2). Hydrogen ion concentrations varied by less than 0.2 units among stations and between tides. Highest pH values were recorded at Station RW1 on both tides.

**Salinity**

During winter monitoring, offshore surface salinity readings averaged 33.40 practical salinity units (psu) during flood tide and 33.37 psu during ebb tide (Table 2-1, Figure 2-5 and Appendix B-1). Salinity increased with depth at all stations on both tides. In general, salinity values were slightly lower with more near-surface variability during the afternoon ebb tide. Bottom salinities were very similar between tides and among stations. Average bottom salinity values were 33.48 psu during flood tide and 33.45 psu during ebb tide. Salinity values throughout the water column varied by 0.2 psu or less among stations, between tides and with depth, with maximum surface-to-bottom difference, an increase of 0.16 psu, at Station RW9 on ebb tide.

At surf-zone stations in winter, surface salinity readings averaged 33.3 psu during flood tide and 33.5 psu during ebb tide (Table 2-2, Figure 2-5 and Appendix B-1). Salinity among surf-zone stations varied by 0.8 psu during flood tide and by 0.5 psu during ebb tide. Lowest salinity values were recorded at Station RW5 on both tides. Highest salinity values were recorded at Station RW1 during flood tide and RW3 during ebb tide.

Summer surface salinity averaged 33.44 psu during flood tide and 33.49 on ebb tide (Table 2-1, Figure 2-6 and Appendix B-2). Salinity increased with depth at most stations on both tides, with slightly lower values and more variability in the upper 4 m during flood tide. Subsurface salinity maxima values were found at all stations on both tides, except Stations RW12 and RW14 on ebb tide where salinity decreased slightly with depth. Near-bottom water salinities averaged 33.51 psu on flood tide and 33.51 psu during ebb tide. Salinity values throughout the water column varied by about 0.2 psu among stations, between tides and with depth, with maximum surface-to-bottom difference (an increase) of 0.15 psu at Station RW9 on flood tide.

At surf-zone stations, surface salinity averaged 33.7 psu during both tides (Table 2-2, Figure 2-6 and Appendix B-2). Salinity varied by only 0.1 psu among stations and between tides. Lowest salinity values were recorded at Stations RW2 and RW4 on flood tide and at Station RW3 on ebb tide. Highest salinity values at all remaining stations during both tides.

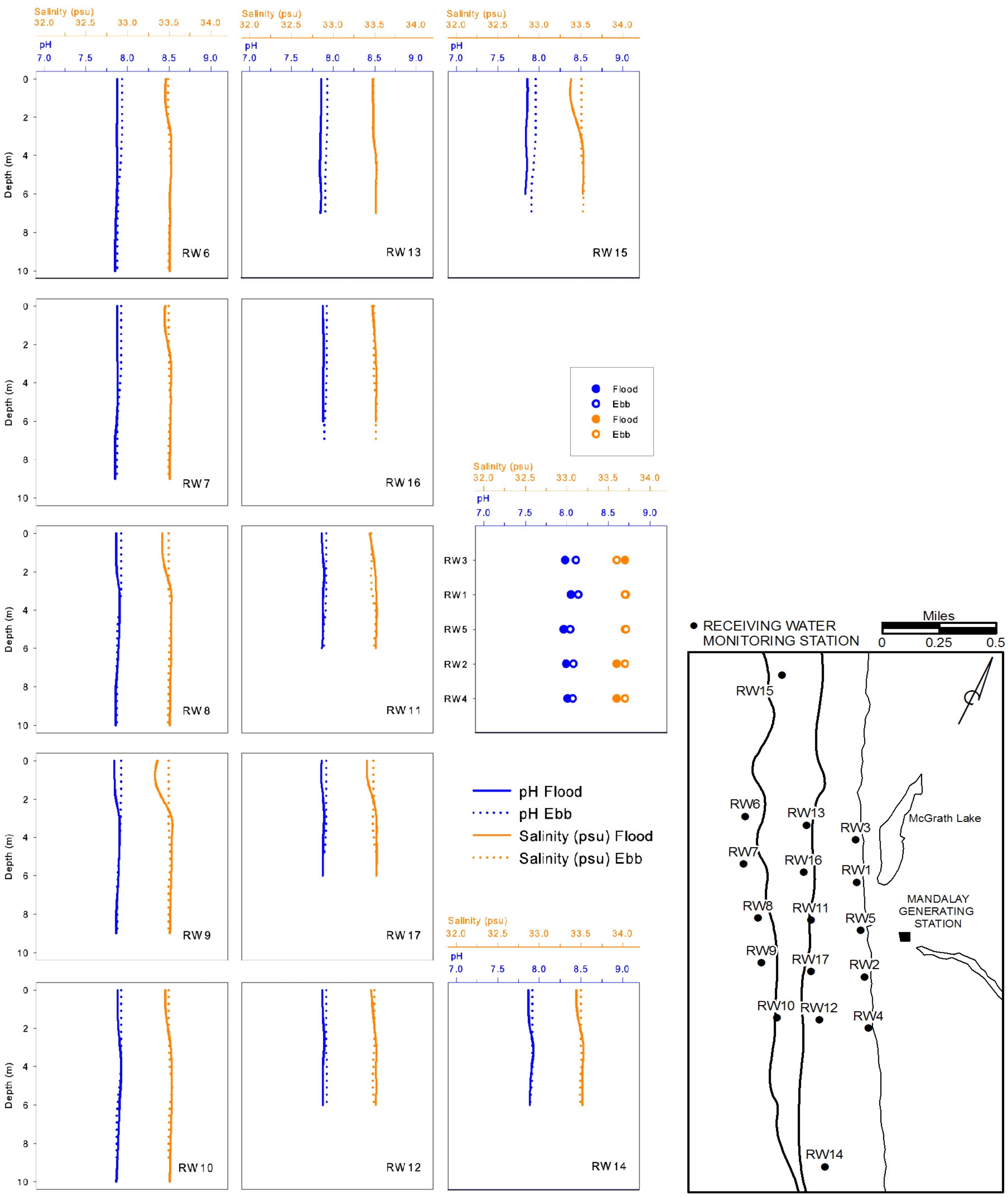



**Figure 2-6. Surf-zone water quality, and hydrogen ion concentration (pH) and salinity vertical profiles during flood and ebb tides, summer survey. Mandalay Generating Station NPDES, 2009.**

## DISCUSSION

Water quality monitoring was conducted on two tides each during winter and summer to determine potential influence of the Mandalay Generating Station discharge on the receiving waters. During the winter water quality sampling, two of four circulating pumps were operating with a flow

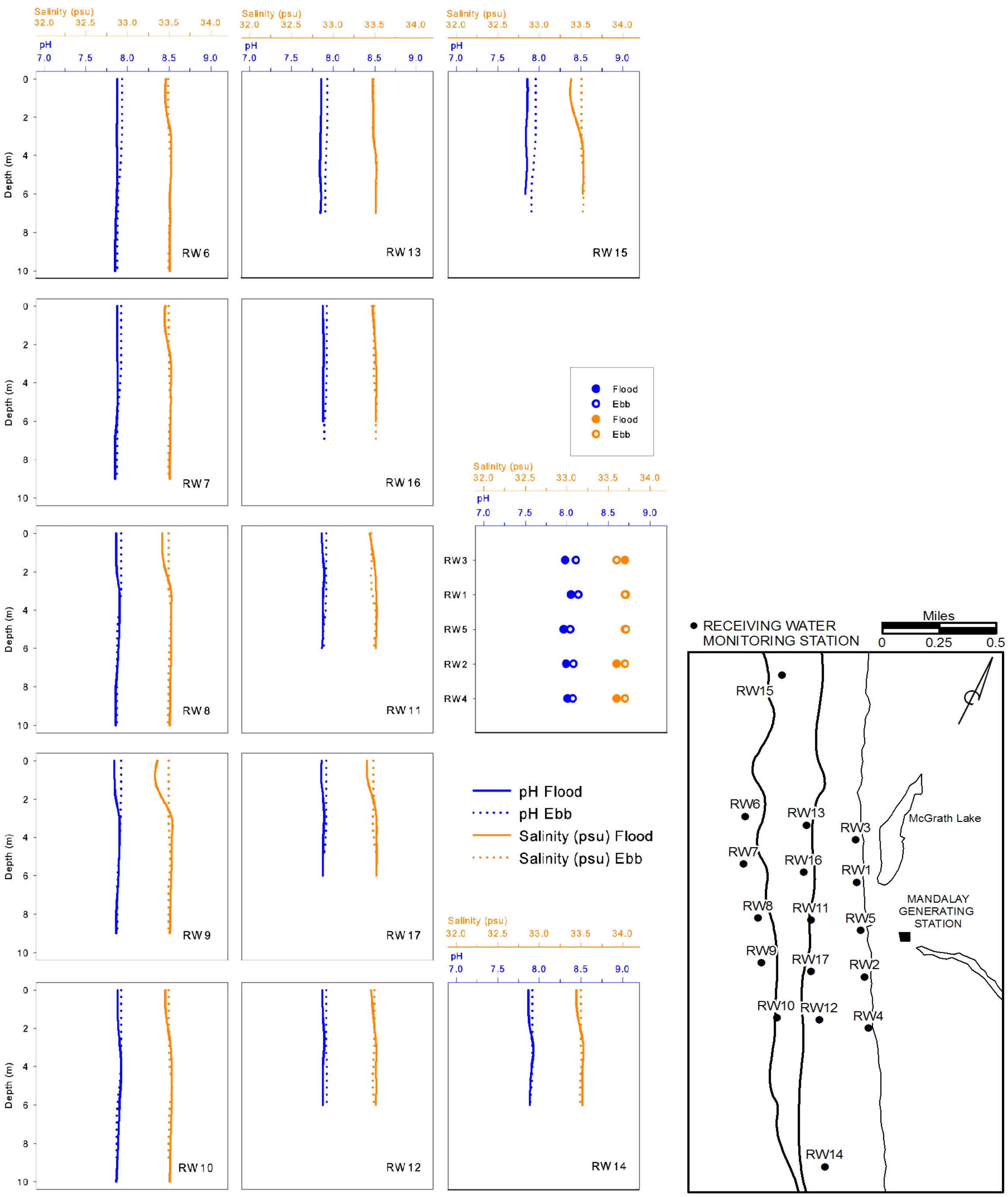



**Figure 2-6. Surf-zone water quality, and hydrogen ion concentration (pH) and salinity vertical profiles during flood and ebb tides, summer survey. Mandalay Generating Station NPDES, 2009.**

## DISCUSSION

Water quality monitoring was conducted on two tides each during winter and summer to determine potential influence of the Mandalay Generating Station discharge on the receiving waters. During the winter water quality sampling, two of four circulating pumps were operating with a flow of 121.2 mgd and a discharge temperature of 25.0°C, approximately 9.4°C above ambient intake temperature (Siekiel-Zdzienicki 2009, pers. comm.). At all offshore stations, surface temperatures during the later ebb tide monitoring were slightly higher than during early morning flood tide monitoring, likely a result of solar insolation. On average, surface water temperatures at all stations were about 0.7°C higher during the later tide, with the greatest increase between tides of 1°C found at the 30-ft station farthest upcoast of the intake channel. Temperature decreased from surface to bottom at all stations, with mild mid-depth thermal gradients noted on both tides. Surface temperatures were more similar among stations during the morning flood tide than found during ebb tide, while bottom temperatures were generally similar at stations between tides. Slightly warmer surface temperatures in the upper 1 m observed downcoast of the discharge at the 20-ft isobath on flood tide and at 30-ft isobath of ebb tide suggested the influence of warm water from the discharge. At surf-zone stations in winter, water temperatures reported during the later ebb tide were about 1°C higher than found on flood tide. Temperatures at the discharge station were higher by about 3.5°C on flood tide and 3.2°C on ebb tide than those found at the other surf-zone stations, while the temperature at the closest station downcoast of the discharge was nearly 1.5°C warmer than the remaining surf-zone stations during flood tide, indicating the presence of warm water from the discharge at the point of discharge on both tides and downcoast on flood tide. Otherwise, temperatures were similar at surf zone stations away from the discharge. Water temperatures in 2009 were typical of winter sampling results commonly reported in winter surveys and generally lower than temperatures found previously in the area (MBC 1986, 1988, 1990, 1994-2005, 2006a-2008a; Ogden 1991-1993). The elevated water temperatures in the surf zone and offshore of the discharge channel have been observed in the area previously and reflect tidal influences on the thermal discharge from the generating station on the day of sampling. Even in areas influenced by the thermal field, surface temperatures were typical of the area and within the range of natural variability observed during previous surveys.

During the summer water quality sampling, all four circulating pumps were in operation with a flow of 226.1 mgd and a discharge temperature of 28.9°C, about 8.9°C above the intake water temperature (Siekiel-Zdzienicki 2009, pers. comm.). As in winter, surface temperatures in 2009 were typical of summer surveys in the area (MBC 1986, 1988, 1990, 1994-2005, 2006a- 2008a; Ogden 1991-1993). Surface temperature increased by less than 0.7°C on average between the flood and ebb tide sampling, though increases of 1°C or more were noted at the three stations offshore and upcoast of the discharge on the 20-ft isobath. Temperature decreased from surface to bottom at all stations during both tides, with near-bottom temperatures similar at most stations on both tides. During flood tide, temperatures declined steadily with depth at all stations with moderate mid-depth thermal gradients observed at some stations, with a relatively strong thermocline found at Station RW14, farthest downcoast. During the later ebb tide, surface water warming resulted in stronger thermal gradients, with thermoclines found between 3- and 5-m depths at all stations except RW10 and RW12, both 2,360 ft downcoast of the discharge, on the 30-ft and 20-ft isobaths, respectively. Because surface temperatures were similar among stations during each tide, thermal influence from the discharge was not evident at the offshore stations in summer. At the surf zone stations, temperatures were comparable to offshore temperatures, with only slightly elevated temperatures at and downcoast of the discharge during flood tide. On ebb tide, temperatures were nearly 2°C higher on average compared to the offshore stations, indicating the presence of warm water from the discharge throughout the surf zone. These patterns have been observed in the area previously and reflect tidal influences on the thermal discharge from the generating station on the day of sampling. Even in areas influenced by the thermal field, surface temperatures were typical of those found in the area during previous surveys.

The concentration of dissolved oxygen in seawater is affected by physical, chemical, and biological variables. High DO levels may be the result of cool water temperatures (solubility of oxygen in water inversely correlates with temperature), active photosynthesis, and/or mixing at the air-water interface (Sverdrup et al. 1942). Conversely, low concentrations may result from high water temperatures, high rates of organic decomposition, and/or extensive mixing of surface waters with oxygen-poor subsurface waters. Dissolved oxygen concentrations typically fluctuates in the nearshore temperate environment around 7.5 mg/l (Kennish 2001), with a threshold of biological concern of 5 mg/l.

During the winter survey, DO concentrations at most stations remained consistent or increased slightly with depth in the upper 5 m, then decreased more rapidly with continued depth to the bottom during both tides. Surface DO values averaged more than 0.5 mg/l higher on ebb tide than during flood tide and in general DO concentrations at stations offshore and upcoast of the discharge were higher throughout the water column during the later tide. Generally higher DO levels later in the day is consistent with replenishment of dissolved oxygen concentrations in the water by increased photosynthetic activity as light becomes available and increases with the progression of the day. Downcoast of the discharge, ebb tide values were similar to flood values throughout the water column, particularly near bottom, with DO concentrations at Stations RW9 and RW17 decreasing slightly in the upper water column between tides. The similarity of DO levels with depth suggests that during the winter sampling the water column was fairly well mixed during both tides. In the surf zone, DO concentrations were slightly reduced compared to the offshore stations, with the highest levels reported at the discharge, likely a result of increased water movement and turbulence in the discharge channel, while lowest levels were found at the station farthest upcoast on both tides. Dissolved oxygen concentrations in winter were well above the level of concern at all stations on both tides. All DO values from the winter survey were within the range previously found in the area and typical of previous winter sampling (MBC 1986, 1988, 1990, 1994-2005, 2006a-2008a; Ogden 1991-1993).

In summer, DO values averaged about 0.5 mg/l higher on ebb tide than during flood tide. In general, DO concentrations were higher in the upper water column on ebb tide at all stations, though at most stations near-bottom DO values were similar between the tides. At Stations RW13 and RW15, farthest upcoast at 20 ft, DO concentrations decreased with depth to the bottom on flood tide. At the remaining offshore stations, DO concentrations increased slightly to a subsurface maxima at about 4 or 5 m, consistent with depth of the thermocline, then decreased rapidly and variably with continued depth to the bottom on both tides. The generally higher DO levels found later in the day were consistent with replenishment by photosynthetic activity, with greatest increases in the upper water column above the depth of the thermal gradients. In the surf zone, DO concentrations were slightly reduced compared to the other offshore stations on both tides, except at Station RW5 where DO indicated influence from the discharge, with levels similar to offshore concentrations during the ebb tide sampling. Dissolved oxygen concentrations in summer were well above the level of concern at all stations on both tides and within the range previously recorded in the survey area (MBC 1986, 1988, 1990, 1994-2005, 2006a- 2008a; Ogden 1991-1993).

In the open ocean, pH remains fairly constant due to the buffering capacity of sea water (Sverdrup et al. 1942). However, in nearshore areas, pH may vary due to physical, chemical, and biological influences. For instance, in areas with a large organic influx, such as bays, estuaries, and near river mouths, microbial decomposition can alter pH levels. Along with a reduction in DO, decomposition also results in the production of humic acids, which reduces pH (Duxbury and Duxbury 1984). Decreased pH values may also occur in areas of fresh water influx, since fresh water generally has a lower pH than salt water. In contrast, phytoplankton blooms, which are often associated with nearshore upwelling, may initially cause an increase in pH. High photosynthetic rates increase the removal of carbon dioxide from water, thus reducing the bicarbonate concentration, resulting in an increase in pH.

In both winter and summer, pH was very consistent throughout the water column at the offshore stations, and in both surveys slightly higher when sampled on the later ebb tides. Hydrogen ion values were slightly less consistent in winter, varying by about 0.3 units during the survey, than during summer when pH values varied by less than 0.2 units among stations, between tides and with depth. At the surf-zone stations, pH was relatively consistent at stations upcoast and downcoast of the discharge, with slightly higher values found during ebb sampling during both seasons, similar to patterns seen offshore. At the discharge, pH values were slightly lower than those found up- and downcoast on flood tide in winter and during both tides during summer, likely related to slight differences in water quality characteristics such as salinity between surf-zone receiving waters and the cooling water source. In 2009 all pH values were consistent with concentrations previously recorded in the study area (MBC 1986, 1988, 1990, 1994-2005, 2006a- 2008a; Ogden 1991-1993).

Salinity in the open ocean is generally 35 parts per thousand (ppt). However, in nearshore areas subjected to freshwater influx, salinity is usually slightly lower. In southern California, salinity values of nearshore waters are generally between 33 and 34 ppt (Dailey et al. 1993). Reductions in nearshore salinity usually result from freshwater input, while slight increases are often associated with upwelling of colder, deeper, more saline waters. Direct measurements of salinity are impractical, however, requiring the evaporation of one kilogram of seawater to obtain a final weight of salts. The most efficient measurement of salinity is determined by the electrical conductivity of seawater, which is precisely measured through the use of a CTD (conductivity-temperature-depth) instrument and is reported in “practical salinity units” (psu) which correlates one-to-one with ppt.

In winter, salinity values at the offshore stations increased with depth at all stations on both tides. In general, salinity values were slightly lower with more near-surface variability during the afternoon ebb tide. Bottom salinities were very similar between tides and among stations in winter. In summer salinity increased with depth at most stations on both tides, with slightly lower values and more variability in the upper 4 m during flood tide. Subsurface salinity maxima values were found at all stations on both tides, except for Stations RW12 and RW14 on ebb tide, where salinity decreased slightly with depth. Salinity values were very consistent in the offshore study area in 2009 varying by less than 0.25 psu or less among all stations between seasons. At the surf-zone stations, lower values at the discharge in winter suggested some local freshwater influence from the discharge plume, likely from urban and agricultural runoff into the harbor and intake canal that supply cooling water to the generating station. Otherwise salinity along the shoreline was similar to, though slightly higher than, levels reported in surface waters at the offshore stations. All values reported in 2009 were typical of the nearshore waters of southern California and within values found previously in the area (MBC 2002-2005, 2006a-2008a). While surface salinity appeared to be slightly reduced in the vicinity of the discharge in winter as a result of operation of the generating station in winter, the influence was local and similar to natural conditions found commonly throughout the study area.

## CONCLUSION

In 2009, water quality parameters were relatively consistent among stations and between tides during both winter and summer. During both seasons, warmer surface water was observed near the discharge during at least one tide, with variations in water quality parameters among nearby stations attributable to tidal influences on the thermal discharge from the generating station. These patterns have been observed in the area in previous surveys and the resulting parameters were similar to natural conditions found commonly throughout the study area. While water quality measurements indicated the presence of a thermal discharge from the Mandalay Generating Station in 2009, the influence was localized and did not appear to have an adverse effect on receiving waters in the study area.

# CHAPTER 3 — SEDIMENT CHARACTERISTICS

Marine sediment characteristics are affected by both natural and anthropogenic influences. Tides, currents, and wave action all influence sediment grain size by suspending and transporting fine-grained material, resulting in coarser sediments in dynamic areas and finer sediments in areas of reduced currents and wave action. Coastal streams and rivers contribute sediments as well as contaminants to the marine environment, with variable influence from year-to-year depending on yearly rain amounts. In coastal environments, man-made structures such as jetties and breakwaters alter water movement and may result in changes in local sediment characteristics and deposition patterns, while sand replenishment projects can influence sediment characteristics over large intertidal and subtidal areas. In addition to influencing grain size, anthropogenic inputs may contribute contaminants, including metals, to the environment, which can bind to sediments. Sediment grain size and sediment chemistry trends are useful in characterizing year-to-year differences that may be related to either natural or anthropogenic influences.

## MATERIALS AND METHODS

Bottom samples for sediment grain size and sediment chemistry analyses were collected at Stations B1 through B5 during the summer of 2009 (Figure 3-1). All samples were collected *in situ* by biologist-divers in conjunction with infauna sampling.

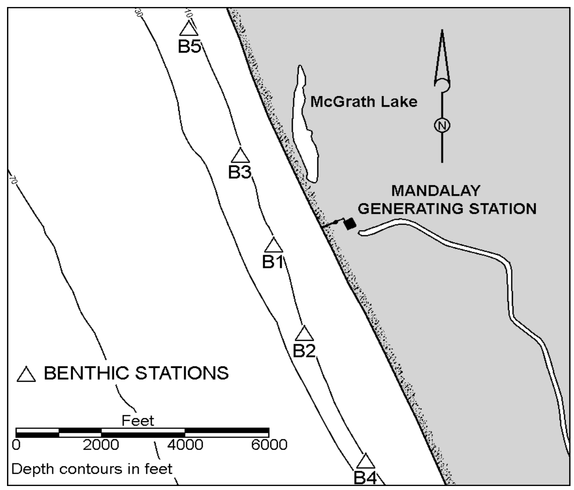



**Figure 3-1. Location of the benthic sampling stations. Mandalay Generating Station NPDES, 2009.**

### Sediment Grain Size

A sample of sediments for grain size analysis was taken at each station using a 3.5-cm-diameter, 15-cm-long plastic core tube. The sample was transferred to a pre-labeled plastic bag prior to laboratory analysis.

The size distributions of sediment particles were determined using two techniques: laser light diffraction to measure the amount and patterns of light scattered by a particle's surface for the sand/silt/clay fraction, and standard sieving for the gravel fraction. Laboratory data from the two methods were combined and presented in tabular format. Resulting analyses include mean and median grain size, standard deviation of the grain size, sorting, skewness, and kurtosis. Data were plotted as size-distribution curves. Additional details are provided in Appendix C-1.

### Sediment Chemistry

Samples for sediment chemistry analysis were taken from the upper two centimeters of the sediments at each station. To ensure that sediments were not contaminated by contact with metal, cleaned glass collection jars were filled with seawater and taken to the sea floor by biologist-divers where sediment samples were collected directly with the jars.

On the surface, sediments were kept on ice while in the field and maintained at approximately 4 °C until laboratory procedures began. Replicate sediment samples were composited by the analytical laboratory prior to analysis and reported as station results. Sediment was analyzed for total percent solids and four metals: chromium, copper, nickel, and zinc. Standard Methods (SM) method 2540 B was used in determining total percent solids, and Environmental Protection Agency (EPA) method 6020 was used for metal analysis.

## RESULTS

Sediment chemistry and grain size samples were collected by biologist-divers at Stations B1 through B5 on 22 July 2009 between 0945 and 1200 hours. Skies were clear with winds from the west that increased from 5 knots to 10 knots over the duration of the sampling. Sea conditions were west at 2 to 4 ft.

### Sediment Grain Size

Sediment distribution curves and parameters describing sediment grain size characteristics for each station are presented in Appendix C and are summarized in Table 3-1. Grain size is expressed in phi (Φ) units, which are inversely related to grain diameter (Appendix C-1).

**Table 3-1. Sediment grain size parameters. Mandalay Generating Station NPDES, 2009.**

| | Station | | | | | | |
|---|---|---|---|---|---|---|---|
| Parameter | B1 | B2 | B3 | B4 | B5 | Mean | S.D. |
| % Gravel | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| % Sand | 94.85 | 96.25 | 91.26 | 96.34 | 87.50 | 93.24 | 3.81 |
| % Silt | 3.70 | 2.46 | 6.22 | 2.37 | 10.19 | 4.99 | 3.30 |
| % Clay | 1.45 | 1.29 | 2.52 | 1.29 | 2.31 | 1.77 | 0.60 |
| Mean grain size | | | | | | | |
| phi | 2.73 | 2.51 | 2.94 | 2.50 | 3.25 | 2.76 | 0.32 |
| micrometers | 150 | 175 | 131 | 177 | 105 | 148 | 30 |
| Sorting | 0.714 | 0.712 | 0.804 | 0.663 | 0.702 | 0.719 | 0.052 |
| Skewness | 0.016 | -0.097 | 0.187 | -0.061 | 0.145 | 0.038 | 0.125 |
| Kurtosis | 1.200 | 1.404 | 1.526 | 1.489 | 1.277 | 1.379 | 0.139 |

Sediments at the five stations in 2009 were composed primarily of sand, with smaller amounts of silt and clay (Table 3-1). Gravel was not collected at any station in 2009. Overall, sediments from the five stations averaged about 93% sand, 5% silt, and 2% clay, with an average mean grain size of 2.76 phi (148 μm, fine sand). Sediments were finest at Station B5, 5,910 ft upcoast of the discharge, where mean grain size was 3.25 phi (105 μm, very fine sand). Sediments were coarsest at Station B4, 5,910 ft downcoast of the discharge, where mean grain size was 2.50 phi (177 μm, fine sand), and at Station B2, 2,360 ft downcoast of the discharge, where mean grain size was similar at 2.51 phi (175 μm, fine sand).

Sorting is a measure of the spread of the particle distribution curve, with poorly-sorted sediments composed of a broad range of particle size classes, while well-sorted sediments contain fewer size classes. In 2009, sorting averaged 0.719 phi (moderately sorted) overall (Table 3-1). Though sorting values ranged narrowly among stations, sediments at the three stations closest to the discharge fell into the moderately sorted category, while sediments at the stations farthest upcoast and downcoast were moderately well sorted. Sediment distribution curves at all stations were essentially unimodal, with a peak in the fine sand category and variable amounts of sediments in other size categories. Slight secondary peaks in the medium sand category occurred at Stations B2 and B4 (Appendix C-2).

Skewness and kurtosis tell how closely the grain size distribution approaches the normal Gaussian probability curve. More extreme skewness and kurtosis values indicate non-normal distributions. Skewness is a measure of the symmetry of the particle distribution curve; a value of zero indicates a symmetrical distribution of fine and coarse materials around the median of the curve, while a value greater then zero (positive) indicates an excess of fine material, and a negative value indicates an excess of coarse material. Skewness in 2009 averaged 0.038 and ranged from -0.097 at Station B2 to 0.187 at Station B1, at the discharge (Table 3-1). At Station B1, sediments were essentially evenly distributed, while at Stations B2 and B4 sediments were slightly skewed toward coarse material, and at Stations B3, 2,360 ft upcoast of the discharge, and B5 sediment distribution was skewed toward fine material.

Kurtosis is a measure of the peakedness of the particle distribution curve. A kurtosis value of 1.0 represents a normal particle distribution curve while a value greater than 1.0 indicates a leptokurtic (peaked) distribution with better sorting in the central portion of the curve than in the tails. A value less than 1.0 indicates a platykurtic (flattened) distribution and a lack of dominance by any one size category. Kurtosis values at all stations were greater than 1.0, indicating leptokurtic (excessively peaked) distributions, with dominance by a narrow range of size classes (Table 3-1). Kurtosis in 2009 ranged from 1.200 at Station B1 to 1.526 at Station B3, and averaged 1.379.

### Sediment Chemistry

Sediment samples collected at the five benthic stations were analyzed for chromium, copper, nickel, and zinc. Values are reported as dry weight. Sediment metal concentrations are presented in Appendix D and summarized in Table 3-2. Metal concentrations were similar among stations, though lowest concentrations of chromium, copper and zinc were found farthest downcoast at Station B4 while lowest nickel levels occurred offshore of the discharge at Station B1.

**Chromium.** Sediment chromium concentrations averaged 9.12 mg/kg and ranged from 8.46 mg/kg at Station B4 to 9.71 mg/kg at Station B2 (Table 3-2).

**Copper.** Sediment copper concentrations averaged 5.38 mg/kg and ranged from 4.63 mg/kg at Station B4 to 6.28 mg/kg at Station B5 (Table3-2).

**Nickel.** Sediment nickel concentrations averaged 8.44 mg/kg and ranged from 8.01 mg/kg at Station B1 to 8.86 mg/kg at Station B3 (Table 3-2).

**Zinc.** Sediment zinc concentrations averaged 28.1 mg/kg and ranged from 23.4 mg/kg at Station B4 to 34.3 mg/kg at Station B5 (Table 3-2).

**Table 3-2. Sediment metal concentrations (mg/dry kg). Mandalay Generating Station NPDES, 2009.**

| | Station | | | | | | | | | Reporting |
|---|---|---|---|---|---|---|---|---|---|---|
| Metal | B1 | B2 | B3 | B4 | B5 | Mean | S.D. | ERL | ERM | Limits |
| Chromium | 8.52 | 9.71 | 9.67 | 8.46 | 9.26 | 9.12 | 0.61 | 81 | 370 | 0.128 - 0.137 |
| Copper | 5.08 | 4.90 | 5.99 | 4.63 | 6.28 | 5.38 | 0.72 | 34 | 270 | 0.128 - 0.137 |
| Nickel | 8.01 | 8.64 | 8.86 | 8.52 | 8.15 | 8.44 | 0.35 | 20.9 | 51.6 | 0.128 - 0.137 |
| Zinc | 25.4 | 27.2 | 30.4 | 23.4 | 34.3 | 28.1 | 4.3 | 150 | 410 | 1.28 - 1.37 |

ERL = Effects Range Low
ERM = Effects Range Median

## DISCUSSION

### Sediment Grain Size

In 2009, sediments were analyzed from five stations offshore the Mandalay Generating Station. Sediments in 2009 were similar among all stations, with sediments composed of about 93% sand with lesser amounts of fine material (silt and clay) and mean grain sizes in the very fine to fine sand categories. Sediments at the two stations downcoast of the discharge (Stations B2 and B4) were coarsest, both comprised of more than 96% sand with similar mean grain sizes greater than those found at the remaining stations. Finest sediments occurred at the station farthest upcoast of the discharge (Station B5), where mean grain size was finest and contribution by fine material was greatest at nearly 13%. Sediment distributions offshore of the Mandalay Generating Station in 2009 were skewed toward fine material at the upcoast stations, slightly skewed toward coarse material at the downcoast stations, and nearly evenly distributed offshore of the discharge in the middle of the survey array (Appendix C-2). Still, characteristics were relatively similar among stations, with sediments at all stations moderately or moderately well sorted with the greatest contribution of sediments made by particles of a size similar to the mean grain size for each station.

Mean grain size in 2009 was finer than found in 2007 and 2008 and finer than the long-term mean grain size for the area, but coarser than the mean grain size reported in 2005 and 2006 (Figure 3-2; Appendix C-3). In 2006, mean grain size in the study area was among the finest on record, although slightly coarser than in 2005. However, in 2007, sediments at the discharge were the third coarsest found in the area long term, which skewed the overall survey mean, while in 2008, sediments were similarly coarse to levels reported in 2003 and 2004. In 2009, though sediments were finer than the previous two years and compared to the long-term mean, sediment grain size was more typical of the sediments previously common in the area, particularly between 1997 and 2002. Sediment grain sizes in the fine to very fine sand categories are common offshore of the generating station (MBC 1990, 1994, 1997-2005, 2006a-2008a; Ogden 1991-1993). In regional sampling conducted in 2003, sediments from shallow (5-30 m) coastal stations throughout the Southern California Bight averaged 31% fines overall, considerably higher than found in the survey area in 2009 or commonly in previous surveys (Schiff et al. 2006; Figure 3-2; Appendix C-3).

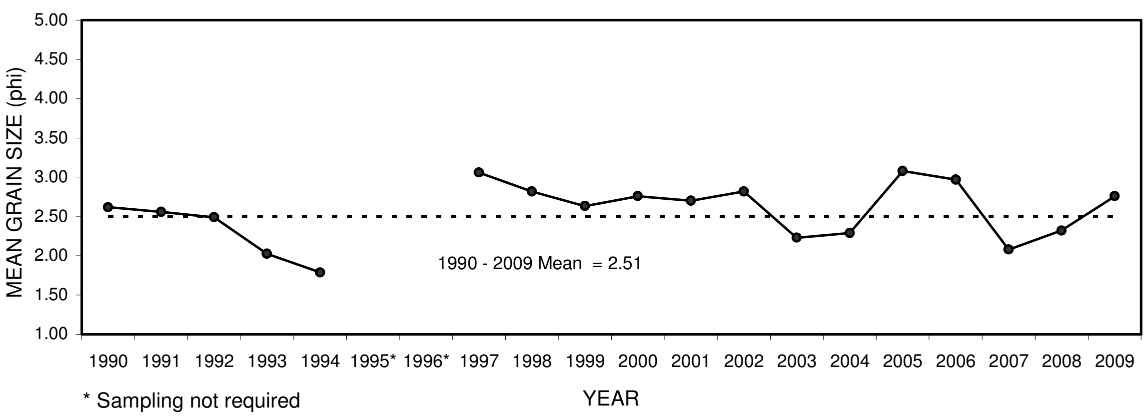



**Figure 3-2. Comparison of sediment mean grain size, 1990 - 2009. Mandalay Generating Station NPDES, 2009.**

There has been great year-to-year variability in grain size among stations off the generating station. Still, some sediment distribution trends have been observed in the area. The smallest mean grain size has historically been found at Station B5, farthest upcoast and nearest the Santa Clara River, in all but three surveys since 1990 (excluding 1998, 2003 and 2008 when this station was not sampled) (Appendix C-3). In contrast, coarsest sediments occurred at the discharge seven times during 18 surveys since 1990, at the farthest downcoast station five times (including this year), at the intermediate upcoast station three times, at the intermediate downcoast station twice and at the farthest upcoast station once (MBC 1990, 1994, 1997-2005, 2006a-2008a; Ogden 1991-1993). Since 1990, no annual surveys have recorded the finest sediments at the discharge.

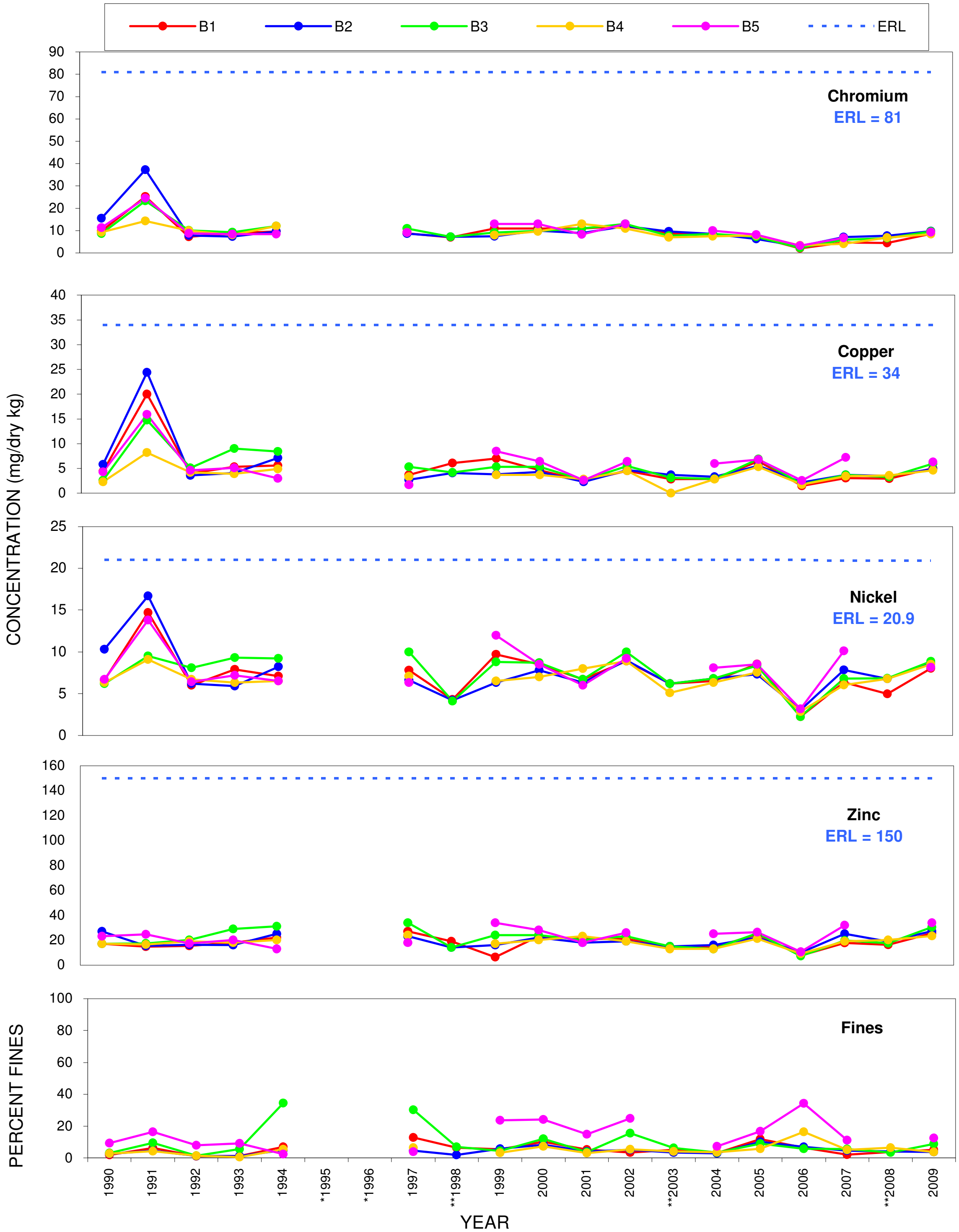
In 2009, mean grain size increased and percent contribution of fine sediments decreased consistently with distance from the station farthest upcoast of the discharge, suggesting that local sediments were more affected by flow and sediment deposition from the river than by generating station operations. This, along with the otherwise similar sediment characteristics among stations indicates that sediment distribution was primarily influenced by normal nearshore processes which influence grain size such as currents, waves and sand sources and movement. In some previous surveys, including in 2007, sediments offshore of the discharge channel appeared to have been influenced by turbulence associated with the cooling water discharge, however this influence has not occurred consistently in the area and was not observed in either 2008 or 2009, suggesting that the effect is localized and transitory (MBC 1990, 1994, 1997-2005, 2006a-2008a; Ogden 1991-1993). Sediment characteristics offshore of the Mandalay Generating Station discharge in 2009 were similar to those found throughout the area in 2009 and to characteristics observed previously in the area and appeared to be influenced primarily by natural causes.

**Sediment Chemistry**

In 2009, sediments at five stations off the Mandalay Generating Station were analyzed for the presence and concentration of chromium, copper, nickel, and zinc. Metal levels in 2009 were relatively similar among all stations (Table 3-2; Figure 3-3). In general, metal levels in 2009 were higher than have been reported in recent years, and similar to levels last found in the area in 2005 (2004 for chromium). This continues a trend of slightly increasing metals levels in the area since 2006 when reported levels were among the lowest found in previous studies (MBC 1990, 1994, 1997-2005, 2006a-2008a; Ogden 1991-1993). Still, in 2009, mean concentrations of chromium were below the respective long-term means at each station, while copper levels were similar to the long-term values and nickel and zinc slightly exceeded those levels somewhat. Still, all metal concentrations reported in 2009 were within levels found in previous surveys in the area.

Differences in metal concentrations among sites are often directly related to the amount of fine-grained material in the sediment. Fine-grained sediments may contain higher amounts of metals due to the greater available surface area (Ackermann 1980, de Groot et al. 1982). Comparisons should take into account the relative amounts of fine and coarse sediments. Sediments in the study area have consistently been sandy. In some previous years, including 2007, the largest percentages of fines (silt and clay combined) and in general, highest concentrations of metals were usually recorded farthest upcoast of the discharge (Station B5) near the Santa Clara River (Figure 3-3). Similarly, lowest metal concentrations were commonly found either offshore of the discharge or farthest downcoast, where percent sand is frequently highest and mean grain size largest (MBC 1990, 1994, 1997-2005, 2006a-2008a; Ogden 1991-1993). This trend continued somewhat in 2009, with lowest concentrations of chromium, copper and zinc found farthest downcoast where sediments were slightly coarser, though lowest nickel occurred offshore of the discharge where sediment size characteristics were intermediate to the remaining stations. Though copper and zinc were highest farthest upcoast where sediments were finest, lowest levels of chromium and nickel were found at the stations immediately downcoast and upcoast of the discharge. Because of an overall similarity in sediment characteristics and relatively low metal concentrations found in the sediments, as in many previous years, metal levels in 2009 do not appear to relate well to the amount of fine material in the sediments.

Metal levels reported in 2009 throughout the Mandalay study area were lower than or comparable to levels reported for the area by the National Oceanographic and Atmospheric Administration (NOAA) and to levels reported in three regional monitoring programs conducted throughout the Southern California Bight (Figure 3-4). Concentrations of metals in the study area have consistently been below levels determined to be potentially toxic to benthic organisms. Ranges of potential toxicity were developed by NOAA (NOAA 1991b) and later updated (Long et al. 1995) using data from spiked sediment bioassays, sediment-water equilibrium partitioning, and the co-occurrence of adversely affected fauna and contaminant levels in the field. Chemical concentrations believed to be associated with adverse biological effects from the various independent studies were compared for each parameter and the lower 10 percentile was designated as the "Effects Range-Low" (ERL). Concentrations below the ERL represent a minimal effects range; a range intended to




*No sampling required; ** 1998 - only three stations required, 2003 and 2008 - only four stations required

**Figure 3-3. Comparison of sediment metal concentrations and percent fines by station, 1990 - 2009. Mandalay Generating Station NPDES, 2009.**

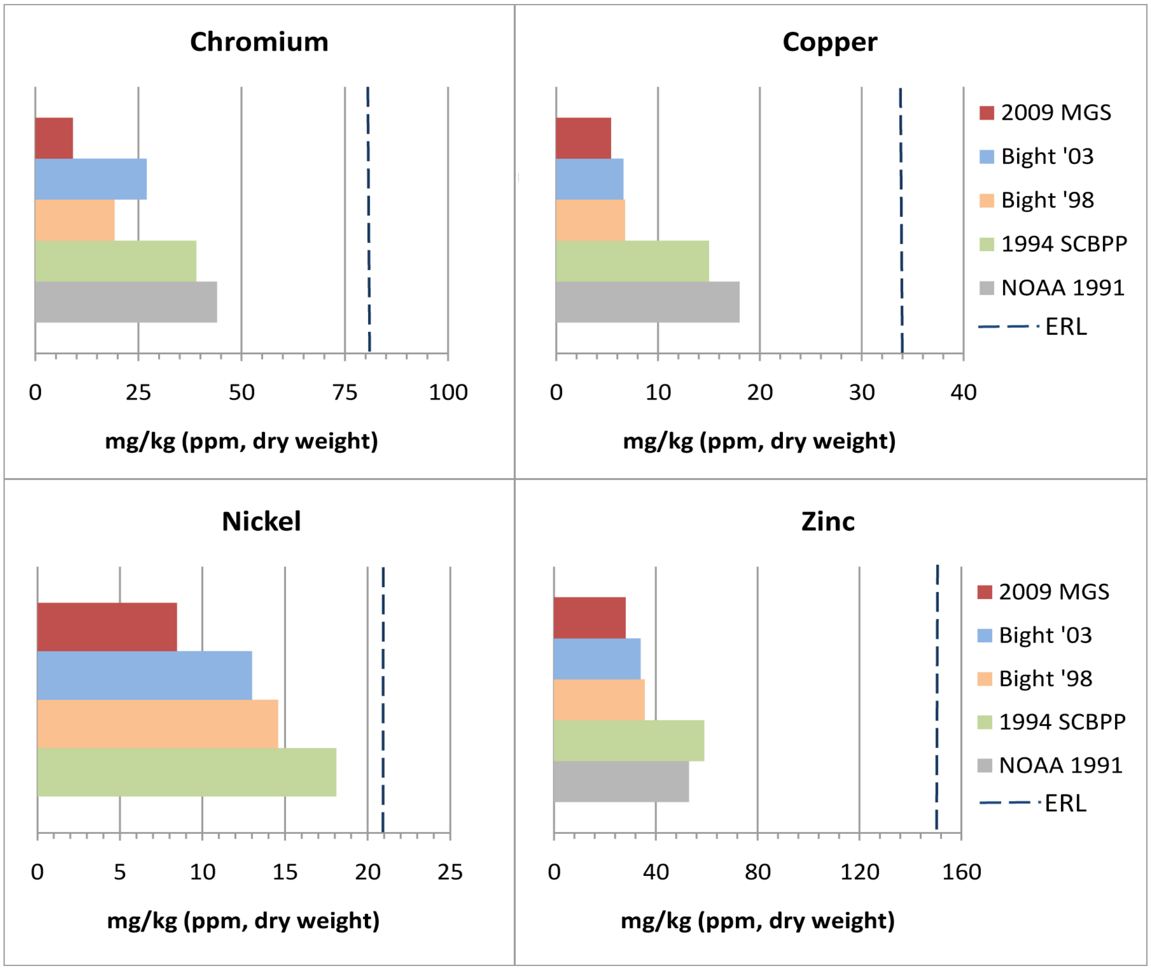



**Figure 3-4. Comparison of metal concentrations off Mandalay Generating Station in 2009 with results from: (1) Shallow (5 to 30 m depth) stations sampled during 2003 and 1998 (Schiff et al. 2006, Noblet et al. 2003), (2) on the southern California shelf (20 to 200 m) in 1994 (Schiff and Gossett 1998), (3) on the Oxnard shelf (SCCWRP 1973, NOAA 1991a), and (4) the Effects Range Low concentration (Long et al. 1995). Mandalay Generating Station NPDES, 2009.**

estimate conditions where effects would be rarely observed (Long et al. 1995). Metal concentrations have never exceeded their respective ERLs in the study area, and in 2009 were again well below the levels of concern (Figure 3-3).

Pollutants come from a variety of sources of both industrial and domestic origin. Oil and gasoline combustion releases many substances, including cadmium, copper, chromium, lead, mercury, and zinc. These and other metals are also used in paints, pigments, batteries, manufacturing, and protective coatings. Aerial fallout is a diffuse and potentially large source of contaminants derived from other sources, and may include metals, chlorinated hydrocarbons, and PAHs (SCCWRP 1973, 1986). As these contaminants accumulate on the ground, they are washed into rivers by rainfall, and are eventually deposited in the ocean.

Sediment metal concentrations have remained relatively consistent in the area since 1990. In 2009 metal concentrations were similar among stations. Although higher than levels reported since 2006, metal concentrations in 2009 were similar to results found commonly in previous surveys. Highest metal concentrations were found variously in the study area, though lowest metal levels occurred at the stations farthest downcoast or offshore of the discharge. Metal concentration did not appear to be related to sediment characteristics in 2009, likely due to an overall similarity in both the sediment characteristics and metal levels among all stations. Metal levels typically vary slightly from year to year and no long-term patterns of metal concentrations relative to the discharge were apparent. Concentrations of sediment metals in 2009 did not appear to be influenced by the operation of the Mandalay Generating Station.

## CONCLUSION

### Sediment Grain Size

In 2009, sediments were analyzed from five stations offshore the Mandalay Generating Station. Distribution characteristics were similar among all stations, though mean grain size increased and percent contribution of fine sediments decreased with distance from the Santa Clara River. The degree of influence of the discharge on local sediments varies from year to year, and the localized and transitory influence near the discharge noted in some previous surveys was not observed in 2009. Sediment characteristics offshore of the Mandalay Generating Station discharge in 2009 were similar to those found previously in the area and appear to be affected primarily by natural causes.

### Sediment Chemistry

Although higher than levels reported since 2006, metal concentrations in 2009 were similar to results found commonly in previous surveys, and the sediment metal concentrations have remained relatively consistent in the area since 1990 at levels below concentrations determined to be potentially toxic to marine organisms. While metal levels typically vary slightly from year to year, no long-term patterns of metal concentrations relative to the discharge were apparent. Concentrations of sediment metals in 2009 did not appear to be influenced by the operation of the Mandalay Generating Station.

# CHAPTER 4 — MUSSEL BIOACCUMULATION

Concentrations of many toxic substances in water are often too low or transitory to be reliably detected through the analysis of water samples. Also, many toxic substances are not water-soluble, but are instead associated with sediments or organic tissues. Tissues from aquatic organisms are preferably sampled because they accumulate and concentrate toxic substances to levels which may be hundreds of times the levels found in water samples, thus facilitating the detection of pollutants. Mussels are excellent subjects for this purpose because they 1) are sessile, 2) are long-lived, 3) can be transplanted and maintained in areas were they do not occur, and 4) reliably concentrate toxic pollutants from the water (SWRCB 1995, 2000).

## MATERIALS AND METHODS

Because the Mandalay discharge does not have an offshore structure, it has been necessary to transplant mussels for tissue analysis to an offshore mooring since 2001. For several years mussels were collected downcoast at the Ormond Beach Generating Station discharge buoy for transplant offshore of the Mandalay Generating Station. Replacement of the Ormond buoy in early 2006, however, eliminated this site as a mussel source, and as a result, starting in 2006, live bay mussels (*Mytilus galloprovincialis*) were purchased from a commercial mussel distributor, Carlsbad Aquafarms, for transplant offshore the Mandalay discharge. Mussels were harvested from Agua Hedionda Lagoon in Carlsbad, California on 10 March 2009, cleaned and placed within protective enclosures that allowed unrestricted water flow to the mussels, and transplanted to a mooring off the Mandalay discharge canal on 11 March 2009. Additional source mussels were frozen for later analysis and comparison with the transplanted mussels. On 22 July 2008 the transplanted mussels were retrieved and returned to the laboratory for chemical analysis.

Forty-five (45) transplanted bay mussels with shell lengths averaging 63 mm were collected from the mooring and returned to the laboratory for chemical analysis. Three replicate samples, each a composite of the tissue from 15 mussels, were analyzed for concentrations of the metals chromium, copper, nickel, and zinc according to methods used in the California State Mussel Watch Program (SMWP; Appendix A and SWRCB 1986). Standard Methods (SM) method 2540B was used in determining total percent solids, and Environmental Protection Agency (EPA) method 6020 was used for metal analysis. The same methods were used with bay mussels collected from the source site and from a set of California mussels (*Mytilus californianus*) collected on 15 July 2009 from Manhattan Beach Pier in Santa Monica Bay, which served as a reference site.

During sample analysis, metals are detectable at very low concentrations. The level below which the analytical method will no longer detect the analyte is referred to as the method detection limit (MDL). However, concentrations are only reported when results can be confirmed by exceeding a confidence level, termed the reporting limit (RL). If metal concentrations are detected at a level below the RL the results cannot reliably be reported and sample results are reported as none detected (ND). Beginning in 2005, analytical reporting limits for bioaccumulated metals were lower than in previous years (MBC 2001-2005, 2006a, 2007a). As a result, in 2005 and 2006 concentrations of some metals were reported at levels lower than possible during earlier surveys. In 2007, it was determined that the extremely low reporting limits utilized in 2005 and 2006 were more sensitive than necessary to detect bioaccumulated metals. So, while reporting limits have been higher since 2007, these levels reliably report metal concentrations commonly found in local mussel tissues without reporting ND results. For QA/QC purposes, the analytical laboratory may analyze one sample twice to confirm results and provide the results from both analyses. While both replicates are usually very similar, some differences in metal concentrations are typical. When QA/QC results are provided the highest value determined during either analysis is presented in the results.

## RESULTS

In 2009, chromium, copper, nickel, and zinc were detected in all mussel tissue replicates from the generating station discharge area, the source site and at a pier reference site (Table 4-1).

Chromium concentrations in mussels from the discharge ranged from 1.33 to 1.55 mg/dry kg with a mean of 1.46 mg/dry kg (Table 4-1). Mean chromium concentration at the discharge was higher than at both the source site (0.820 mg/dry kg), and the reference site (1.20 mg/dry kg).

Copper concentrations from the discharge averaged 2.15 mg/dry kg with a range from 2.10 to 2.22 mg/dry kg (Table 4-1). Copper levels were lower in the source mussels (1.13 mg/dry kg), but higher in mussels from the reference site (3.76 mg/dry kg).

Nickel levels in mussels from the discharge ranged from 0.665 to 0.863 mg/dry kg with a mean of 0.742 mg/dry kg (Table 4-1). Nickel at the discharge was higher than the mean concentration at both the source site (0.405 mg/dry kg) and the reference site (0.448 mg/dry kg).

Zinc concentrations at the discharge site ranged from 24.8 to 26.0 mg/dry kg, with a mean concentration of 25.4 mg/dry kg (Table 4-1). Zinc concentrations were higher in the source mussels, with a mean concentration of 25.6 mg/dry kg, and at the reference site with a mean of 35.5 mg/dry kg.

**Table 4-1. Mussel tissue metal concentrations (dry weight and reporting limits, mg/dry kg; wet weight and EDL, mg/wet kg). Mandalay Generating Station NPDES, 2009.**

| | Dry Weight | | | | | | Wet Weight | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Replicate | | | | | Reporting | Replicate | | | | | | |
| Metal | 1 | 2 | 3 | Mean | SD | Limits | 1 | 2 | 3 | Mean | SD | EDL 85 | EDL 95 |
| Discharge | | | | | | | | | | | | | |
| Chromium | 1.55 | 1.33 | 1.49 | 1.46 | 0.11 | 0.179 - 0.191 | **0.83** | 0.70 | **0.83** | **0.79** | 0.08 | 0.73 | 1.60 |
| Copper | 2.22 | 2.10 | 2.12 | 2.15 | 0.06 | 0.269 - 0.287 | 1.19 | 1.10 | 1.18 | 1.16 | 0.05 | 2.28 | 4.28 |
| Nickel | 0.863 | 0.665 | 0.698 | 0.742 | 0.11 | 0.0896-0.0956 | 0.46 | 0.35 | 0.39 | 0.40 | 0.06 | 0.78 | 1.06 |
| Zinc | 24.8 | 26.0 | 25.3 | 25.4 | 0.60 | 1.79 - 1.91 | 13.3 | 13.6 | 14.1 | 13.7 | 0.43 | 42.92 | 52.60 |
| % Solids | 53.5 | 52.3 | 55.8 | 53.9 | 1.78 | 0.100 | - | - | - | - | - | - | - |
| Source Mussels | | | | | | | | | | | | | |
| Chromium | 0.982 | 0.885 | 0.594 | 0.820 | 0.202 | 0.145 - 0.165 | 0.63 | 0.54 | 0.41 | 0.53 | 0.11 | 0.73 | 1.60 |
| Copper | 1.17 | 1.29 | 0.938 | 1.13 | 0.18 | 0.217 - 0.247 | 0.75 | 0.78 | 0.65 | 0.73 | 0.07 | 2.28 | 4.28 |
| Nickel | 0.462 | 0.478 | 0.275 | 0.405 | 0.113 | 0.0725-0.0824 | 0.30 | 0.29 | 0.19 | 0.26 | 0.06 | 0.78 | 1.06 |
| Zinc | 27.7 | 26.4 | 22.6 | 25.6 | 2.7 | 1.45 - 1.65 | 17.73 | 16.02 | 15.59 | 16.45 | 1.13 | 42.92 | 52.60 |
| % Solids | 64.0 | 60.7 | 69.0 | 64.6 | 4.2 | 0.100 | - | - | - | - | - | - | - |
| Manhattan Beach Pier Reference Site | | | | | | | | | | | | | |
| Chromium | 1.21 | 1.12 | 1.26 | 1.20 | 0.07 | 0.157 - 0.163 | **0.77** | **0.70** | **0.77** | **0.75** | 0.04 | 0.55 | 1.04 |
| Copper | 3.75 | 3.89 | 3.63 | 3.76 | 0.13 | 0.236 - 0.245 | **2.38** | **2.42** | **2.23** | **2.34** | 0.10 | 1.59 | 2.12 |
| Nickel | 0.427 | 0.347 | 0.570 | 0.448 | 0.113 | 0.0787 - 0.0816 | 0.27 | 0.22 | 0.35 | 0.28 | 0.07 | 0.63 | 0.82 |
| Zinc | 35.6 | 32.6 | 38.3 | 35.5 | 2.9 | 1.57 - 1.63 | 22.6 | 20.3 | 23.5 | 22.1 | 1.65 | 33.64 | 38.87 |
| % Solids | 63.5 | 62.2 | 61.3 | 62.3 | 1.1 | 0.100 | - | - | - | - | - | - | - |

EDL = Elevated Data Levels　　**Blue** values exceed EDL 85　　**Red** values exceed EDL 95

## DISCUSSION

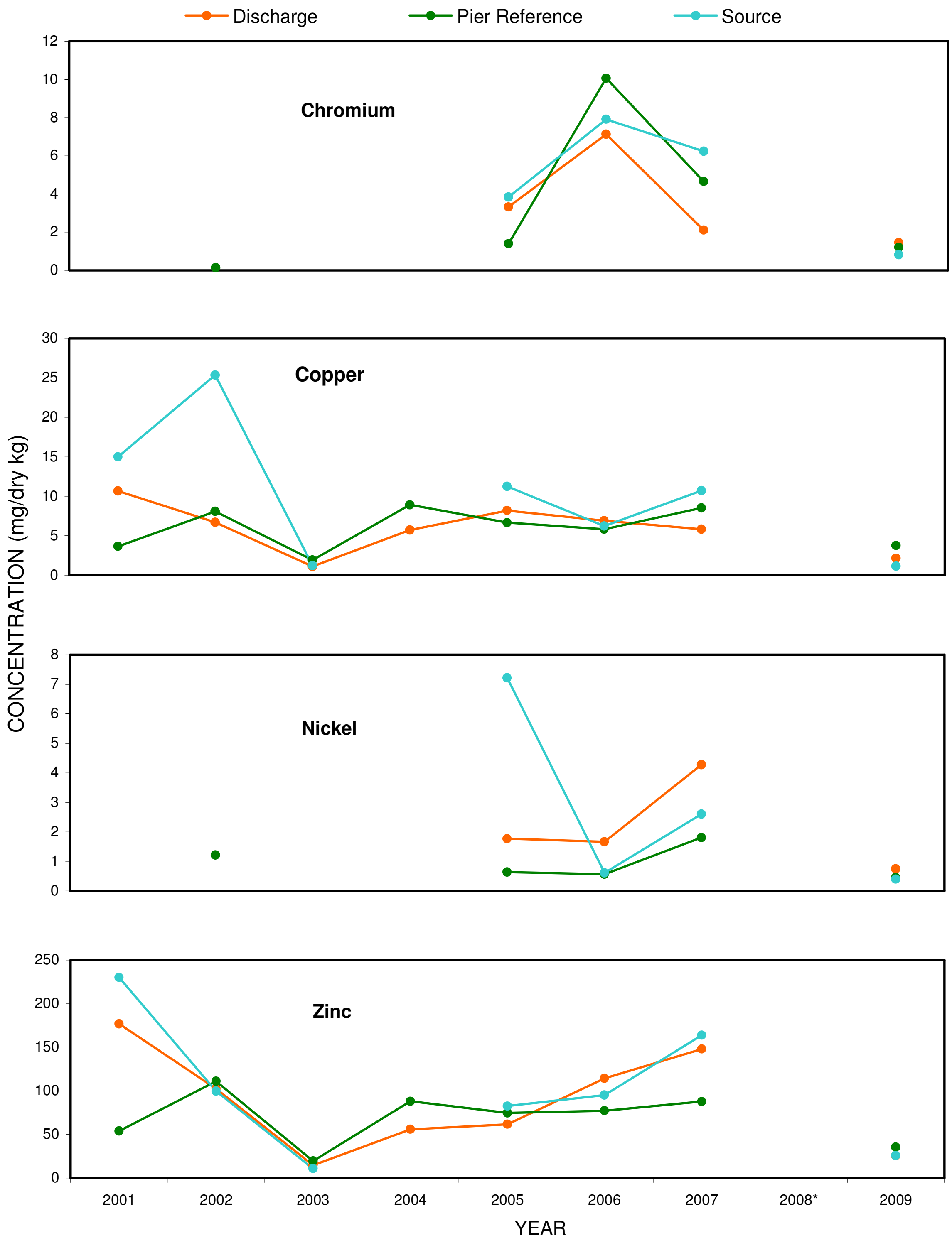
The SMWP monitors levels of metals and organic pollutants in both native California mussels and bay mussels. Bioaccumulation of pollutants by the two species was found to be comparable, although some differences were found between the mussels, likely related to habitat preference (SWRCB 1995, 2000). California mussels are preferentially used for analysis. However, a resident population of mussels is sometimes not available in an area, such as offshore of the Mandalay Generating Station. In that case, mussels are transplanted into the area for at least 90 days. All analytical results are reported on a dry weight basis; however, wet weight concentrations were calculated for comparison with evaluation criteria.

Water quality standards for evaluating bioaccumulation in mussel tissues are primarily based on human or animal health criteria, and several standards of comparison are currently available (SWRCB 1995, 2000). However, action levels for only a few organic chemicals have been determined. Because of this, the SMWP developed a method of comparison among samples based on elevated data levels (EDL). The EDL for any particular substance is based on a ranking of statewide tissue levels for that substance from the ongoing SMWP. Elevated data levels are determined for each species and may vary depending on whether the mussels are resident or transplanted. Elevated data levels are updated periodically based on recent data. In the EDL ranking system the 50$^{th}$ percentile corresponds to the median of all values rather than to a mean. The 85$^{th}$ percentile (EDL 85) indicates that a chemical is markedly elevated from the median. The 95$^{th}$ percentile (EDL 95) indicates values that are highly elevated above the median. While no studies have strictly compared these values, this information is useful in determining if a particular substance has been found in unusually high concentrations and in comparing local results to recent statewide results.

In 2009, all four metals were reported in all mussels tissue replicates from the generating station discharge, in the source mussels, and at the reference site. Chromium levels at the discharge were similar to, but slightly higher than values in both the source mussels and in reference site mussels (Table 4-1 and Figure 4-1). Values as all sites in 2009 were lower than levels reported at the discharge in the previous three surveys. Tissue concentrations of chromium at the discharge in 2009 were detected at about 30% of the level reported in 2007, and at less than one-half the levels reported in both 2005 and 2006. No analysis for tissue metal concentrations was performed in 2008 as part of the resource exchange for participation in the Bight ‘08 Regional Monitoring Program (MBC 2008a). Previous to 2005, chromium was not reported in mussels from the discharge (Figure 4-1 and Figure 4-1; MBC 1990, 1999-2005, 2006a, 2007a; Ogden 1991-1993). The chromium concentration found in mussels from the discharge in 2009 was the lowest reported in the discharge area. Still, as in 2006, wet-weight chromium levels in mussels from the Mandalay discharge exceeded the EDL 85 for bay mussels, indicating that chromium was elevated in the study area (Table 4-1). Chromium levels in mussel tissue from the Manhattan Beach Pier reference site were also elevated, exceeding the EDL 85 value for resident California mussels. Wet-weight concentrations of chromium in tissues from the source site did not exceed levels considered elevated by SMWP for bay mussel.

Copper concentrations in mussels from the discharge in 2009 were the second lowest reported in mussels from the area and less than one-half the values reported in the area since 2004 (Table 4-1 and Figure 4-1). Concentrations of copper at the discharge were nearly twice the values found in source mussels, but 40% lower than concentrations reported at the reference site. Wet-weight copper levels at the discharge and at the source site were below the EDL 85 value for bay mussels, indicating that in 2009 copper concentrations were not elevated in these areas. Copper values at the reference site, however, were highly elevated, at concentrations above the EDL 95 value for native California mussels.

Nickel concentrations in mussels from the discharge in 2009 were the lowest reported in the area at less than one-half the levels found in 2005, 2006 and less than 20% of the value reported in 2007 (Table 4-1 and Figure 4-1). Previous to 2005, nickel was not reported in mussels from the discharge. Since 2006 nickel has been detected at higher concentrations in mussels from the discharge compared to the source mussels and mussels from the reference site. While this was found again in 2009, the levels at all sites were similarly low compared to previous results. Wet-weight concentrations of nickel in mussel tissues from the discharge were below the EDL 85 value for bay mussels indicting that levels were not elevated. Nickel concentrations in mussel




* Mussels not available in 2008.

**Figure 4-1. Comparison of mean chromium, copper, nickel, and zinc concentrations in mussel tissue at discharge and at reference sites, 2001 - 2009. Mandalay Generating Station NPDES, 2009.**

tissues collected from the source site and from the reference site were also below levels considered elevated by the SMWP for the respective mussel species.

Zinc concentrations from the discharge in 2009 were the second lowest reported in the area and lower than reported since 2003 (Table 4-1 and Figure 4-1). Zinc levels were very similar in discharge and source mussels, both of which were below the concentration found at the reference site. Wet-weight zinc concentrations from the discharge were notably lower than the EDL 85 values for bay mussels, indicating that zinc levels were not elevated near the Mandalay discharge. Wet-weight concentrations of zinc at both the source site and the reference site were also below levels considered elevated.

**CONCLUSION**

In 2009, concentrations of metals decreased from levels reported commonly in previous surveys and were among the lowest reported in mussels from offshore the Mandalay discharge. Metal levels were also reduced in source mussels and in mussels from the reference site. In general, levels were comparable among the sites. Still, chromium at the discharge and at the reference site exceeded values considered elevated by the State Mussel Watch Program, while copper was found to be highly elevated at the reference site. The similarity of tissue metal levels among sites, to previous studies, and to other areas in southern California suggests that the operation of the Mandalay Generating Station is not elevating metal concentrations above background levels.

# CHAPTER 5 — BENTHIC INFAUNA

The benthic infauna, invertebrates that live in the bottom sediments, are an important part of the marine ecosystem. These animals are a major food source for fish and other larger invertebrates, and contribute to nutrient recycling. Some species are highly sensitive to effects of human activities, while others thrive under altered conditions. The assessment of the benthic community is, therefore, a major component of many marine monitoring programs, which document both existing conditions and trends over time.

The benthic infaunal community offshore of the Mandalay Generating Station has been sampled as part of the NPDES environmental monitoring program since 1978. Benthic samples were collected in both winter and summer from 1978 to 1988, and only in summer since 1990. Five stations have been sampled in most surveys; as part of the resource exchange for participating in the Southern California Bight Regional Monitoring programs, only three stations were sampled in 1998, and four stations in 2003 and 2008, with only two replicates each. New in 2006 was inclusion of the Southern California Benthic Response Index (BRI) which was developed to provide a scientifically valid criterion or threshold that can be used to distinguish “healthy” and “unhealthy” benthic communities (Smith et al. 2003, SCCWRP 2009).

## MATERIALS AND METHODS

Biologist-divers collected sediment cores for analysis of infaunal composition at Stations B1 through B5 on 22 July 2009 between 0945 and 1200 hours (Figure 5-1). Skies were clear with winds from the west that increased from 5 to 10 kn over the duration of sampling. Seas were from the west at 2 to 4 ft. Four replicate cores were collected at each station using a hand-held, diver-operated box corer which collects a uniform sample of 100.0 $cm^2$ surface area to a depth of 10.0 cm, for a total sample volume of 1.0 liter (l) (Figure 5-2). The box corer was pushed into the sediment and a closing blade was swung across the mouth of the box. The core was then withdrawn from the sediment and sealed by a neoprene cover for transport to the surface. Samples were washed in the field on a 0.5-mm mesh stainless-steel screen, labeled, and fixed in buffered 10% formalin-seawater.

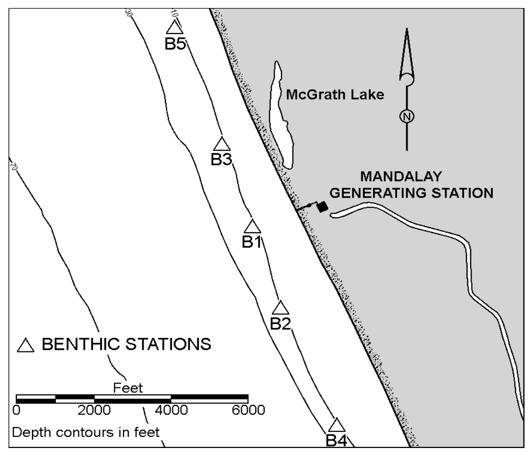



**Figure 5-1. Location of the benthic sampling stations. Mandalay Generating Station NPDES, 2009.**

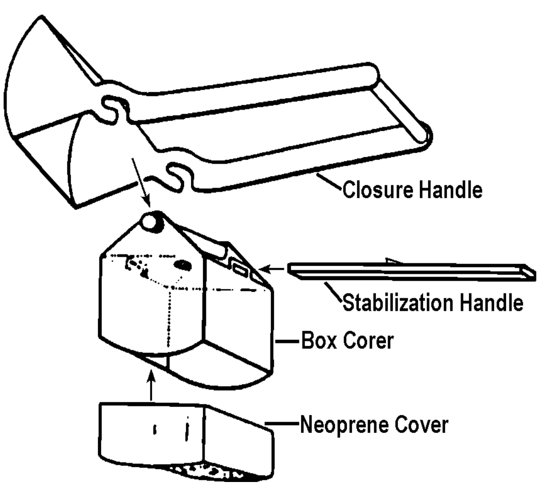



**Figure 5-2. Diver-operated box corer used to collect infaunal samples. Mandalay Generating Station NPDES, 2009.**

In the laboratory, samples were transferred to 70% isopropyl alcohol, sorted to major taxonomic groups, identified to the lowest practical taxonomic level, and counted. Identifications and nomenclature followed the usage accepted by the Southern California Association of Marine Invertebrate Taxonomists (SCAMIT 2008). Representative specimens were added to MBC's reference collection. Following identification, the weight of organisms in major taxonomic groups was obtained for each replicate. Specimens were placed on small, preweighed mesh screens that had been immersed in 70% isopropyl alcohol, blotted on a paper towel, and air-dried for five minutes. Large organisms were weighed separately. Data are presented by station and replicate in Appendix F.

## RESULTS

**Species Composition.** In 2009, the infauna samples from the five benthic stations in the study area offshore of the Mandalay Generating Station contained a total of 4,549 individuals representing 91 species in 10 phyla (major taxonomic groups) (Table 5-1, Appendices F-1 and F-2). Annelids were most abundant, comprising 54% of the individuals and 35% of the species. Cnidarians (sea anemones) were second in abundance with 20% of the organisms collected, but were represented by only two species. Arthropods and mollusks were next in abundance, comprising about 15% and 8% of the individuals, and 30% and 19% of the species, respectively. Nemerteans (ribbon worms) were not abundant but were diverse, representing almost 8% of the species collected. Each of the remaining five phyla comprised less than 1% of the abundance; echinoderms were represented by only two species, and the other four species, by only one species each.

**Table 5-1. Number of infaunal species and individuals by phylum. Mandalay Generating Station NPDES, 2009.**

| | Station | | | | | | Percent |
|---|---|---|---|---|---|---|---|
| Parameter | B1 | B2 | B3 | B4 | B5 | Total | Total |
| Number of species | | | | | | | |
| Annelida | 19 | 24 | 20 | 14 | 16 | 32 | 35.2 |
| Arthropoda | 17 | 11 | 15 | 13 | 10 | 27 | 29.7 |
| Mollusca | 8 | 8 | 8 | 6 | 10 | 17 | 18.7 |
| Nemertea | 4 | 3 | 4 | 4 | 4 | 7 | 7.7 |
| Cnidaria | 1 | 1 | 1 | 1 | 2 | 2 | 2.2 |
| Echinodermata | 1 | 2 | 1 | 1 | 1 | 2 | 2.2 |
| Chordata | - | - | - | 1 | - | 1 | 1.1 |
| Nematoda | - | 1 | 1 | - | 1 | 1 | 1.1 |
| Phorona | - | - | 1 | - | 1 | 1 | 1.1 |
| Platyhelminthes | 1 | 1 | - | 1 | - | 1 | 1.1 |
| Total | 51 | 51 | 51 | 41 | 45 | 91 | |
| Number of individuals | | | | | | | |
| Annelida | 362 | 640 | 716 | 144 | 600 | 2462 | 54.1 |
| Cnidaria | 164 | 228 | 507 | 1 | 26 | 926 | 20.4 |
| Arthropoda | 139 | 262 | 125 | 78 | 95 | 699 | 15.4 |
| Mollusca | 55 | 91 | 71 | 45 | 97 | 359 | 7.9 |
| Nemertea | 11 | 10 | 12 | 9 | 8 | 50 | 1.1 |
| Echinodermata | 6 | 19 | 3 | 8 | 3 | 39 | 0.9 |
| Nematoda | - | 2 | 2 | - | 3 | 7 | 0.2 |
| Phorona | - | - | 1 | - | 2 | 3 | 0.1 |
| Platyhelminthes | 1 | 1 | - | 1 | - | 3 | 0.1 |
| Chordata | - | - | - | 1 | - | 1 | 0.0 |
| Total | 738 | 1253 | 1437 | 287 | 834 | 4549 | |

Note: 0.0 = <0.1

**Abundance.** Abundance averaged 910 individuals per station (227 individuals per replicate, or 22,745 individuals/m$^2$), and ranged from 287 individuals at Station B4, farthest downcoast of the generating station, to 1,437 individuals at Station B3, immediately upcoast (Table 5-2, Appendices F-2 and F-3).

**Species Richness.** The number of species averaged 48 per station, or 27 species per replicate (Table 5-2, Appendices F-2 and F-3). Species richness ranged from 41 species at Station B4 to 51 species at three locations: Station B1, nearest the generating station discharge, Station B2, immediately downcoast, and Station B3.

**Species Diversity (H').** Shannon-Wiener species diversity averaged 2.64 per station (2.51 per replicate) and ranged from 2.30 at Station B3 to 2.96 at Station B4 (Table 5-2, Appendices F-2 and F-3).

**Benthic Response Index.** The Southern California Benthic Response Index (BRI) is the abundance-weighted average pollution tolerance of species occurring in a sample. The pollution tolerance scores ($p_i$) for shallow coastal shelf habitat (10 to 30 m) were used in the computations, even though the stations are shallower than the depth range recommended for application of the index. In addition, the screen mesh size used for sieving the samples from the study area (0.5 mm) was smaller than the mesh size used for the samples from which the BRI was developed (1 mm). BRI values averaged 22.7 for the five stations, and ranged from 17.4 at Station B4 to 30.5 at Station B5, farthest upcoast (Table 5-2). The value for the station offshore of the discharge was the same as the study area mean.

**Biomass.** Biomass totaled 15.70 g and averaged 3.14 g per station (78 g/m$^2$), ranging from 0.83 g at Station B4 to 5.29 g at Station B3 (Table 5-2, Appendix F-4). About 61% of the total biomass was contributed by annelids, while a single individual of a cnidarian, the sea pansy *Renilla koellikeri*, comprised 23% of the total.

**Table 5-2. Infaunal community parameters. Mandalay Generating Station NPDES, 2009.**

| | Station | | | | | | |
|---|---|---|---|---|---|---|---|
| Parameter | B1 | B2 | B3 | B4 | B5 | Total | Mean |
| Number of species | | | | | | | |
| Total | 51 | 51 | 51 | 41 | 45 | 91 | 48 |
| Rep. Mean | 26 | 30 | 29 | 24 | 26 | | 27 |
| Rep. S.D. | 2 | 3 | 7 | 2 | 1 | | |
| Number of individuals | | | | | | | |
| Total | 738 | 1253 | 1437 | 287 | 834 | 4549 | 910 |
| Rep. Mean | 185 | 313 | 359 | 72 | 209 | | 227 |
| Rep. S.D. | 17 | 133 | 104 | 14 | 59 | | |
| Density (#/m$^2$) | | | | | | | 22,745 |
| Diversity (H') | | | | | | | |
| Total | 2.60 | 2.65 | 2.30 | 2.96 | 2.69 | 2.83 | 2.64 |
| Rep. Mean | 2.45 | 2.60 | 2.19 | 2.74 | 2.56 | | 2.51 |
| Rep. S.D. | 0.10 | 0.21 | 0.24 | 0.07 | 0.22 | | |
| Benthic Respose Index (BRI) | | | | | | | |
| Total | 20.9 | 21.8 | 22.7 | 17.4 | 30.5 | 22.9 | 22.7 |
| Biomass (g) | | | | | | | |
| Total | 1.96 | 2.60 | 5.29 | 0.83 | 5.03 | 15.70 | 3.14 |
| Rep. Mean | 0.49 | 0.65 | 1.32 | 0.21 | 1.26 | | 0.78 |
| Rep. S.D. | 0.21 | 0.25 | 0.87 | 0.18 | 2.10 | | 0.72 |
| g/m$^2$ | | | | | | | 78.49 |

**Community Composition.** Seventeen species each represented 1% or more of the individuals in the infauna collection (Table 5-3 and Appendix F-2). These 17 species together were less than 19% of the species in the collection but contributed 90% of the individuals. All but four of the top species occurred at all five stations, and all were found at no fewer than four of the stations. Four phyla were represented among the most abundant species: 10 species of annelids, five arthropods, one cnidarian, and one mollusk. The most abundant species was a cnidarian, the burrowing sea anemone *Zaolutus actius* which was very abundant at Station B3, but only one individual was found at Station B4. Second most abundant was the polychaete annelid *Apoprionospio pygmaea*, which, like the clam *Tellina modesta*, sixth in abundance, was more evenly distributed among stations. As with *Z. actius*, the annelids *Owenia collaris*, *Armandia brevis*, and

*Ampharete labrops*, third, fourth, and fifth in abundance, respectively, were also quite uneven in their distribution among the five stations. Small individuals of rock crabs (*Romaleon* sp) were moderately abundant at Station B3, but, as they were scarce elsewhere, they were not among the community dominants for the study area as a whole.

**Cluster Analyses.** Normal (station) and inverse (species) cluster analyses were performed on the 17 most abundant species in the infauna collection (Table 5-3). The five study-area stations clustered into three groups, based on their relative abundances of the numerically dominant species

**Table 5-3. The 17 most abundant infaunal species. Mandalay Generating Station NPDES, 2009.**

| | | Station | | | | | | Percent | Cum. |
|---|---|---|---|---|---|---|---|---|---|
| Phylum | Species | B1 | B2 | B3 | B4 | B5 | Total | Total | Percent |
| CN | *Zaolutus actius* | 164 | 228 | 507 | 1 | 25 | 925 | 20 | 20 |
| AN | *Apoprionospio pygmaea* | 164 | 84 | 66 | 60 | 199 | 573 | 13 | 33 |
| AN | *Owenia collaris* | 74 | 163 | 276 | 10 | 33 | 556 | 12 | 45 |
| AN | *Armandia brevis* | 44 | 209 | 137 | 3 | 133 | 526 | 12 | 57 |
| AN | *Ampharete labrops* | 5 | 87 | 112 | - | 69 | 273 | 6 | 63 |
| MO | *Tellina modesta* | 40 | 57 | 52 | 30 | 76 | 255 | 6 | 68 |
| AR | *Photis macinerneyi* | 50 | 147 | 37 | 9 | 10 | 253 | 6 | 74 |
| AR | *Diastylopsis tenuis* | 12 | 26 | 29 | 8 | 28 | 103 | 2 | 76 |
| AN | *Onuphis* sp A SCAMIT 1992 | 19 | 29 | 24 | 14 | 12 | 98 | 2 | 78 |
| AN | *Mediomastus acutus* | 6 | 2 | 1 | 7 | 68 | 84 | 2 | 80 |
| AR | *Rhepoxynius menziesi* | 2 | 25 | 6 | 25 | 20 | 78 | 2 | 82 |
| AN | *Pectinaria californiensis* | 2 | 6 | 32 | 2 | 35 | 77 | 2 | 84 |
| AR | *Euphilomedes carcharodonta* | 46 | 6 | 2 | 21 | - | 75 | 2 | 85 |
| AN | *Scoloplos armiger* Cmplx | 17 | 13 | 16 | 25 | - | 71 | 2 | 87 |
| AR | *Uromunna ubiquita* | 8 | 43 | 10 | 1 | 9 | 71 | 2 | 88 |
| AN | *Chone eiffelturris* | - | 16 | 11 | 7 | 14 | 48 | 1 | 89 |
| AN | *Spiophanes bombyx* | 11 | 7 | 16 | 4 | 9 | 47 | 1 | 88 |

AN = Annelida; AR = Arthropoda; CN = Cnidaria; MO = Mollusca

(Figure 5-3). Stations B2 and B3, downcoast and upcoast of the discharge, clustered most closely as their communities were similar. Station B1, near the discharge, clustered with these two stations due to a somewhat similar community composition, although several of the very abundant species, such as *Zaolutus actius*, were less dominant there while *Apoprionospio pygmaea* was more dominant. These three stations formed Station Group I. This group clustered next with Station B5 (Group II), where *Z. actius* was less abundant than at the stations in Group I and *A. pygmaea*, *Tellina modesta*, and the annelids *Mediomastus acutus* and *Pectinaria californiensis* were more abundant. The community at Station B4 (Group III) was least like those at the other stations, with low abundances of several species that were very abundant elsewhere.

The 17 most abundant species separated into four groups, based on their similarity of occurrence (Figure 5-3). Species Group A included only two species, both of which were absent from Station B5. Group A clustered with Group B, which included species that were moderately abundant and were, for the most part, well distributed throughout the study area. Group C contained the very abundant species that were evenly distributed. This group clustered with Group D, which was composed of the top species that were most abundant at the stations in Group I. Of the 17 species, the annelid *Onuphis* sp A and the cumacean *Diastylopsis tenuis* clustered most closely, due to their very similar abundances in the five communities.

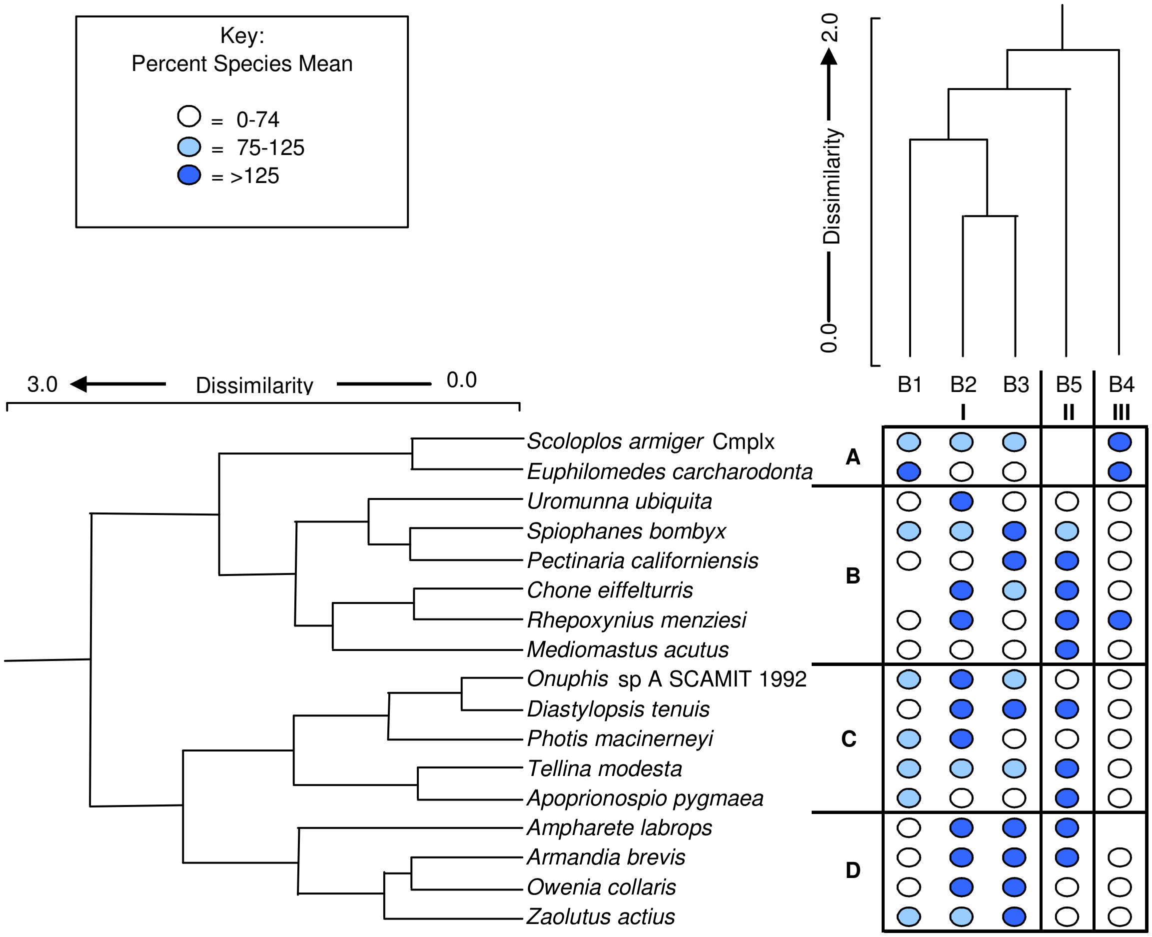



**Figure 5-3. Two-way coincidence table resulting from normal (station) and inverse (species) classification dendrograms for the 17 most abundant infaunal species. Mandalay Generating Station NPDES, 2009.**

## DISCUSSION

The infauna community in the study area in 2009 was comprised primarily of small burrowing sea anemones, annelid worms, arthropods, and mollusks. For the station near the discharge, values for all parameters except species richness were slightly below the average for the study area. Abundance and biomass of organisms were highest immediately upcoast of the generating station and lowest farthest downcoast; they were also quite high immediately downcoast of the generating station (biomass was second highest farthest downcoast, but almost three-quarters of the biomass at that location was due to one individual organism). Species richness was equally high at three stations: near the discharge canal and immediately upcoast and downcoast. It was lowest farthest downcoast where abundance was lowest. However, species diversity was highest at that location because the community was not dominated by a single species. Diversity was lowest where abundance was highest, due to the strong dominance of the community by *Zaolutus actius*. The Benthic Response Index value was highest farthest upcoast and lowest farthest downcoast. Most of the BRI values were in the range for the Reference category for the shallow coastal shelf, indicating undisturbed, or healthy, communities. However, the value for the station farthest upcoast was in the range for Response Level 1 (greater than 25 but less than 34), implying minor perturbation of the community. Levels of two of the four sediment metals evaluated were highest at that location, but all of the values were far below their ERLs, suggesting they probably were not the source of disturbance. In general, communities were most similar among the three station closest to the discharge, while the community farthest downcoast was least like those elsewhere.

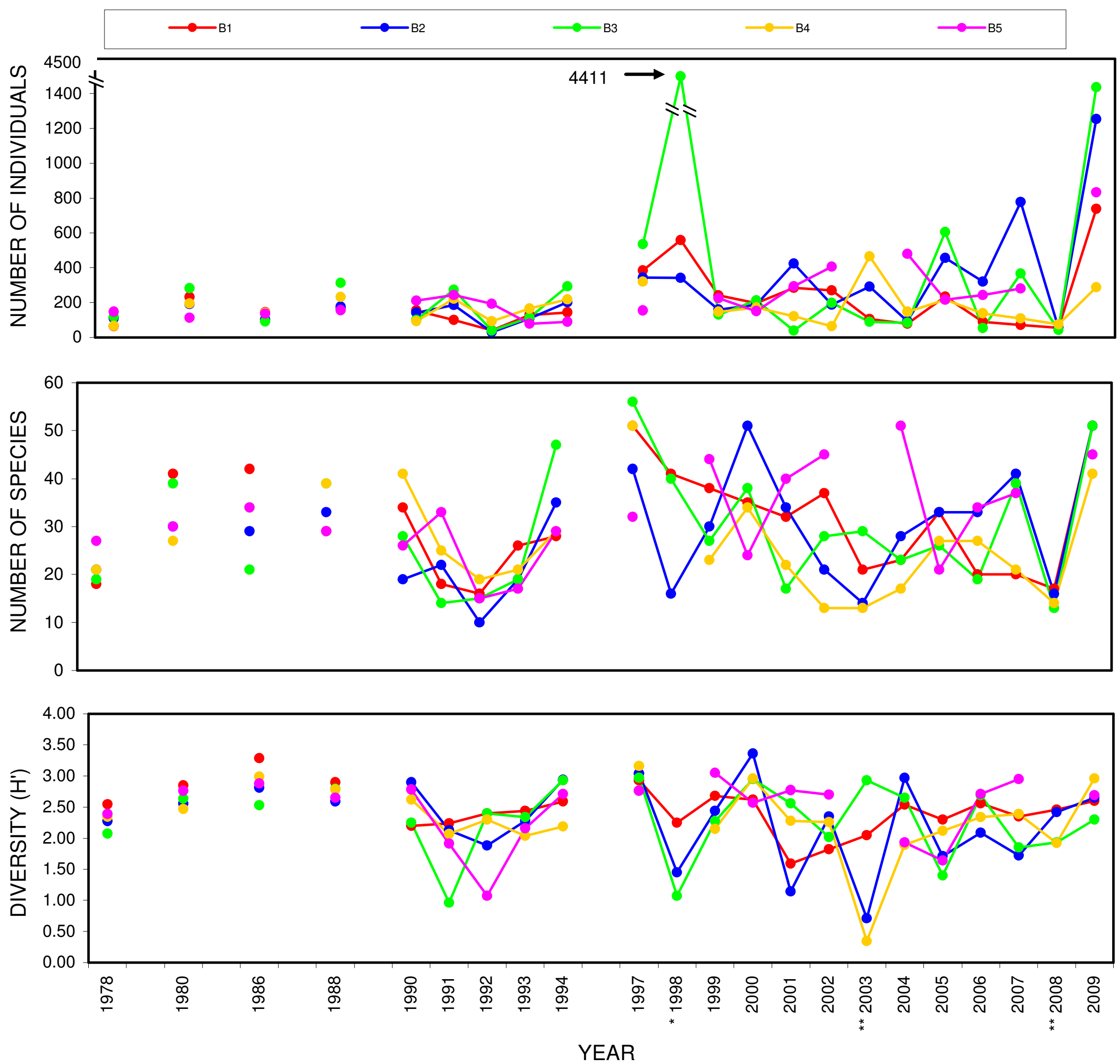
Infaunal organisms reflect the substrate in which they live (Johnson 1970, Gray 1974). The coastline at the Mandalay Generating Station is exposed to ocean swell from both the south and west, and the shallow subtidal sediments are routinely subject to disturbance from normal wave activity and infrequent severe disturbance during storms. Sediments are generally coarse, with little organic matter, due to the winnowing effect of moving water. Usually, coarse sediments support smaller and less diverse infaunal communities than do finer sediments (Barnard 1963). In some circumstances, particle sorting plays a role in community characteristics, with poorly-sorted sediments providing more ecological niches. This pattern was seen to some degree in the 2009 communities, as abundance and species richness were lowest where sediments were coarsest and moderately well sorted, farthest downcoast of the generating station. In addition, abundance was highest where sediments were finer-than-average and also the most poorly sorted, just upcoast of the discharge. Mean grain size of the sediments near the discharge were about average for the study area. Species occupying the nearshore habitat are adapted to both coarse sediment and nearly constant disruption of the substrate (Oliver et al. 1980). Although small, they are capable of reburying themselves quickly if dislodged. Several of these species were abundant in 2009, including *Armandia brevis*, *Tellina modesta*, *Diastylopsis tenuis*, and the amphipod *Rhepoxynius menziesii*. In addition, their life history strategies, such as frequent and abundant production of young, allow them to rapidly repopulate habitat severely disrupted by winter storms.

Species that comprised the infauna communities in 2009 are typical of the shallow nearshore environment (Barnard 1963, Dexter 1978, Carlton 2007). All of the abundant species in 2009 have been among the 31 most abundant species found in the study area since 1978 (Appendix F-5) (MBC 1979, 1981, 1986, 1988, 1990, 1994, 1997-2005, 2006a-2008a; Ogden 1991-1993). *Zaolutus actius*, the most abundant species, is a common inhabitant of the nearshore sandy environment; most of its body is buried in the sediments with its tentacle lying on the surface. It has been found in only eight of the previous 21 summer surveys, and its abundance in 2009 was much greater than in the past. *Apoprionospio pygmaea* is a generalist, living in tubes built below the shifting surface layer of sediment, and is wide-spread in sandy shallow-water habitats along the coast of southern California (MBC 2009a-d). It has been the most abundant species in the study area since 1978, although it was the top species in only 11 of the 22 summer surveys. Other commonly abundant species include *Mediomastus acutus*, Pacific sand dollar (*Dendraster excentricus*), *Diastylopsis tenuis*, *Rhepoxynius menziesi*, *Owenia collaris*, *Armandia brevis*, and other polychaete annelids such as *Scoloplos armiger*, *Chone eiffelturris*, and *Spiophanes bombyx*, *Tellina modesta* and another clam, *Siliqua lucida*, and the nemertean *Carinoma mutabilis*. All of these were abundant to moderately abundant in the study area in 2009.

A few species have occurred only sporadically but have been highly abundant in some years. Gould beanclam (*Donax gouldii*) has been uncommon in the area but was extremely abundant in 1998. The ostracod *Euphilomedes carcharodonta* was very abundant in 1997 and moderately abundant in 2009, but has been seen in only five other surveys. Other inconsistently occurring but sometimes abundant species include the amphipods *Photis macinerneyi*, *Americhelidium shoemakeri*, *Rhepoxynius* sp A, and *Mandibulophoxus gilesi*, the annelids *Ampharete labrops*, *Goniada littorea*, *Magelona pitelkai*, and *Pectinaria californiensis*, and the ostracod *Euphilomedes longiseta*, only six of which were found in 2009. Despite these differences, comparison of the communities observed since 1978 shows that a core group of species has persisted. The Spearman rank correlation, based on the Index of Relative Importance, suggests that, based on the numerically dominant species, community composition in 2009 was about average in similarity to those in other years and was most similar to that in 1997 (Appendix F-6). Communities were most similar between the survey years 1998 and 2001, followed by 2003 and

2008; the latter two were years in which sampling was reduced as part of Regional Monitoring. Surveys were quite dissimilar between 2002 and both 2003 and 2008. The community in 2004 was most similar to those in all other years, while the community in 2003 was least similar to those in other years.

In 2009, mean abundance for the study area, based on density of organisms, was almost eight times that for 2008, and was the second highest recorded since 1978 (MBC 1979, 1981, 1986, 1988, 1990, 1994, 1997-2005, 2006-2008a; Ogden 1991-1993). Abundances have usually been similar among stations, although values have differed considerably among stations in some years, particularly in 1998 (due to *Donax*) and 2007, as well as 2009 (Figure 5-4). (Values for 2003 and 2008 would be about twice those indicated in Figure 5-4 if four replicates had been collected at each station instead of only two.) Highest abundance has most frequently been found immediately upcoast of the generating station. Long-term mean values show that, on average, abundance has




Sampling was not required in years not shown; * 1998 - only three stations required; **2003 and 2008 only four stations and two reps required.

**Figure 5-4. Comparison of infaunal community parameters, 1978 - 2009. Mandalay Generating Station NPDES, 2009.**

been highest at that location, and second highest immediately downcoast of the station, with below-average abundance near the discharge. Lowest abundance has generally been at the station farthest downcoast; sediments have usually been coarsest at that location. Mean species richness in 2009 was more than twice that in 2008, and was the highest seen since 1978. Mean species diversity was also greater than in 2008 and the second highest recorded. The infaunal communities offshore of the Ormond Beach Generating, about six nautical miles southeast of Mandalay Generating Station, were also much larger and diverse than usual in 2009, but a similar pattern was not seen for the communities offshore of other generating stations farther south (MBC 2009a,b,c). On average, species richness and diversity have been similar among stations, with highest values for the station farthest upcoast. Mean species richness has been lowest farthest downcoast, while mean diversity was lowest at the station immediately upcoast of the discharge, probably because of the higher abundance seen there. However, species richness has also been quite dissimilar among stations in some years, with extremely wide ranges in numbers of species in 2000, 2002, and 2004, and in species diversity in 2001 and 2003. The mean of the BRI values was greater than both that in 2008 and the mean since 2006, the first year in which the index was used. The higher value seen for the station farthest upcoast was the second time that a value in the range of Response Level 1 was found at that location. These higher values probably relate to the finer sediments there, some of which derive from the Santa Clara River to the north.

## CONCLUSION

The infauna communities in the nearshore shallow subtidal environment in the vicinity of the Mandalay Generating Station in 2009 were similar to those found in previous studies conducted since 1978. The communities were typical of the nearshore habitat in the Southern California Bight, and the Benthic Response Index values indicated that the communities at most of the stations were healthy; for the station farthest upcoast, the BRI value suggested a minor, undetermined source of community disturbance. Infaunal parameters appeared to be somewhat related to sediment characteristics, as values for most infaunal parameters were lowest where sediments were coarsest, farthest downcoast of the generating station, although species diversity was highest there as no single species dominated the community. Abundance was highest immediately upcoast of the discharge where sediments were poorly sorted, but species diversity was lowest there due to strong dominance of the community by burrowing sea anemones. The community near the discharge was about average for the study area. No adverse pattern related to the generating station discharge was apparent. Abundance, species richness and diversity were greater than in almost all previous summer surveys. Biological events such as settlement of new recruits, competition, or failure to reproduce, combined with natural oceanographic events, result in occasionally large spatial or temporal changes in abundance and community composition.

# CHAPTER 6 — DEMERSAL FISH AND MACROINVERTEBRATES

In recent years, demersal fish and macroinvertebrate communities have come under greater scrutiny due to their close proximity to potentially impacted sediments. Numerous sites associated with discharges, either from municipal wastewater treatment plants or power plant once through cooling water systems, are the subject of ongoing monitoring within the Southern California Bight (Cross and Allen 1993). Trawl surveys of the demersal fish and macroinvertebrate assemblages within the receiving waters of Mandalay Generating Station began in 1971, with a total of eight surveys from 1971 to 1988. Beginning in 1990, surveys were conducted annually during winter and summer, as required by National Pollutant Discharge Elimination System permit requirements. The goal of this monitoring is to assess the effects of the heated seawater discharged from the station on the local marine fauna. Intra-annual and interannual variation was examined to assess the composition and stability of the populations within the receiving waters.

## MATERIALS AND METHODS

Otter trawl sampling for fishes and macroinvertebrates was conducted on 12 March and 23 July 2009 between 0700 and 1100 hours. During the winter March sampling, skies were clear with northeast winds at 2 to 3 knots (kn) that switched to west winds at 2 to 3 kn. Winter seas were west at 2 to 4 feet (ft). In July, the skies gradually cleared during the survey with west winds at 3 to 5 kn and west swells at 3 to 4 ft.

Trawl paths for the four stations were parallel to the shoreline along the 20-ft isobath (Figure 6-1). Stations T2 and T3 were centered 1,180 ft upcoast and downcoast of the discharge, respectively, with portions of the trawl path directly offshore the discharge. Stations T1 and T4 acted as reference sites and were centered approximately 5,910 ft upcoast and downcoast of the discharge. Two replicate tows were made at each station with a 25-ft wide semi-balloon otter trawl net. The headrope was equipped with regularly spaced floats, while the footrope was weighted with chain and equipped with plastic rollers to reduce fouling. The body of the net consisted of 1.5-inch (in) bar mesh with a 0.5-in bar mesh liner in the cod end.

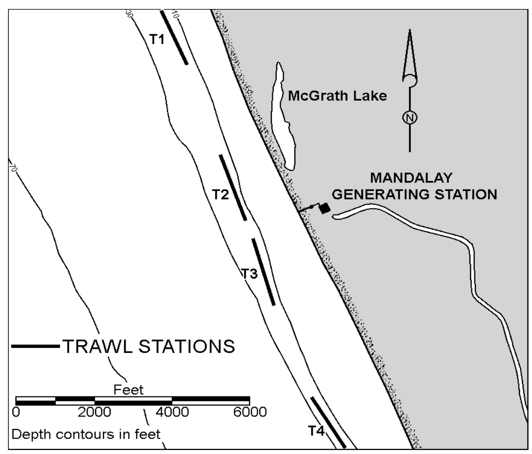



**Figure 6-1. Location of the trawl sampling stations. Mandalay Generating Station NPDES, 2009.**

During each replicate, the otter trawl net was towed at 2.0 to 2.5 knots for ten minutes. Time was measured from the point at which the net began fishing at the bottom to the time retrieval began. Fish and epibenthic macroinvertebrates from each catch were separated from debris and identified to the lowest possible taxonomic category. Up to 200 individual fish of each species were measured to the nearest millimeter (mm) standard length (SL), disc width (DW) or total length (TL), where appropriate and examined for external parasites, anatomical anomalies, or other abnormalities. Aggregate weight, in kilograms (kg), was recorded by species. All individuals of species represented by 200 individuals or less were weighed; for species with more than 200 per trawl, the 200 measured individuals were weighed separately from the remaining fish. Total species abundance was then estimated based on the weight of the 200 measured individuals by the following equation: Estimated abundance = (Unmeasured Fish Weight)/(Mean Weight of Measured Individuals). Macroinvertebrates were counted and aggregate weights recorded. In cases of high abundance (>200 individuals), the total abundance was estimated in the same fashion as was used for fish. Specimens were returned to the sea after processing, except in cases of rare occurrence or uncertain identity. These individuals were retained for later confirmation and inclusion in the MBC voucher collection.

All field data were recorded on preprinted data sheets and later entered into Microsoft Excel spreadsheets. In-house quality assurance/quality control (QA/QC) protocols were followed to ensure accurate transcription into digital format. Descriptive (summary) statistics were performed using Microsoft Excel. Summary statistics included abundance, biomass, number of species, Shannon-Wiener species diversity index (Shannon and Weaver 1962), and evenness index (Pielou 1977). The index of relative importance (IRI) (Stephens et al. 1994) was calculated for the ten most abundant fish species and five most abundant macroinvertebrate species taken during annual trawl surveys, 1990-2009.

Species and station relationships for fish were graphically derived through hierarchical clustering analysis and two-way coincidence tables. A minimum of 10 individuals per species was used as the criterion for inclusion in the cluster analysis. Abundance was natural log (ln+1) transformed before the calculation of the inter-entity distance (dissimilarity) matrix. Cluster diagrams were drawn based on these dissimilarities. In this analysis, a dissimilarity value of 1.5 was determined *a priori* as the minimal value indicating a significant separation between faunal and station groups. Similarity between annual catches was visualized based on multidimensional scaling per the methods described by Clarke and Ainsworth (1993). A similar analysis was done relating the similarities of the ten most abundant species. Similarities are illustrated by the spatial proximity between two items. Stress values indicate the relative accuracy of the placement of items in two-dimensional space; lower stress = more accurate depiction. Length frequency histograms were created to examine potential age structure of the sampled assemblage. The three most abundant species overall were included in the length frequency analysis. Individual lengths were rounded to the nearest 10 mm (i.e., 35-44 mm SL = 40 mm SL) for inclusion in the length frequency histograms.

## RESULTS

Monitoring data are presented in both tabular and graphical format. The complete 2009 data records, including fish lengths by centimeter size class, are presented in Appendix G.

### Fish

In 2009, a total of 2,694 fish of 30 species weighing 34.62 kg was recorded during otter trawl sampling during the two seasons (Tables 6-1 and 6-2). Overall fish species diversity was 1.70, while evenness was 0.50. Winter sampling recorded 769 fish weighing 14.57 kg representing 19 species with an overall species diversity of 1.72. Summer trawling caught 1,925 fish, or 71% of the total, weighing 20.05 kg, 58% of the total, representing 22 species. Eight species were unique to winter while five were only caught in summer. Eighty-eight percent of the total catch was represented by five species. White croaker (*Genyonemus lineatus*) accounted for 45% of the total with 1,212 individuals followed by 778 speckled sanddab (*Citharichthys stigmaeus*), 183 barred surfperch (*Amphistichus argenteus*), 116 northern anchovy (*Engraulis mordax*), and 73 pricklebreast poacher (*Stellerina xyosterna*). Five species contributed 73% to the total biomass. Two elasmobranchs, spiny dogfish (*Squalus acanthias*) and bat ray (*Myliobatis californica*), combined, accounted for 44% of the total biomass with 8.06 kg and 7.30 kg, respectively. Speckled sanddab contributed an additional 4.38 kg followed by white croaker (2.94 kg) and barred surfperch (2.92 kg). No parasites or physical abnormalities were observed on the fish caught in either season.

Seventy percent of the winter catch was contributed by white croaker (339 individuals) and speckled sanddab (201), with an additional 20% of the catch accounted for by 50 northern anchovy, 38 spiny dogfish, 37 barred surfperch, and 31 barcheek pipefish (*Syngnathus exilis*) (Table 6-1). Six of the eight species unique to winter sampling were represented by two, or fewer, individuals. Only the eight spiny dogfish and nine California corbina (*Menticirrhus undulatus*) were present in greater numbers. Trawls at Station T1 resulted in the highest abundance with 64% of

**Table 6-1. Abundance and catch parameters for fish species taken by otter trawl. Mandalay Generating Station NPDES, 2009.**

| | Winter | | | | | Summer | | | | | Annual | Percent |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | T1 | T2 | T3 | T4 | Total | T1 | T2 | T3 | T4 | Total | Total | Total |
| white croaker | 301 | 8 | 28 | 2 | 339 | 873 | - | - | - | 873 | 1,212 | 45 |
| speckled sanddab | 113 | 39 | 22 | 27 | 201 | 17 | 158 | 262 | 140 | 577 | 778 | 29 |
| barred surfperch | 7 | 10 | 5 | 15 | 37 | 1 | 17 | 109 | 19 | 146 | 183 | 7 |
| northern anchovy | 16 | 17 | 4 | 13 | 50 | 48 | 8 | 1 | 9 | 66 | 116 | 4 |
| pricklebreast poacher | 1 | 7 | 1 | 1 | 10 | 57 | 5 | 1 | - | 63 | 73 | 3 |
| shiner perch | - | 1 | - | - | 1 | 38 | 15 | 2 | - | 55 | 56 | 2 |
| barcheek pipefish | 19 | 3 | 4 | 5 | 31 | 4 | 9 | 6 | 5 | 24 | 55 | 2 |
| spiny dogfish | - | - | 8 | 30 | 38 | - | - | - | - | - | 38 | 1 |
| kelp pipefish | 21 | - | 2 | 3 | 26 | 8 | - | 1 | 2 | 11 | 37 | 1 |
| walleye surfperch | - | - | - | - | - | 11 | 15 | - | - | 26 | 26 | 1 |
| queenfish | 1 | - | - | - | 1 | 22 | - | - | - | 22 | 23 | 1 |
| English sole | 1 | - | 1 | 2 | 4 | - | - | 1 | 17 | 18 | 22 | 1 |
| thornback | - | - | 5 | 8 | 13 | - | 1 | 1 | - | 2 | 15 | 1 |
| California lizardfish | - | - | - | - | - | - | - | 5 | 8 | 13 | 13 | <1 |
| California corbina | 6 | 1 | 2 | - | 9 | - | - | - | - | - | 9 | <1 |
| Pacific staghorn sculpin | - | - | - | - | - | 4 | 1 | 1 | 3 | 9 | 9 | <1 |
| white seaperch | - | - | - | - | - | 6 | 2 | 1 | - | 9 | 9 | <1 |
| bat ray | - | - | - | - | - | - | 4 | 1 | - | 5 | 5 | <1 |
| calico rockfish | 1 | 1 | - | - | 2 | - | - | - | - | - | 2 | <1 |
| slough anchovy | 1 | - | 1 | - | 2 | - | - | - | - | - | 2 | <1 |
| vermilion rockfish | - | - | - | 2 | 2 | - | - | - | - | - | 2 | <1 |
| basketweave cusk-eel | - | - | 1 | - | 1 | - | - | - | - | - | 1 | <1 |
| California halibut | - | - | - | - | - | 1 | - | - | - | 1 | 1 | <1 |
| deepbody anchovy | 1 | - | - | - | 1 | - | - | - | - | - | 1 | <1 |
| diamond turbot | - | - | 1 | - | 1 | - | - | - | - | - | 1 | <1 |
| fantail sole | - | - | - | - | - | - | 1 | - | - | 1 | 1 | <1 |
| Pacific sardine | - | - | - | - | - | - | - | - | 1 | 1 | 1 | <1 |
| painted greenling | - | - | - | - | - | - | 1 | - | - | 1 | 1 | <1 |
| shovelnose guitarfish | - | - | - | - | - | 1 | - | - | - | 1 | 1 | <1 |
| tubesnout | - | - | - | - | - | 1 | - | - | - | 1 | 1 | <1 |
| Total Abundance | 489 | 87 | 85 | 108 | 769 | 1,092 | 237 | 392 | 204 | 1,925 | 2,694 | |
| Number of Species | 13 | 9 | 14 | 11 | 19 | 15 | 13 | 13 | 9 | 22 | 30 | |
| Diversity (H') | 1.20 | 1.62 | 2.00 | 1.93 | 1.72 | 0.91 | 1.33 | 0.89 | 1.18 | 1.61 | 1.70 | |
| Evenness (J') | 0.47 | 0.74 | 0.76 | 0.81 | 0.59 | 0.34 | 0.52 | 0.35 | 0.54 | 0.52 | 0.50 | |

the total, while catches at each of the remaining three sites were relatively similar with each contributing between 11 and 14% of the total catch (Figure 6-2). The high abundance at Station T1 was largely attributed to the substantially higher catches of white croaker and speckled sanddab in comparison to the remaining three sites. Bottom water temperatures were higher at Station T1 (13.0°C) than at each of the remaining stations (<12.8°C). The minimum and maximum species richness were recorded on either side of the discharge at Stations T2 and T3, respectively. Species diversity was also highest at Station T3 ($H'$ = 2.00) and lowest at Station T1 ($H'$ = 1.20). Eighty percent of the winter biomass was accounted for by spiny dogfish (8.06 kg), California corbina (1.89 kg), and thornback (*Platyrhinoidis triseriata*, 1.75 kg) (Table 6-2). Most of the biomass (55%) was taken at Station T4, largely due to the 30 spiny dogfish taken. An additional 41% of the biomass was recorded at Stations T1 and T3, 3.38 kg and 2.54 kg, respectively, due to the abundance of white croaker and speckled sanddab at Station T1 and the eight spiny dogfish taken at Station T3. An additional 206 white croaker less than 30 mm SL weighing 0.09 kg were taken in winter.

Cluster analysis of the winter catch revealed four species groups and two station groups (Figure 6-3). Station Group I included Station T1 while the remaining stations were in Group II. Species Group A included pricklebreast poacher, kelp pipefish (*Syngnathus californiensis*), and barcheek pipefish. Group A was generally more abundant in Group I, except pricklebreast

**Table 6-2. Biomass (kg) of fish species taken by otter trawl. Mandalay Generating Station NPDES, 2009.**

| | Winter | | | | | Summer | | | | | Annual | Percent |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | T1 | T2 | T3 | T4 | Total | T1 | T2 | T3 | T4 | Total | Total | Total |
| spiny dogfish | - | - | 1.66 | 6.40 | 8.06 | - | - | - | - | - | 8.06 | 23 |
| bat ray | - | - | - | - | - | - | 5.20 | 2.10 | - | 7.30 | 7.30 | 21 |
| speckled sanddab | 0.36 | 0.15 | 0.21 | 0.09 | 0.80 | 0.08 | 1.17 | 1.41 | 0.92 | 3.58 | 4.38 | 13 |
| white croaker | 0.36 | 0.01 | 0.02 | 0.00 | 0.39 | 2.55 | - | - | - | 2.55 | 2.94 | 8 |
| barred surfperch | 0.22 | 0.25 | 0.13 | 0.38 | 0.98 | 0.01 | 0.27 | 1.45 | 0.21 | 1.94 | 2.92 | 8 |
| thornback | - | - | 0.65 | 1.10 | 1.75 | - | 0.49 | 0.24 | - | 0.73 | 2.48 | 7 |
| California corbina | 1.45 | 0.09 | 0.35 | - | 1.89 | - | - | - | - | - | 1.89 | 5 |
| northern anchovy | 0.01 | 0.01 | 0.01 | 0.02 | 0.04 | 0.72 | 0.15 | 0.01 | 0.12 | 1.00 | 1.04 | 3 |
| queenfish | 0.02 | - | - | - | 0.02 | 0.52 | - | - | - | 0.52 | 0.54 | 2 |
| California halibut | - | - | - | - | - | 0.51 | - | - | - | 0.51 | 0.51 | 1 |
| shiner perch | - | 0.05 | - | - | 0.05 | 0.16 | 0.15 | 0.01 | - | 0.31 | 0.36 | 1 |
| shovelnose guitarfish | - | - | - | - | - | 0.35 | - | - | - | 0.35 | 0.35 | 1 |
| diamond turbot | - | - | 0.33 | - | 0.33 | - | - | - | - | - | 0.33 | 1 |
| pricklebreast poacher | 0.01 | 0.08 | 0.01 | 0.01 | 0.11 | 0.14 | 0.02 | 0.01 | - | 0.17 | 0.28 | 1 |
| Pacific staghorn sculpin | - | - | - | - | - | 0.11 | 0.04 | 0.03 | 0.08 | 0.26 | 0.26 | 1 |
| walleye surfperch | - | - | - | - | - | 0.10 | 0.11 | - | - | 0.21 | 0.21 | 1 |
| California lizardfish | - | - | - | - | - | - | - | 0.08 | 0.11 | 0.19 | 0.19 | 1 |
| fantail sole | - | - | - | - | - | - | 0.16 | - | - | 0.16 | 0.16 | <1 |
| English sole | 0.00 | - | 0.00 | 0.00 | 0.00 | - | - | 0.03 | 0.11 | 0.15 | 0.15 | <1 |
| barcheek pipefish | 0.04 | 0.01 | 0.01 | 0.01 | 0.07 | 0.01 | 0.02 | 0.01 | 0.01 | 0.05 | 0.12 | <1 |
| kelp pipefish | 0.05 | - | 0.01 | 0.01 | 0.07 | 0.01 | - | 0.00 | 0.00 | 0.02 | 0.09 | <1 |
| Pacific sardine | - | - | - | - | - | - | - | - | 0.03 | 0.03 | 0.03 | <1 |
| white seaperch | - | - | - | - | - | 0.01 | 0.00 | 0.00 | - | 0.01 | 0.01 | <1 |
| slough anchovy | 0.00 | - | 0.00 | - | 0.01 | - | - | - | - | - | 0.01 | <1 |
| tubesnout | - | - | - | - | - | 0.01 | - | - | - | 0.01 | 0.01 | <1 |
| basketweave cusk-eel | - | - | 0.00 | - | 0.00 | - | - | - | - | - | 0.00 | <1 |
| deepbody anchovy | 0.00 | - | - | - | 0.00 | - | - | - | - | - | 0.00 | <1 |
| calico rockfish | 0.00 | 0.00 | - | - | 0.00 | - | - | - | - | - | 0.00 | <1 |
| painted greenling | - | - | - | - | - | - | 0.00 | - | - | 0.00 | 0.00 | <1 |
| vermilion rockfish | - | - | - | 0.00 | 0.00 | - | - | - | - | - | 0.00 | <1 |
| Total Biomass (kg) | 2.54 | 0.63 | 3.38 | 8.02 | 14.57 | 5.29 | 7.78 | 5.38 | 1.60 | 20.05 | 34.62 | |

Note: 0.00 = < 0.005, "-" = absent, anomalies due to rounding

poacher which was more abundant at Station T2 (Group II). Group B included thornback and spiny dogfish, both of which were unique to Group II (Stations T3 and T4). Group C included barred surfperch, northern anchovy, and speckled sanddab and was generally cosmopolitan with individuals taken at stations in both Groups I and II. Group D was limited to white croaker which was nearly unique to Group I with comparatively few individuals taken in Group II.

Five species accounted for 90% of the total summer catch (Table 6-1). White croaker led all species with 873 individuals followed by 577 speckled sanddab, 146 barred surfperch, 66 northern anchovy, and 63 pricklebreast poacher. Consistent with winter sampling, the catch at Station T1 represented more than 50% of the total (57%) with 1,092 individuals, including all 873 white croaker (Figure 6-2). Sampling at Station T3 recorded the next highest abundance with 392 fish followed by 237 fish at Station T2 and 204 individuals at Station T4. Speckled sanddab was most common at Station T3, hence the comparatively high abundance, with similar abundances at Stations T2 and T4. In addition to white croaker; northern anchovy, pricklebreast poacher, and queenfish (*Seriphus politus*) were substantially more abundant, or unique, to Station T1. Unlike winter, bottom water temperatures were highest at Station T4 (15.4°C), where the lowest abundance was recorded, but Station T1 was the second warmest (15.3°C). The only California halibut (*Paralichthys californicus*) taken in 2009 was caught at Station T1 in summer, while the remaining five species unique to summer sampling were represented by at least five individuals. Species richness was again highest at Station T1, consistent with winter, while 13 species were taken at Stations T2 and T3, and another nine species at Station T4. Diversity, however, was highest at Station T2 ($H'$ = 1.33) followed by Station T4 ($H'$ = 1.18). Species diversities at both

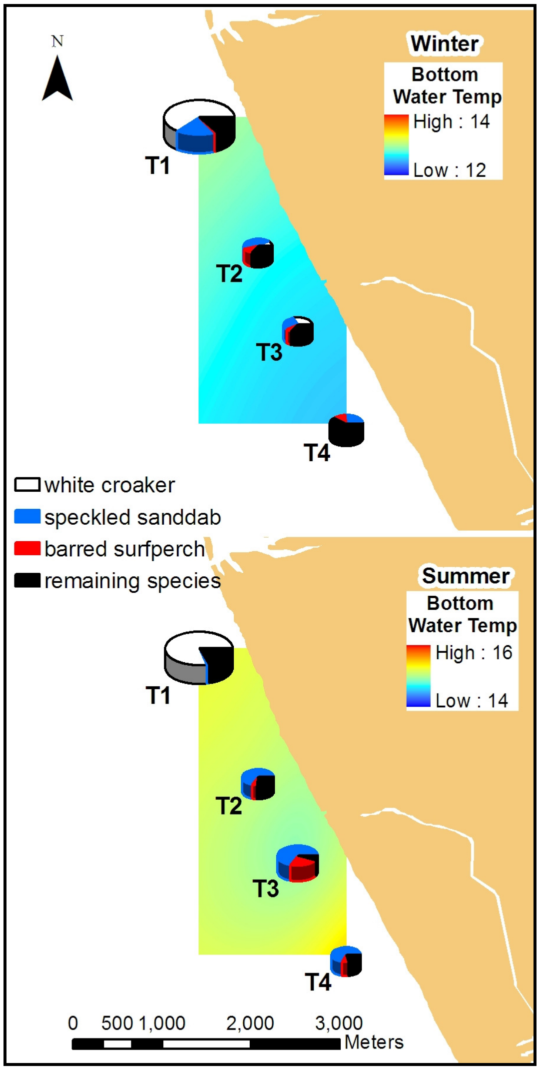



**Figure 6-2. Proportional fish abundance by site and species recorded during winter and summer surveys. Mandalay Generating Station NPDES, 2009.**

Stations T1 and T3 were less than 1.00. Seventy-seven percent of the summer biomass was contributed by the combination of bat ray (7.30 kg), speckled sanddab (3.58 kg), white croaker (2.55 kg), and barred surfperch (1.94 kg) (Table 6-2). Trawls at Station T2 collected the highest biomass (7.78 kg), largely due to four out of the five bat rays taken being caught at Station T2. The fish weight at Stations T1 and T3 were similar, 5.29 kg and 5.38 kg, respectively, due to the abundance of white croaker at Station T1 and the one bat ray caught at Station T3. The catch at Station T4 was 1.60 kg, or 8% of the seasonal total.

Cluster analysis of the summer catch resulted in four species groups and two station groups (Figure 6-4). Station Group I included Station T1 while Group II included the remaining three stations. Species Group A included barred surfperch and speckled sanddab, both of which were most common in Group II. California lizardfish (*Synodus lucioceps*) and English sole (*Parophrys vetulus*) comprised Group B and were unique to Group II, specifically Stations T3 and T4. Group C included seven species that were all taken in Group I, but also common at some stations in Group II. White croaker comprised Group D and was unique to Group I.

**Fish Length**

Fishes taken in winter ranged in size from a 15 mm SL English sole to a 464 mm TL thornback (Table 6-3). The summer catch sizes ranged from a 31 mm SL speckled sanddab to a 702 mm DW bat ray. Barred surfperch averaged 98 mm SL and ranged from 90 to 110 mm SL in the winter (n = 37) and 77 mm SL in the summer (n = 146) with individuals from 63 to 95 mm SL taken. The winter individuals were larger with the principle mode at the 100-mm SL size class while the summer catch was dominated by the 80-mm SL size class (Figure 6-5a). The 201 speckled sanddab measured in winter averaged 54 mm SL (22 - 112 mm SL range) and the 577 individuals measured during the summer averaged 64 mm SL (31 - 120 mm SL). Speckled sanddab caught in winter were smaller than those taken in summer with a peak in the 50-mm SL size class but also large proportions in the 30- and 40-mm SL size classes (Figure 6-5b). The summer speckled sanddab catch was dominated by the 60-mm SL size class with nearly 40% of all individuals. The 339 white croaker taken in winter averaged 36 mm SL and ranged from 30 to 96 mm SL. White croaker taken in summer averaged 58 mm SL with individual sizes from 32 to 72 mm SL. The winter catch was predominantly in the 30- and 40-mm SL size classes, which was smaller than the 60-mm SL size class that dominated the summer catch with over 60% of all individuals.

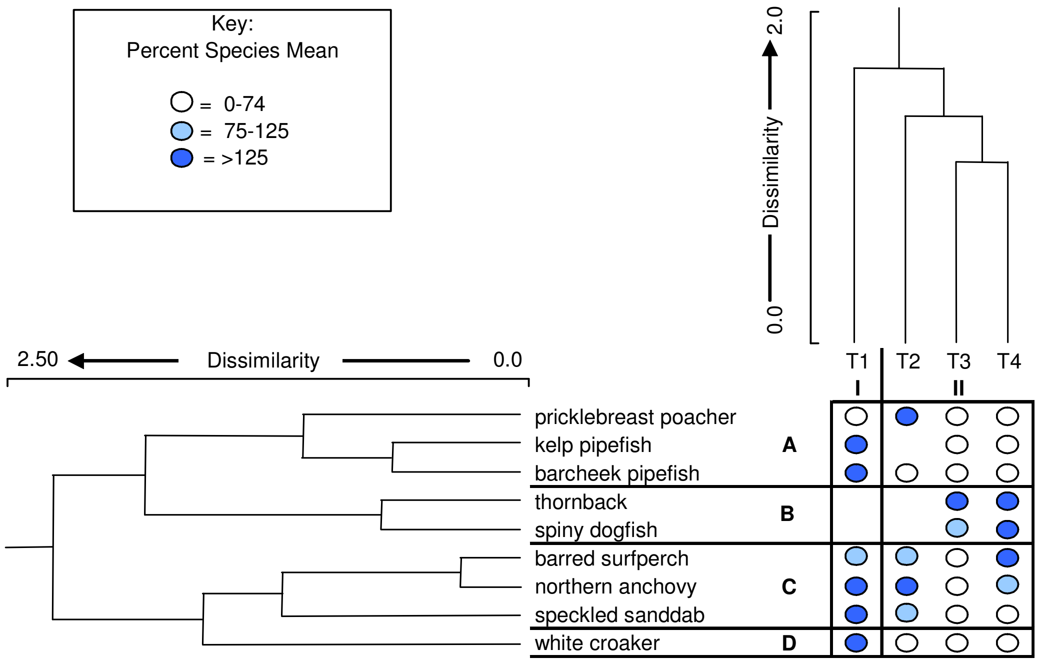



**Figure 6-3. Two-way coincidence table resulting from normal (station) and inverse (species) classification dendrograms for the most abundant fish taken by otter trawl, winter survey. Mandalay Generating Station NPDES, 2009.**

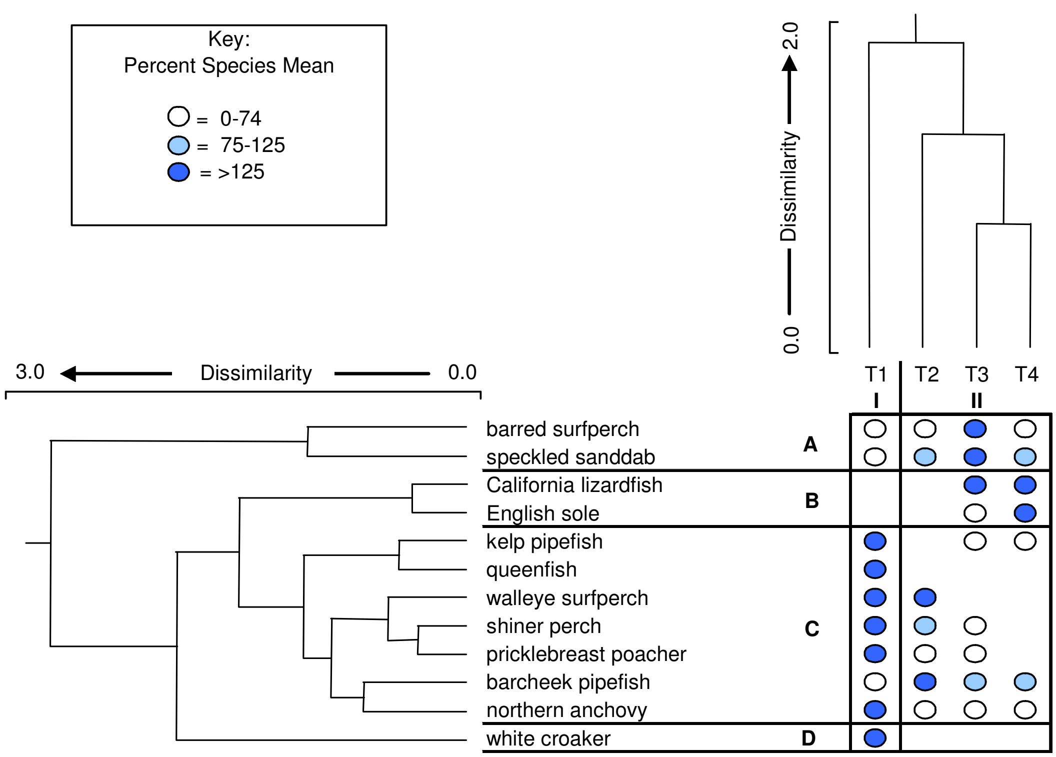



**Figure 6-4. Two-way coincidence table resulting from normal (station) and inverse (species) classification dendrograms for the most abundant fish taken by otter trawl, summer survey. Mandalay Generating Station NPDES, 2009.**

**Table 6-3. Measured length (mm) of fish species taken by otter trawl. Mandalay Generating Station NPDES, 2009.**

| | Winter | | | | | Summer | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Species | Number | Min | Max | Mean | SD | Number | Min | Max | Mean | SD |
| barcheek pipefish | 31 | 105 | 223 | 188 | 26.5 | 24 | 130 | 256 | 200 | 26.9 |
| barred surfperch | 37 | 90 | 110 | 98 | 5 | 146 | 63 | 95 | 77 | 5.9 |
| basketweave cusk-eel | 1 | 83 | 83 | 83 | - | - | - | - | - | - |
| bat ray* | - | - | - | - | - | 5 | 560 | 702 | 633 | 62.1 |
| calico rockfish | 2 | 24 | 28 | 26 | 2.8 | - | - | - | - | - |
| California corbina | 9 | 181 | 281 | 233 | 29.6 | - | - | - | - | - |
| California halibut | - | - | - | - | - | 1 | 303 | 303 | 303 | - |
| California lizardfish | - | - | - | - | - | 13 | 89 | 134 | 111 | 14.3 |
| deepbody anchovy | 1 | 65 | 65 | 65 | - | - | - | - | - | - |
| diamond turbot | 1 | 235 | 235 | 235 | - | - | - | - | - | - |
| English sole | 4 | 15 | 19 | 17 | 1.9 | 18 | 40 | 128 | 64 | 25.8 |
| fantail sole | - | - | - | - | - | 1 | 191 | 191 | 191 | - |
| kelp pipefish | 26 | 153 | 274 | 211 | 22.9 | 11 | 144 | 224 | 185 | 25.8 |
| northern anchovy | 50 | 32 | 67 | 46 | 6.4 | 66 | 53 | 136 | 111 | 17.9 |
| Pacific sardine | - | - | - | - | - | 1 | 137 | 137 | 137 | - |
| Pacific staghorn sculpin | - | - | - | - | - | 9 | 88 | 128 | 107 | 14.6 |
| painted greenling | - | - | - | - | - | 1 | 44 | 44 | 44 | - |
| pricklebreast poacher | 10 | 93 | 112 | 104 | 6.1 | 63 | 38 | 89 | 60 | 13.8 |
| queenfish | 1 | 109 | 109 | 109 | - | 22 | 94 | 137 | 111 | 10.5 |
| shiner perch | 1 | 121 | 121 | 121 | - | 55 | 34 | 116 | 53 | 21.8 |
| shovelnose guitarfish** | - | - | - | - | - | 1 | 449 | 449 | 449 | - |
| slough anchovy | 2 | 62 | 66 | 64 | 2.8 | - | - | - | - | - |
| speckled sanddab | 201 | 22 | 112 | 54 | 19.4 | 577 | 31 | 120 | 64 | 15.5 |
| spiny dogfish** | 38 | 339 | 460 | 391 | 35.8 | - | - | - | - | - |
| thornback** | 13 | 134 | 464 | 224 | 130.4 | 2 | 335 | 410 | 373 | 53.0 |
| tubesnout | - | - | - | - | - | 1 | 110 | 110 | 110 | - |
| vermilion rockfish | 2 | 31 | 33 | 32 | 1.4 | - | - | - | - | - |
| walleye surfperch | - | - | - | - | - | 26 | 61 | 75 | 67 | 3.5 |
| white croaker | 339 | 30 | 96 | 36 | 7.4 | 355 | 32 | 72 | 58 | 6.0 |
| white seaperch | - | - | - | - | - | 9 | 36 | 55 | 40 | 6.3 |

* Disc Width = , ** =Total Length

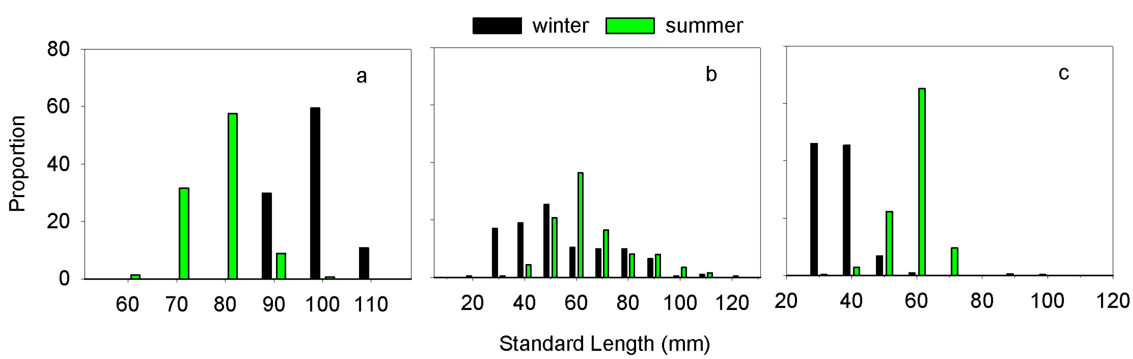



**Figure 6-5. Proportional seasonal catch by size class for a) barred surfperch (winter n = 37, summer n = 146); b) speckled sanddab (winter n = 201, summer n = 577); c) white croaker (winter n = 339, summer n = 355). Mandalay Generating Station NPDES, 2009.**

## Macroinvertebrates

A total of 10,145 macroinvertebrates representing 17 species and weighing 34.07 kg were taken during the 2009 trawl surveys (Table 6-4). The overall species diversity was 1.08 while evenness was 0.38. Winter trawls caught 3,437 individuals (34% of annual total) representing 14 species and weighing 10.44 kg (31%). The summer survey took 6,708 individuals (66%) representing nine species and weighing 23.63 kg (69%). Winter species diversity was 0.70 while summer diversity was 0.92. Eight species were unique to winter trawls while three were unique to summer sampling. Combined, 4,600 Pacific sand dollar (*Dendraster excentricus*), 4,058 blackspotted bay shrimp (*Crangon nigromaculata*), and 1,346 graceful crab (*Metacarcinus gracilis*) accounted for 98% of the annual catch.

**Table 6-4. Abundance and catch parameters for macroinvertebrates species taken by otter trawl. Mandalay Generating Station NPDES, 2009.**

| | Winter | | | | | Summer | | | | | Annual | Percent |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | T1 | T2 | T3 | T4 | Total | T1 | T2 | T3 | T4 | Total | Total | Total |
| Pacific sand dollar | 31 | 159 | 50 | 31 | 271 | 4,329 | - | - | - | 4,329 | 4,600 | 45 |
| blackspotted bay shrimp | 909 | 1,182 | 339 | 413 | 2,843 | 1,033 | 148 | 16 | 18 | 1,215 | 4,058 | 40 |
| graceful crab | 120 | 65 | 11 | 13 | 209 | 162 | 383 | 533 | 59 | 1,137 | 1,346 | 13 |
| Alaska bay shrimp | 8 | 30 | 6 | 5 | 49 | 15 | - | - | - | 15 | 64 | 1 |
| sea pansy | - | 5 | 19 | 1 | 25 | - | - | 5 | - | 5 | 30 | <1 |
| smooth bay shrimp | 2 | 7 | 2 | 3 | 14 | - | - | - | - | - | 14 | <1 |
| yellow crab | 11 | 1 | 1 | - | 13 | - | - | - | - | - | 13 | <1 |
| California spiny lobster | - | - | 1 | 1 | 2 | 3 | - | - | 1 | 4 | 6 | <1 |
| globose sand crab | - | 1 | 1 | 2 | 4 | - | - | - | - | - | 4 | <1 |
| Xantus swimming crab | 1 | 2 | - | - | 3 | - | - | - | - | - | 3 | <1 |
| northern kelp crab | 1 | - | - | - | 1 | - | - | - | - | - | 1 | <1 |
| Pacific rock crab | 1 | - | - | - | 1 | - | - | - | - | - | 1 | <1 |
| red jellyfish | - | - | - | - | - | 1 | - | - | - | 1 | 1 | <1 |
| sheep crab | - | - | - | - | - | - | 1 | - | - | 1 | 1 | <1 |
| spiny mole crab | 1 | - | - | - | 1 | - | - | - | - | - | 1 | <1 |
| Stimpson coastal shrimp | - | - | - | - | - | 1 | - | - | - | 1 | 1 | <1 |
| yellowleg shrimp | - | - | 1 | - | 1 | - | - | - | - | - | 1 | <1 |
| Total Abundance | 1,085 | 1,452 | 431 | 469 | 3,437 | 5,544 | 532 | 554 | 78 | 6,708 | 10,145 | |
| Number of species | 10 | 9 | 10 | 8 | 14 | 7 | 3 | 3 | 3 | 9 | 17 | |
| Diversity (H') | 0.61 | 0.69 | 0.81 | 0.52 | 0.70 | 0.63 | 0.60 | 0.18 | 0.61 | 0.92 | 1.08 | |
| Evenness (J') | 0.27 | 0.32 | 0.35 | 0.25 | 0.26 | 0.33 | 0.55 | 0.17 | 0.55 | 0.42 | 0.38 | |
| Biomass (kg) | 2.98 | 4.14 | 1.63 | 1.69 | 10.44 | 10.83 | 5.14 | 6.46 | 1.20 | 23.63 | 34.07 | |
| Fish parasites (not included above): | | | | | | | | | | | | |
| none | - | - | - | - | - | - | - | - | - | - | - | |

Blackspotted bay shrimp accounted for 83% of the winter catch with 2,843 individuals (Table 6-4). Only 271 Pacific sand dollar and 209 graceful crab represented another 5% or more of the winter total. Each of the remaining species was represented by 49, or fewer, individuals. Catches upcoast of the discharge at Stations T1 and T2 were similar in total abundance, both with more than 1,000 individuals, although trawls at Station T2 caught 367 more individuals than at Station T1 (Figure 6-6 and Table 6-4). Sampling at Stations T3 and T4 also recorded similar catches, although their combined total (900 individuals) was less than that taken at Station T1 (1,085 individuals). The disparity between the two areas, upcoast and downcoast of the discharge, was largely due to the distribution of blackspotted bay shrimp, which was at least twice as abundant upcoast as downcoast. Species richness was similar with all four stations ranging from eight species taken at Station T4 to 10 species, each, taken at Stations T1 and T3. Likewise, diversity was similar with a high of 0.81 at Station T3 to a low of 0.52 at Station T4. Biomass, like abundance, was higher upcoast than downcoast with an average of 3.56 kg/station taken upcoast and 1.66 kg/station taken downcoast of the discharge.

Ninety-four percent of the 4,600 Pacific sand dollar taken in 2009 (4,329 individuals) were caught at one station during the summer trawls (Table 6-4). These, along with the 1,215

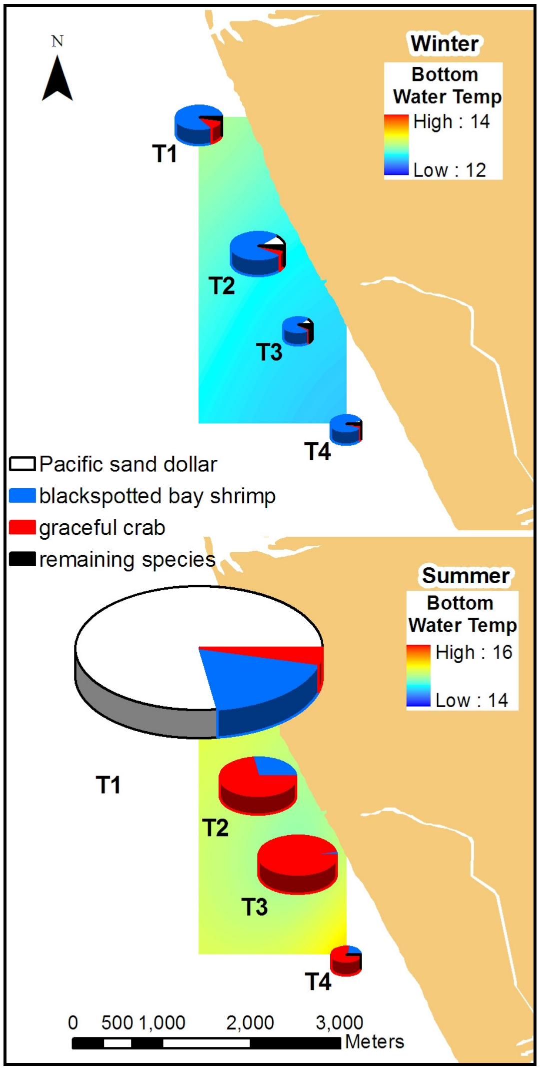



**Figure 6-6. Proportional macroinvertebrate abundance by site and species recorded during winter and summer surveys. Mandalay Generating Station NPDES, 2009.**

blackspotted bay shrimp and 1,137 graceful crab, accounted for over 99% of the total summer catch. The remaining six species contributed another 27 animals, combined. Nearly 83% of the summer catch (5,544) was taken at Station T1, including all of the Pacific sand dollar and most (85%) of the blackspotted bay shrimp (Figure 6-6). The catches at Stations T2 and T3 were relatively similar, 532 and 554 individuals, respectively, with graceful crab accounting for almost all of the catch (96%) at Station T3. Graceful crab and blackspotted bay shrimp, with 383 and 148 individuals, respectively, dominated the catch at Station T2 in addition to the only sheep crab (*Loxorhynchus grandis*) taken in 2009. Seventy-eight macroinvertebrates were taken at Station T4, or 1% of the total, with 59 graceful crab accounting for 76% of the catch. Seven species were taken at Station T1 while three species, each, were taken at the remaining three stations. Species diversity ranged from 0.60 to 0.63 except for Station T3 ($H' = 0.18$). Forty-six percent of the biomass was taken at Station T1 (10.83 kg) followed by 6.46 kg at Station T3, and 5.14 kg at Station T2. The catch at Station T4 weighed 1.20 kg.

## DISCUSSION

The 2009 winter fish catch was consistent with historic records, although it was well below some of the most abundant years, such as 2005 and 1992 (Figure 6-7). While the abundance was consistent with that observed since 1990, the faunal composition continued a shift away from the white croaker/queenfish dominated catches common prior to 2004 (Table 6-5). Speckled sanddab has been the most important species in the catches each of the last three winters while white croaker has ranked first only once since 2004, and queenfish has not ranked first in the IRI since 2001 (Table 6-5). Prior to 2004, white croaker and queenfish combined to dominate the IRI in every winter survey since 1990. While the IRI details differences in the community dominance, 2009 was generally consistent with most of the 1990's, but not the 2000's, based on the catch of the top ten species caught since 1990 (Figure 6-8).

Summer fish abundance in 2009 was below average ranking as the 11$^{th}$ largest catch since 1990, ahead of only 1990, 1997, 1999, 2003, 2005, and 2008 (Figure 6-7). Consistent with historic patterns, white croaker contributed a substantial portion to the catch in addition to speckled sanddab, which became more abundant beginning in 2006. Speckled sanddab ranked first in the IRI for the first time since 2005 and the third time overall, all since 2002 (Table 6-5). Historically, white croaker has been the dominant species in the summer catches, ranking first in the IRI in eight surveys since 1990, but only once since 2002. White croaker was absent in the three summer catches since 2002. The results in 2009 most closely aligned with the 2007, 2003,

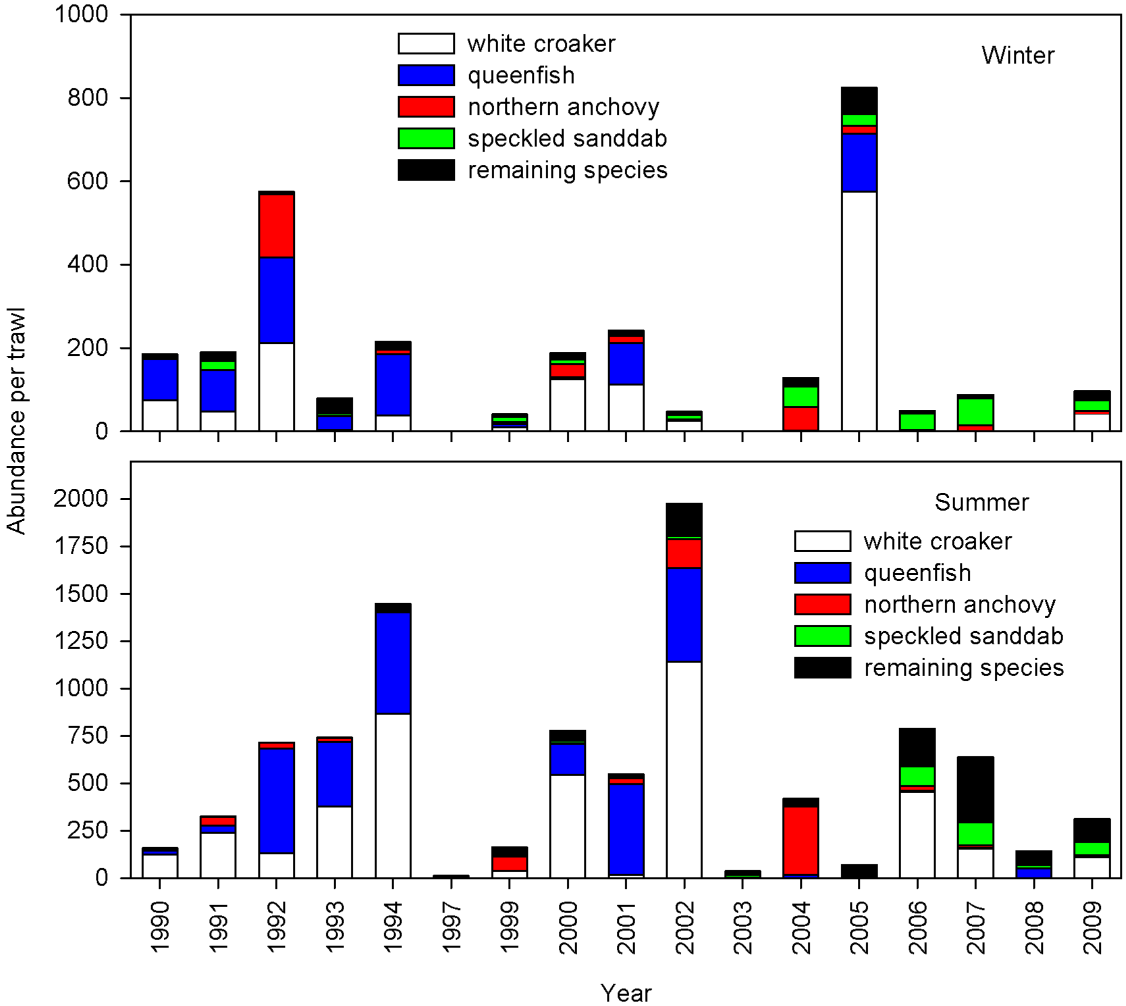



**Figure 6-7. Fish abundance per trawl recorded during winter and summer trawl surveys, 1990-2009 (non-consecutively). Winter sampling not required in 1997, 2003, or 2008. Mandalay Generating Station NPDES, 2009.**

and 1990 catches, based on the abundance patterns of the ten most abundant species. These four years were generally segregated from the remaining years.

During both seasonal surveys, the catch at Station T1 was the greatest with trawls at the remaining three sites resulting in relatively similar catches (Figure 6-2). Station T1 is located farthest upcoast of the discharge and closest to the Santa Clara River, where generally higher bottom water temperatures were recorded in comparison to the remaining sites, especially those nearest the discharge (Stations T2 and T3) and sediments are typically finest (Figure 3-3). Abundance has been highest at Station T1 in eight out of 17 summer surveys and eight out of 14 winter surveys conducted since 1990. Since 2005, the summer bottom water temperatures at Station T1 have been higher, on average, during flood tide than at the remaining three stations, while the winter temperatures are typically equal, on average, at Stations T1 and T4. The distribution of the catch, both in 2009 and since 1990, may be related to the elevated bottom temperature and potential habitat differences between Station T1 and the remaining sites.

White croaker, the most abundant fish caught in 2009, is typically abundant over sandy nearshore areas (Hobson and Chess 1976, Allen and DeMartini 1983) at depths of 15 to 22 m (Love et al. 1984), such as the habitat at Station T1 where they were predominantly taken. Their

**Table 6-5. Index of Relative Importance for the top ten fish species collected during trawl surveys, 1990 - 2009 (non-consecutively). Mandalay Generating Station NPDES, 2009.**

| Winter | 1990 | 1991 | 1992 | 1993 | 1994 | 1997 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| speckled sanddab | 3 | 3 | 6 | 3 | 6 | - | 2 | 3 | 4 | 2 | - | 2 | 5 | 1 | 1 | - | 1 |
| white croaker | 2 | 2 | 1 | 4 | 2 | - | 1 | 1 | 2 | 1 | - | 5 | 1 | 4 | - | - | 3 |
| thornback | - | 4 | 4 | 6 | 7 | - | 6 | 8 | 9 | 3 | - | 9 | 8 | 5 | 5 | - | 6 |
| queenfish | 1 | 1 | 2 | 1 | 1 | - | 2 | 4 | 1 | 5 | - | 7 | 2 | - | - | - | 8 |
| northern anchovy | 4 | - | 3 | - | 4 | - | 5 | 2 | 2 | 8 | - | 1 | 6 | 3 | 2 | - | 2 |
| barred surfperch | - | 5 | 7 | 2 | 3 | - | 9 | 7 | 7 | 6 | - | 4 | 7 | - | 4 | - | 3 |
| California corbina | - | 6 | 8 | 5 | 5 | - | 8 | 5 | 6 | 6 | - | 7 | 10 | - | 7 | - | 7 |
| shiner perch | - | 7 | 8 | 7 | 8 | - | - | - | 10 | 8 | - | 9 | 4 | 6 | 6 | - | 8 |
| kelp pipefish | - | - | - | - | - | - | 2 | 6 | 5 | 4 | - | 3 | 3 | 2 | 2 | - | 5 |
| bat ray | 4 | - | 4 | 8 | - | - | 6 | - | 8 | 10 | - | 6 | 9 | 6 | - | - | - |

| Summer | 1990 | 1991 | 1992 | 1993 | 1994 | 1997 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| shiner perch | 5 | 7 | 5 | 6 | 3 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 2 | 3 | 1 | 1 | 5 |
| speckled sanddab | 6 | 4 | 7 | 5 | 9 | 2 | 3 | 3 | 6 | 3 | 1 | 4 | 1 | 2 | 2 | 2 | 1 |
| northern anchovy | 3 | 3 | 3 | 3 | 4 | - | 1 | 10 | 2 | 6 | 3 | 1 | 7 | 4 | 3 | 4 | 3 |
| queenfish | 2 | 5 | 1 | 1 | 2 | - | 7 | 2 | 1 | 5 | 4 | 2 | 8 | 6 | 8 | 3 | 7 |
| barred surfperch | 3 | 2 | 4 | 7 | 5 | 4 | - | 7 | 8 | 4 | - | 5 | 4 | 8 | 4 | 5 | 2 |
| walleye surfperch | - | 6 | 6 | 7 | 5 | 6 | 8 | 7 | 3 | 9 | 5 | 5 | 2 | 5 | - | 6 | 6 |
| thornback | 7 | 8 | - | 4 | 7 | 5 | 6 | 6 | 7 | 7 | - | 8 | 6 | 7 | 6 | 8 | 9 |
| white croaker | 1 | 1 | 2 | 1 | 1 | 1 | 2 | 1 | 3 | 1 | - | - | 5 | 1 | 5 | - | 3 |
| fantail sole | 9 | 9 | 7 | 9 | 8 | 6 | 5 | 5 | 9 | 7 | - | - | 9 | - | 9 | 8 | 10 |
| bat ray | 8 | 10 | 7 | 9 | 10 | - | 8 | 9 | 9 | 10 | - | 7 | - | 9 | 7 | 7 | 8 |

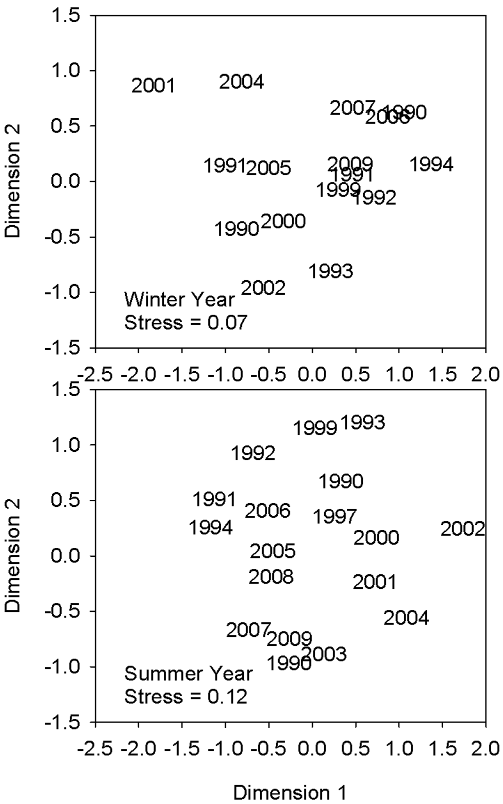



**Figure 6-8. Multidimensional scaling maps, by season, illustrating relationships between annual catches and between the ten most abundant fish species recorded, 1990-2009 (non-consecutively). Winter sampling not required in 1997, 2003, or 2008. Mandalay Generating Station NPDES, 2009.**

range extends from British Columbia to Baja California and they are typically found forming loose schools in the nearshore open coast, shallow bays or lagoons, and industrialized harbors (Moore and Wild 2001, Love et al. 2005). They are primarily nocturnal and tend to occur inshore during the day in resting schools, remaining nearshore at night to feed on bottom-dwelling polychaetes and crustaceans (Ware 1979, Allen 1982). Juveniles (less than 130 mm SL) are usually limited to shallow nearshore areas and embayments, which they may use as nursery grounds. They are an important sport fish commonly caught from piers and jetties throughout the Southern California Bight as well as a commercial species that is sold as fresh fish, although a small amount is used for live bait (Eschmeyer et al. 1983, Love et al. 1984, Moore and Wild 2001, Love 2006). Although white croaker spawning can occur throughout the year, distinct seasonal peaks are generally found in January through April (Love et al. 1984, Goldberg 1976). White croaker individuals typically mature at approximately one year at a length of 120 to 130 mm SL (Love et al. 1984). Length frequency analysis of the white croaker community in 2009 indicates the majority were less than one year old (Love et al. 1984). Bight-wide, white croaker and queenfish populations have been in decline since at least the early 1980s (Miller et al. In review).

In 2009, speckled sanddab was the second most abundant fish species collected (Table 6-1). It has become increasingly abundant throughout the

Southern California Bight (MBC 2008a-f). In regional sampling, speckled sanddab abundances increased between 1998 and 2003, accounting for 1.8 and 11% of the total fish catch, respectively (Allen et al. 2002, Allen et al. 2007), suggesting that the species has recently increased in abundance in southern California. Since 2000, speckled sanddab has been a more important member of the local demersal fish community, ranking no less than fifth in winter and sixth in summer in any given year (Table 6-5). Speckled sanddab is a non-schooling species commonly associated with soft-bottom habitats throughout the shallow nearshore environment of southern California (Allen 1982, Allen 1985). A sandy-bottom species that feeds mainly during the day, speckled sanddab hunts primarily by sight on epifaunal invertebrates (Ford 1965, Allen 1982). This typically small sanddab has not been an important part of the commercial catch, although it is present in some of the commercial landings. Sanddabs, however, are frequently sought by recreational anglers (Allen and Leos 2001). The similarity of abundances among years of this species suggests that the fish assemblage of the nearshore, soft-bottom community remains stable in the area. The differences in length frequency distributions between the two seasons suggests the same community was sampled each season with a slight increase in size attributed to aging (Figure 6-5b).

Barred surfperch, the third most abundant species caught in 2009, occurred in the highest summer abundances and second highest winter abundances recorded since 1990. Taken in all but two previous winter and two previous summer surveys, barred surfperch is a common member of the area’s community (Table 6-5). Ranking second in summer and third in winter, their IRI in both seasons were at or near the highest since 1990. Barred surfperch are common to the Southern California Bight surf-zone habitat (Love et al. 2005, Allen and Pondella 2006), such as that offshore the Mandalay Generating Station as represented by their generally consistent occurrence in the annual trawl surveys. Juvenile barred surfperch are typically born between March and July at about 50 mm SL, on average (Carlisle et al. 1960). Prior age and growth studies by Carlisle et al. (1960) indicate that the summer catch was dominated by fish less than one year old, mostly individuals born that prior spring. Individuals taken in winter were typically older, approximately 1 year old. Tagging studies by Carlisle suggest barred surfperch do not migrate great distances, with all tag returns occurring within 31 miles of their release site. The barred surfperch sport fishery far outweighs the commercial fishery with an annual average (1993-1999) catch of 176,000 fish State-wide (Fritzsche and Collier 2001). Ryan et al. (2003) reported the mean annual recreational catch over the 1993-2001 period declined 13% in comparison to the 1981-1989 period.

Both seasonal surveys recorded above average macroinvertebrate abundances, largely due to the abundances of blackspotted bay shrimp (winter) and Pacific sand dollar (summer) (Figure 6-9). This was consistent with most years since 1990, with blackspotted bay shrimp most abundant in most winter surveys and Pacific sand dollar numerically dominant the summer. Since 2003, however, blackspotted bay shrimp has dominated both seasonal surveys while Pacific sand dollar was greatly reduced in abundance during the summer sampling, although it was the most abundant species taken in winter 2006. For the first time since 2001, the winter and summer catches in 2009 were similarly abundant in relation to historic surveys, with the winter catch 0.33 standard deviations above its mean and the summer catch 0.44 standard deviations above its mean. Recently, either the winter or summer catch was comparatively elevated, but not both. Just as the fish are historically more abundant upcoast of the discharge, so too are the macroinvertebrates, as seen in 2009 (Figure 6-6). Since 1990, the total catch at Station T2 has ranked first in six out of 13 winter surveys while Station T1 ranked first in seven out of 16 summer surveys. The catch at Station T4 is the lowest in most years during both seasons. As described before, the area upcoast of the discharge is typically the warmest and may be the most affected by flow out of the Santa Clara River. The IRI of the top five species, historically, is dominated by blackspotted bay shrimp in both seasons (Table 6-6). Winter results recorded Pacific sand dollar and graceful crab as the second and third highest ranked IRI values in 2009, which is consistent with recent years where these two species have consistently ranked either second or third. Summer IRI values, however, recorded a return of Pacific sand dollar after a two year absence,

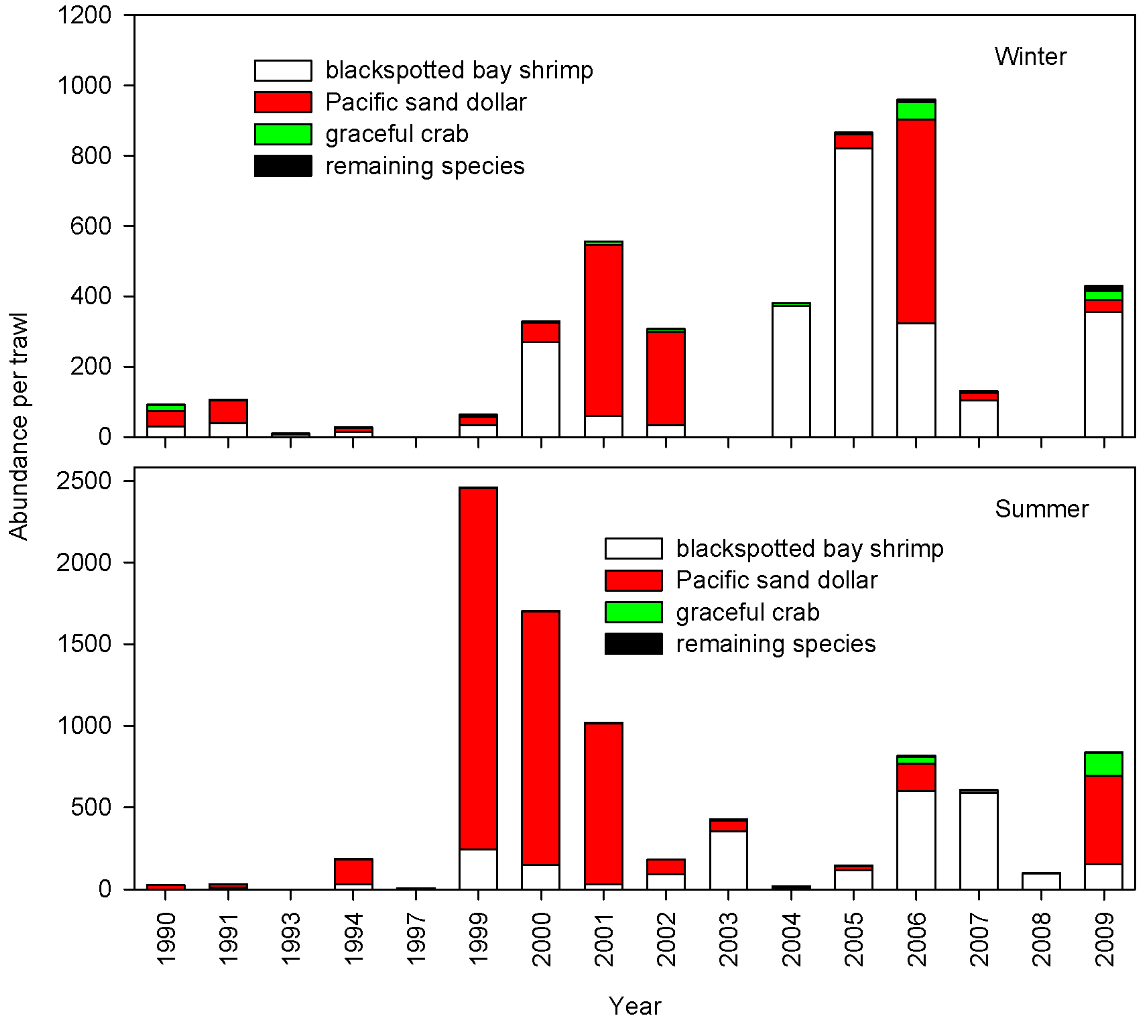



**Figure 6-9. Macroinvertebrate abundance per trawl recorded during winter and summer trawl surveys, 1990-2009 (non-consecutively). Winter sampling not required in 1997, 2003, or 2008. Mandalay Generating Station NPDES, 2009.**

with it tying graceful crab with the second ranked IRI. This was the first summer since 2005 that Pacific sand dollar ranked second while graceful crab has ranked at least second each summer since 2002. Overall the catch in 2009, both seasons, was relatively unique, although the winter catch was somewhat reminiscent of winter 2000 and 2007 (Figure 6-10).

Historically, Pacific sand dollar has been among the most abundant macroinvertebrate species taken in the area since 1978 (MBC 1979, 1981, 1986, 1988, Figure 6-9). Cumulatively across all winter surveys between 1990 and 2003, it ranked first in abundance. Across all summer surveys since 1990, Pacific sand dollar is 2.5-times as abundant as blackspotted bay shrimp, the second most abundant species in summer since 1990. Erratic recruitment is common in this species (Timko 1975), and although the reproductive strategy of Pacific sand dollar is one of dispersal, larval settlement is often highest within or adjacent to existing sand dollar beds which already contain up to several hundred adults per square meter, perhaps in response to a chemical cue from the adults (Highsmith 1982).

**Table 6-6. Index of Relative Importance for the five most abundant and most frequently occurring macroinvertebrate species collected during trawl surveys, 1990 - 2009 (non-consecutively). Mandalay Generating Station NPDES, 2009.**

| Winter | 1990 | 1991 | 1993 | 1994 | 1997 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| blackspotted bay shrimp | 2 | 1 | 1 | 1 | - | 1 | 1 | 3 | 2 | - | 1 | 1 | 1 | 1 | - | 1 |
| graceful crab | 3 | 3 | 2 | 4 | - | 4 | 3 | 2 | 3 | - | 2 | 3 | 3 | 2 | - | 3 |
| Pacific sand dollar | 1 | 1 | 4 | 2 | - | 2 | 2 | 1 | 1 | - | 3 | 2 | 2 | 3 | - | 2 |
| Xantus swimming crab | - | - | 3 | 3 | - | 3 | - | 5 | - | - | 4 | 4 | - | 5 | - | 4 |
| California spiny lobster | - | 4 | - | - | - | 5 | 3 | 4 | 4 | - | - | - | - | 4 | - | 5 |

No surveys required in 1997, 2003, and 2008.

| Summer | 1990 | 1991 | 1993 | 1994 | 1997 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| blackspotted bay shrimp | 2 | 2 | 1 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Pacific sand dollar | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 1 | 3 | 3 | - | - | 2 |
| graceful crab | 2 | - | - | 3 | - | 4 | 3 | 3 | 3 | 2 | 1 | 2 | 2 | 2 | 2 | 2 |
| tuberculate pear crab | - | - | - | 4 | - | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | - | - |
| sheep crab | - | - | 2 | - | 3 | - | - | - | 4 | - | - | 5 | 5 | 3 | 3 | 4 |

Blackspotted bay shrimp is common in trawl surveys in southern California, and annual abundance off some areas of California has varied widely, sometimes by more than tenfold (Siegfried 1989). In regional trawl monitoring conducted throughout the Southern California Bight in 1998, blackspotted bay shrimp was the most abundant macroinvertebrate species collected on the inner shelf, accounting for 0.7% of the total macroinvertebrate catch (Allen et al. 2002). In 2003 regional monitoring, blackspotted bay shrimp was the most abundant macroinvertebrate species collected in bays and harbors, accounting for 1.2% of the total macroinvertebrate catch (Allen et al. 2007). The species plays an important role in the coastal food web, feeding on small epibenthic and benthic fauna over mud and sand bottoms. In turn, blackspotted bay shrimp are preyed on by a number of fish, including Pacific staghorn sculpin (*Leptocottus armatus*), brown smoothhound (*Mustelus henlei*) and white croaker (Ware 1979, Siegfried 1989). Ovigerous females (those with eggs) are found in coastal embayments in summer but are uncommon in winter. Seasonal migrations of some crangonid shrimp have been linked to changing seawater temperatures (Siegfried 1989).

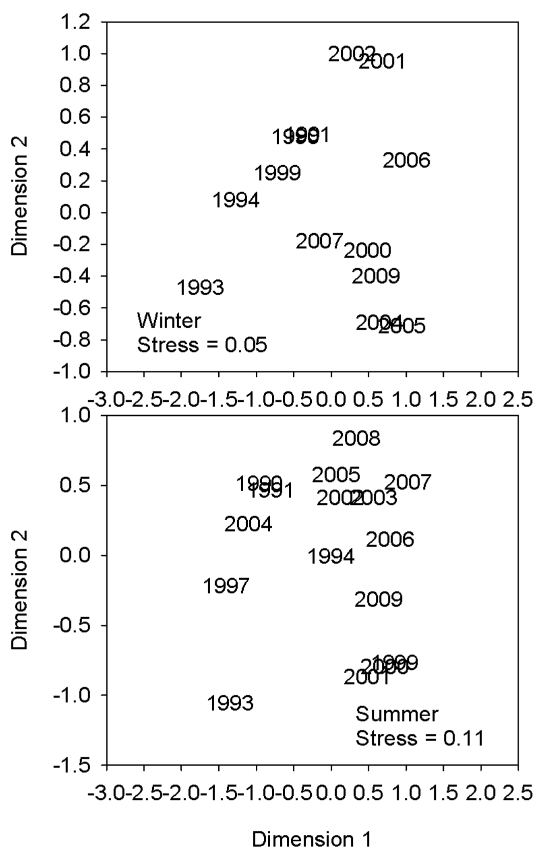



**Figure 6-10. Multidimensional scaling maps, by season, illustrating relationships between annual catches and the relationships between the five most abundant macroinvertebrate species recorded, 1986-2009 (non-consecutively). Winter sampling not required in 1997, 2003, or 2008. Data unavailable for 1992. Mandalay Generating Station NPDES, 2009.**

## CONCLUSION

Fish and macroinvertebrate species composition were similar to those in past surveys in the study area. While similar, the fish catch was lower than most years, largely due to the reduced abundance of queenfish and white croaker while the speckled sanddab catch was consistent with two out of the past three surveys. Macroinvertebrates, specifically the winter catch, was substantially greater in 2009 than most winter surveys since 1990. The summer catch was also above average, but generally consistent with two out of the three most recent summer surveys. For both fish and macroinvertebrates, catches were highest upcoast of the discharge, where bottom water temperatures were typically higher than downcoast of the discharge. This area is also more proximate to the Santa Clara River, which may have further affected the community due to habitat differences. Overall, there is no indication that plant operations have adversely affected the fish or macroinvertebrate populations offshore of the Mandalay Generating Station.

# CHAPTER 7 — IMPINGEMENT

Once through cooling water systems are commonly used by electric power generating stations sited adjacent to large water bodies (e.g., lake, river, bay, coastal ocean). Such systems may potentially entrap organisms present in the source water entrained into the cooling system. Cooling water is typically screened prior to entering the condensers to remove material that may interfere with the proper operation of the system.

Mandalay Generating Station is located on the coast approximately 4.8 km west of the City of Oxnard, California. Two units are supplied by the once through cooling (OTC) water system. Cooling water is supplied to the system via Edison Canal, a 4-km long canal which connects to Channel Islands Harbor at its northern end, located approximately 4.8 km downcoast of the generating station. Water enters the plant through two angled 5.9 meter-wide intake bays. Debris is removed as cooling water passes through two pairs of trash racks, with 57 mm mesh, as well as two pairs of vertical slide screens, which measure 3.5 meters wide by 6.4 meters high with 12.7 mm mesh. The slide screens are operated parallel to one another and perpendicular to the intake flow. One slide screen is deployed while the other is cleaned of debris by a high pressure wash that automatically activates by pressure differential across the screen. All debris was accumulated in a trash basket where impingement samples were taken.

Impingement was monitored by Proteus Sea Farms International, Inc., Ojai, California, during two distinct operational modes, normal operation and heat treatments. Normal operation refers to the typical daily operational mode of the OTC water system. Historically, heat treatments were periodically conducted to reduce biofouling by recirculating the heated discharge water throughout the cooling water system until the temperature at the slide screens reached or exceeded 100°F (Graham et al. 1977). All organisms within the influence of the heated waters succumb and were typically impinged upon the slide screens. No heat treatments were conducted in 2009.

## MATERIALS AND METHODS

At Mandalay Generating Station, six surveys were conducted to assess the impingement of organisms at the generating station during representative periods of operation, usually over 24 hours. During these surveys, the sliding screens and trash baskets were cleared of all debris at the start of the sampling period. At the end of the survey period all accumulated material was sorted and processed. Fish and macroinvertebrates were identified to the lowest practical taxonomic level. Up to 50 individuals of each fish species were measured to the nearest millimeter (mm) standard length (SL) or other appropriate length (disc width [DW] or total length [TL]), aggregate biomass (kg) was recorded for all measured and unmeasured individuals. Total abundance for species with more than 50 individuals was estimated by dividing the total weight of the unmeasured individuals by the mean weight of the measured individuals of that species. Macroinvertebrates were also sorted to the lowest possible taxonomic category, counted and an aggregate weight (kg) taken.

Due to variation in daily operating patterns, all normal operation survey fish and macroinvertebrate data was extrapolated over reported circulated water volumes, in million gallons, to determine the estimated monthly impingement by the equation: Estimated Impingement = (Abundance/Survey water volume) x Analysis period water volume. The analysis period flow volume is listed in Appendix H-4 and includes flows represented by the normal operation survey. Annual abundance represents the summation of all estimated normal operation impingement abundances. Biomass values were analyzed in the same fashion.

Data was recorded in the field on preprinted data sheets by Proteus Sea Farms. Field sheets were provided to MBC for transcription into digital format. Species-specific lengths were rounded to the nearest 10-mm bin, i.e., 35-44 mm SL = 40 mm SL bin. Abundance per size class was plotted.

## RESULTS

Impingement sampling results, including a master species list, for the sample year 2009 (1 October 2008 to 30 September 2009) are presented in Appendix H.

### Fish

An estimated total of 11,525 fish weighing 162.07 kg representing 14 species was impinged in 2009 at Mandalay Generating Station (Table 7-1). Eighty-one percent of abundance was accounted for by 4,781 shiner perch (*Cymatogaster aggregata*) and 4,661 Pacific staghorn sculpin (*Leptocottus armatus*). The remaining 12 species collectively contributed 2,083 individuals. Three species accounted for 87% of the total biomass; Pacific staghorn sculpin (94.12 kg), shiner perch (26.00 kg), and jacksmelt (*Atherinopsis californiensis*; 20.42 kg). The remaining 11 species, combined, contributed an additional 21.53 kg. Overall, six species were observed once during the six impingement surveys. Ninety-five percent of the total observed abundance was recorded during the 3 October and 2 December 2008 surveys.

**Table 7-1. Estimated abundance and biomass (kg) of fish taxa impinged during normal operation surveys. Mandalay Generating Station NPDES, 2009.**

| | Obser. Norm. Op. | | Est. Norm. Op. | | Percent Total | |
|---|---|---|---|---|---|---|
| Taxa | Abu. | Biom. (kg) | Abu. | Biom. (kg) | Abu. | Biom. (kg) |
| shiner perch | 127 | 0.671 | 4,781 | 26.00 | 41 | 16 |
| Pacific staghorn sculpin | 98 | 2.164 | 4,661 | 94.12 | 40 | 58 |
| northern anchovy | 9 | 0.030 | 568 | 1.56 | 5 | 1 |
| topsmelt | 11 | 0.085 | 403 | 3.39 | 3 | 2 |
| bay pipefish | 10 | 0.013 | 354 | 0.45 | 3 | <1 |
| jacksmelt | 2 | 0.269 | 152 | 20.42 | 1 | 13 |
| Pacific sardine | 2 | 0.149 | 127 | 9.88 | 1 | 6 |
| diamond turbot | 1 | 0.003 | 94 | 0.28 | 1 | <1 |
| crevice kelpfish | 3 | 0.032 | 93 | 0.99 | 1 | 1 |
| queenfish | 1 | 0.001 | 77 | 0.08 | 1 | <1 |
| reef finspot | 1 | 0.013 | 77 | 1.00 | 1 | 1 |
| Pacific chub mackerel | 1 | 0.035 | 76 | 2.66 | 1 | 2 |
| longjaw mudsucker | 1 | 0.028 | 31 | 0.87 | <1 | 1 |
| Pacific barracuda | 1 | 0.012 | 31 | 0.37 | <1 | <1 |
| Total | 268 | 3.505 | 11,525 | 162.07 | | |
| Number of taxa | 14 | | 14 | | | |

### Length Frequency Analysis

In 2009, nine 10-mm size classes of Pacific staghorn sculpin were taken in impingement samples (Figure 7-1a). They were unimodally distributed with a peak in the 100-mm SL size class. While five size classes of shiner perch were represented, more than 50% of all individuals were in the 60-mm SL size class (Figure 7-1b).

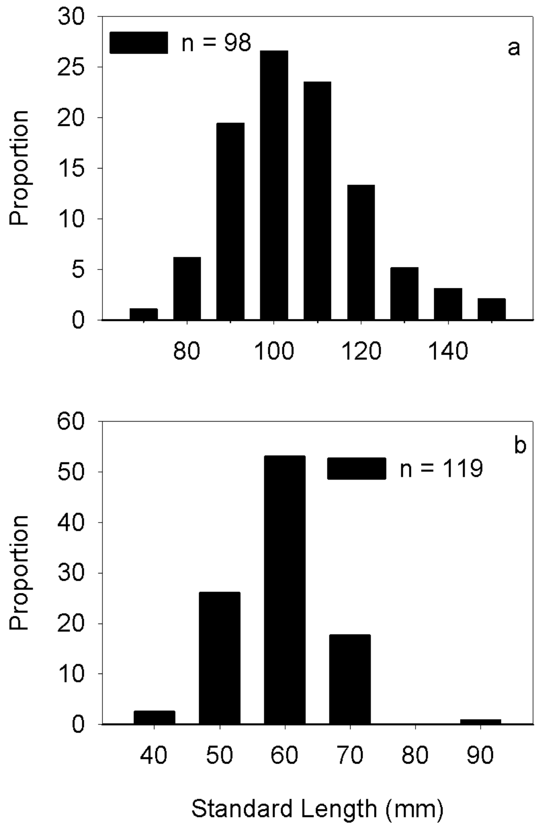



**Figure 7-1. Length frequency distribution of a) Pacific staghorn sculpin and b) shiner perch. Mandalay Generating Station NPDES, 2009.**

## Macroinvertebrates

An estimated total of 574 macroinvertebrates weighing 119.31 kg representing four species was impinged at Mandalay Generating Station in 2009 (Table 7-2). An estimated 216 California two-spot octopus (*Octopus bimaculatus/bimaculoides*), 188 California aglaja (*Navanax inermis*), 94 California seahare (*Aplysia californica*), and 76 striped shore crab (*Pachygrapsus crassipes*) comprised the total abundance. Together, California seahare (96.14 kg) and California two-spot octopus (15.79 kg) accounted for 94% of the total biomass. Another 6% was contributed by California aglaja (7.23 kg) while less than 1% was contributed by striped shore crab (0.15 kg).

## DISCUSSION

The total abundance of impinged fish in 2009 was among the lowest recorded since 2001, and consistent with that reported in each of the last two years (Figure 7-2). Since 2001, impingement monitoring at Mandalay Generating Station has recorded notable cycles of fish abundances, with highly abundant years (2002, 2005, and 2006) contrasted with low abundance years (2001, 2003, 2007, 2008, 2009). Only 2004 appeared to be "average." Shiner perch has remained among the most abundant species in each year. Silversides, either topsmelt or California grunion (*Leuresthes tenuis*), have been the source of most of the variability, with exceptionally high abundances reported in 2002, 2003, and 2005. Changes in total annual cooling water flow do not accurately reflect trends in impingement, suggesting a lack of direct relationship between cooling water flow and fish impingement (Figure 7-2). Rather, the apparent discontinuity between the two suggests other factors, such as source population densities, impart a greater effect on the annual impingement abundance than does the operation of the cooling water system.

**Table 7-2. Estimated abundance and biomass (kg) of macroinvertebrate species impinged during normal operation surveys. Mandalay Generating Station NPDES, 2009.**

| | Obser. Norm. Op. | | Est. Norm. Op. | | Percent Total | |
|---|---|---|---|---|---|---|
| Species | Abu. | Biom. (kg) | Abu. | Biom. (kg) | Abu. | Biom. (kg) |
| California two-spot octopus | 6 | 0.468 | 216 | 15.79 | 38 | 13 |
| California aglaja | 2 | 0.077 | 188 | 7.23 | 33 | 6 |
| California seahare | 1 | 1.024 | 94 | 96.14 | 16 | 81 |
| striped shore crab | 1 | 0.002 | 76 | 0.15 | 13 | <1 |
| Total | 10 | 1.571 | 574 | 119.31 | | |
| Number of Species | 4 | | 4 | | | |

Seasonal precipitation has historically acted as one of many factors influencing impingement at the generating station. The abundance of several species, especially topsmelt, can be influenced by recent rainfall, which often precipitates anomalously high impingement (MBC 2006b). The rapid change in salinity that presumably accompanied the freshwater runoff into the canal after the storm event may have impaired the osmotic balance of fishes in the area. This likely weakened them, lessening their ability to swim against the intake current and leading to their subsequent impingement. In 2009, no rainfall was recorded in the Ventura area within three days prior to each of the two surveys which documented the highest abundance, 3 October and 2 December 2008.

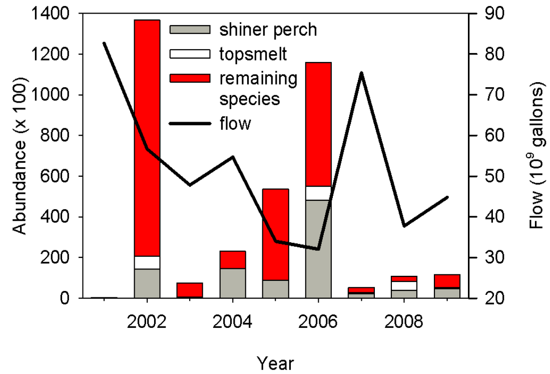



**Figure 7-2. Annual abundance of shiner perch, topsmelt, and remaining fish species impinged and total cooling water flow, 2001-2009. Mandalay Generating Station NPDES, 2009.**

Consistent with recent trends, shiner perch and Pacific staghorn sculpin were among the most abundant species impinged (Figure 7-2; MBC 2008a). Shiner perch were recorded every year since 2001, although their abundances have varied each year. Pacific staghorn sculpin has been recorded every year since 2001 in variable abundances, although numbers over the last three years have remained consistent, their estimated abundance in 2009 exceeds the combined total of the last eight years. As was seen in the total fish abundance, Pacific staghorn sculpin abundances do not exhibit a pattern similar to that of total cooling water flow. Comparatively few topsmelt were impinged in 2009. Topsmelt were first reported in 2002 and have been common in recent surveys while California grunion, closely related to topsmelt, was collected in high abundances each year from 2002 to 2005 (MBC 2002-2005).

The size of the shiner perch impinged in 2009 (Figure 7-1b) indicates most fish were near one year old (Eckmayer 1979). Shiner perch range from San Quintin Bay, Baja California to Sitka, Alaska (Love et al. 2005). Emmett et al. (1991) reports shiner perch occur primarily in shallow-water marine, bay, and estuarine habitats, taking up a demersal lifestyle over sandy and muddy bottoms. Pacific staghorn sculpin range from San Quintin, Baja California, Mexico to Port Moeller on the Bering Sea from shallow tidepools to depths of 91 m (Miller and Lea 1972, Love et al. 2005). Common to bays and estuaries throughout its range, Pacific staghorn sculpin has been recorded in 13 bays or estuaries in California and Baja California, ranging from the Klamath River mouth to Bahia de San Quintin, and has been commonly observed during impingement sampling at stations drawing seawater from bays and harbors (Allen et al. 2006, MBC 2007b). Moyle (2002) reported that Pacific staghorn sculpins move freely between salinity regimes, with juveniles most abundant in coastal streams. Pacific staghorn sculpins mature at 120 to 150 mm SL (4.7 to 5.9 in), or one-year-old (Moyle 2002), which suggests the majority of individuals observed in 2009 were near one-year-old.

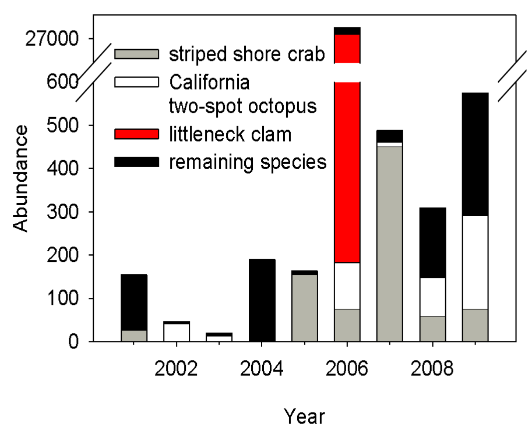



**Figure 7-3. Annual abundance of striped shore crab, California two-spot octopus, littleneck clam, and remaining macroinvertebrate species impinged, 2001-2009. Mandalay Generating Station NPDES, 2009.**

Macroinvertebrate impingement in 2009 was consistent with that recorded in recent years, exceeding that reported in 2006 and 2007 (Figure 7-3). With the exception of the anomalous occurrence in 2006 of 27,020 Pacific littleneck clams (*Protothaca staminea*) impinged during a single heat treatment; striped shore crab, though fourth in abundance in 2009, ranks as the most abundant macroinvertebrate impinged at Mandalay Generating Station. California two-spot octopus has also contributed a substantial portion of the long term abundance, ranking first in 2002, 2008 and again in 2009. All macroinvertebrate species impinged in 2009 are commonly reported in the Southern California Bight, especially during impingement sampling at facilities drawing seawater from coastal bays and harbors (Morris et al. 1980, MBC 2007b,c).

**CONCLUSION**

Overall, impingement monitoring at Mandalay Generating Station in 2009 recorded abundances within recent ranges for both fish and macroinvertebrates. Fish abundances were greater than reported in 2007 and similar to 2008 levels, but well short of those recorded from 2004 through 2006. Still, the core species group of topsmelt, shiner perch, and Pacific staghorn sculpin persisted, though in reduced numbers. Macroinvertebrates impinged in 2009 were more abundant than in most years since 2001, and second only to 2006. As with fish, a similar core species group persisted. Abundances of both phylogenetic groups showed no relationship to the volume of cooling water circulated by the facility since 2001, indicating that other factors, including source densities and seasonal precipitation probably exerted more effect on impingement than did the operation of the cooling water system. The similarity of species composed primarily of frequently occurring and long-term dominant species indicates a relatively stable assemblage typical of southern California embayments. There is no indication that plant operations have adversely affected the fish or macroinvertebrate populations in the vicinity of the Mandalay Generating Station intake canal.

# CHAPTER 8 — LITERATURE CITED


Ackermann, F. 1980. A procedure for correcting the grain size effect in heavy metal analyses of estuarine and coastal sediments. Environ. Tech. Letters 1:518-527.

Allen, L.G. 1985. A habitat analysis of the nearshore marine fishes from southern California. Bull. South Calif. Acad. Sci. 84(3): 133-155.

Allen, L.G. and E.E. DeMartini. 1983. Temporal and spatial patterns of nearshore distribution and abundance of the pelagic fishes off San Onofre-Oceanside, California. Fish. Bull., U.S. 81(3):569-586.

Allen, L.G., A. M. Findlay, C.M. Phalen. 2002. Structure and standing stock of the fish assemblages of San Diego Bay, California from 1994 to 1999. Bull. Southern California Acad. Sci. 101(2):49-85.

Allen, L.G. and D.J. Pondella, II. 2006. Surf zone, coastal pelagic zone, and harbors. *In*: The Ecology of Marine Fishes; California and Adjacent Waters. L. G. Allen, D. J. Pondella, II, and M. H. Horn, *eds.* University of California Press, Berkeley and Los Angeles, California. 660 p.

Allen, L.G., M. M. Yoklavich, G. M. Cailliet, and M. H. Horn. 2006. Bays and estuaries. Pp. 119-148. *In.* The ecology of marine fishes: California and adjacent waters, Allen, L. G., D. J. Pondella II, and M. H. Horn. Univ. Calif. Press.

Allen, M.J. 1982. Functional structure of the soft-bottom fish communities of the southern California shelf. Ph.D. thesis, Univ. Calif., San Diego, La Jolla, CA. 577 p. (avail. Univ. Microfilms Internat., Ann Arbor, MI 48106).

Allen, M. J. and R. Leos. 2001. Sanddabs. Pages 201-203 *in* Leet, W.S., C.M. Dewees, R. Klingbeil, and E.J. Larson (eds.) California's Living Marine Resources: A Status Report. University of California, Agriculture and Natural Resources Publication SG01-11, 592pp.

Allen, M.J., T. Mikel, D. Cadien, J.E. Kalman, E.T. Jarvis, K.C. Schiff, D.W. Diehl, S.L. Moore, S. Walther, G. Deets, C. Cash, S. Watts, D.J. Pondella II, V. Raco-Rands, C. Thomas, R. Gartman, L. Sabin, W. Power, A.K. Groce, and J. L. Armstrong. 2007. Southern California Bight 2003 Regional Monitoring Program: IV: Demersal Fishes and Megabenthic Invertebrates. Southern California Coastal Water Research Project, Costa Mesa, CA. 340 p.

Barnard, J.L. 1963. Relationship of benthic Amphipoda to invertebrate communities of inshore sublittoral sands of southern California. Pac. Nat. 3(15):439-467.

Boesch, D.F. 1977. Application of numerical classification in ecological investigations of water pollution. U.S. Environmental Protection Agency EPA-600/3-77-033. 115 p.

California Regional Water Quality Control Board. 1994. Basin plan for the coastal watersheds of Los Angeles and Ventura Counties, Los Angeles Region (4). Approved by State Water Resources Control Board November 17, 1994.

Carlisle, J.G., J.W. Schott, and N.J. Abramson. 1960. The barred surfperch (*Amphistichus argenteus* Agassiz) in southern California. California Department of Fish and Game, Fish Bulletin 109.

Carlton, J.T. (ed.). 2007. The Light and Smith Manual: Intertidal Invertebrates from Central California to Oregon. 4th ed. Univ. Calif. Press. 1001 pp.

Clarke, K. R. and M. Ainsworth. 1993. A method of linking multivariate community structure to environmental variables. Mar. Eco. Prog. Ser. 92:205-219.

Clifford, H.T. and W. Stephenson. 1975. An Introduction to Numerical Classification. Academic Press, New York. 229 p.

Cross, J .N. and L.G. Allen. 1993. Chapter 9. Fishes. Pages 459-540 *in* M.D. Dailey, D.J. Reish, and J.W. Anderson (eds.) Ecology of the southern California bight: a systhesis and interpretation. University of California Press, Berkeley, CA.

de Groot, A.J., K.H. Zschuppe, and W. Salomons. 1982. Standardization of methods of analysis for heavy metals in sediments. Hydrobiologia 92:689-695.

Dexter, D.H. 1978. The infauna of a subtidal, sand-bottom community at Imperial Beach, California. Calif. Fish and Game 64(4):268-279.

Duxbury, A.C. and A. Duxbury. 1984. An Introduction to the World's Oceans. Addison-Wesley Publishing Co., Menlo Park, CA. 549 p.

Eckmayer, W.J. 1979. Age and growth of four surfperches (Embiotocidae) from the outer harbor of Anaheim Bay, California. Calif. Fish and Game. 65(4):265-272.

Emmett, R.L., S.L. Stone, S.A. Hinton, and M.E. Monaco. 1991. Distribution and abundance of fishes and invertebrates in west coast estuaries, Vol. II. Species life history summaries. ELMR Rep. 8. NOAA/NOS Strategic Environmental Assessments Division, Rockville, MD. 329 p.

EPA. See United States Environmental Protection Agency.

Eschmeyer, W.N., E.S. Herald, and H. Hamman. 1983. A field guide to Pacific coast fishes of North America. Houghton-Mifflin Co., Boston, MA. 336p.

Ford, R.F. 1965. Distribution, population dynamics, and behavior of a bothid flatfish, *Citharichthys stigmaeus*. Ph.D. dissertation. University of California, San Diego. La Jolla, CA.

Fritzsche, R.A. and P. Collier. 2001. Surfperches. Pages 236-240 *in*: Leet, W.S., C.M. DeWees, R. Klingbeil, and E.J. Larson (eds.). University of California Press, Agriculture and Natural Resources Publication SG01-11. 592 p.

Goldberg, S. R. 1976. Seasonal spawning cycles of the sciaenid fishes *Genyonemous lineatus* and *Seriphus politus*. Fish Bull 74(4): 983 p.

Graham, J.W., J.N. Stock and P.H. Benson. 1977. Further studies on the use of heat treatment to control biofouling in seawater cooling systems. Oceans 23A-1:23A-6.

Gray, J.S. 1974. Animal-sediment relationships. Oceanogr. Mar. Biol. Ann. Rev. 12:223-261.

Hickey, B.M. 1992. Circulation over the Santa Monica-San Pedro Basin and Shelf. Progress in Oceanography 30:37-115.

Highsmith, R.C. 1982. Induced settlement and metamorphosis of sand dollar (*Dendraster excentricus*) larvae in predator-free sites: adult sand dollar beds. Ecology 63(2):329-337.

Hintze, J. L. 1998. NCSS 2000 statistical system for windows. Number cruncher statistical systems, Kaysville, UT.

Hobson, E.S. and J.R. Chess. 1976. Trophic interactions among fishes and zooplankters near shore at Santa Catalina Island, California. Fish. Bull., U.S. 74(3)567-598.

Intersea Research Corporation. 1973. Thermal effect study for the Mandalay Steam Plant, March 1973 progress report. Prepared for Southern California Edison Company.

IRC. see Intersea Research Corporation

Johnson, R.G. 1970. Variations in diversity within benthic marine communities. Am. Nat. 104(937):285-300.

Kennish, M.J. 2001. Practical Handbook of Marine Science, 3rd Edition, CRC Press, Boca Raton, FL. 876 p.

Long, E.R., D.D. MacDonald, S.L. Smith, and F.D. Calder. 1995. Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments. Environ. Management 19(1):81-97.

Love, M.S. 2006. Subsistence, commercial, and recreational fisheries. *In*: The Ecology of Marine Fishes; California and Adjacent Waters. L. G. Allen, D. J. Pondella, II, and M. H. Horn, *eds.* University of California Press, Berkeley and Los Angeles, California. 660 p.

Love, M., G.E. McGowen, W. Westphal, R.J. Lavenberg, and L. Martin. 1984. Aspects of the life history and fishery of the white croaker, *Genyonemus lineatus* (Sciaenidae), off California. Fish. Bull., U. S. 32:179-198.

Love, M.S., C.W. Mecklenburg, T.A. Mecklenburg, and L.K. Thorsteinson. 2005. Resource Inventory of Marine and Estuarine Fishes of the West Coast and Alaska. U. S. Department of the Interior, USGS, Seattle, WA. OCS Study MMS 2005-030.

MBC. See Marine Biological Consultants, Inc. or MBC Applied Environmental Sciences.

Marine Biological Consultants, Inc. 1979. National Pollutant Discharge Elimination System reporting and monitoring program, Mandalay Generating Station winter and summer 1978 surveys. Prepared for Southern California Edison Company, 79-RD-37. April 1979, 53 p. with appendices.

Marine Biological Consultants, Inc. 1981. National Pollutant Discharge Elimination System receiving water monitoring program, Mandalay Generating Station winter and summer 1980 surveys. Prepared for Southern California Edison Company, March 1981 81-RD-20. 50 p. with appendices.

MBC Applied Environmental Sciences. 1986. National Pollutant Discharge Elimination System, 1986 receiving water monitoring report, Mandalay Generating Station, Ventura County, California. Prepared for Southern California Edison Company, SCE Research and Development Ser. 86-RD-58. 40 p. plus appendices.

MBC Applied Environmental Sciences. 1988. National Pollutant Discharge Elimination System, 1988 receiving water monitoring report, Mandalay Generating Station, Ventura County, California. Prepared for Southern California Edison Company, SCE Research and Development Ser. 88-RD-52. 41 p. plus appendices.

MBC Applied Environmental Sciences. 1990. National Pollutant Discharge Elimination System, 1990 receiving water monitoring report, Mandalay Generating Station, Ventura County, California. Prepared for Southern California Edison Company, SCE Research and Development Ser. 90-RD-89. 40 p. plus appendices.

MBC Applied Environmental Sciences. 1994. National Pollutant Discharge Elimination System, 1994 receiving water monitoring report, Mandalay Generating Station, Ventura County, California. Prepared for Southern California Edison Company, SCE Research and Development Ser. 94-RD-010. 46 p. plus appendices.

MBC Applied Environmental Sciences. 1995. National Pollutant Discharge Elimination System 1995 receiving water monitoring report, Los Angeles Region. Prepared for Los Angeles Dept. of Water and Power and Southern California Edison Company. 96-RD-001. 110 p. plus appendices.

MBC Applied Environmental Sciences. 1996. National Pollutant Discharge Elimination System 1996 receiving water monitoring report, Los Angeles Region. Prepared for Los Angeles Dept. of Water and Power and Southern California Edison Company. 97-RD-001. 134 p. plus appendices.

MBC Applied Environmental Sciences. 1997. National Pollutant Discharge Elimination System, 1997 receiving water monitoring report, Mandalay Generating Station, Ventura County, California. Prepared for Southern California Edison Company, SCE Research and Development Ser. 97-EA-01. 45 p. plus appendices.

MBC Applied Environmental Sciences. 1998. National Pollutant Discharge Elimination System, 1998 receiving water monitoring report, Reliant Energy Mandalay Generating Station, Ventura County, California. Prepared for Southern California Edison Company and Reliant Energy. 98-EA-06. 33 p. plus appendices.

MBC Applied Environmental Sciences. 1999. National Pollutant Discharge Elimination System, 1999 receiving water monitoring report, Reliant Energy Mandalay Generating Station, Ventura County, California. Prepared for Southern California Edison Company and Reliant Energy. 99-EA-05. 50 p. plus appendices.

MBC Applied Environmental Sciences. 2000. National Pollutant Discharge Elimination System, 2000 receiving water monitoring report, Reliant Energy Mandalay Generating Station, Ventura County, California. Prepared for Reliant Energy. 54 p. plus appendices.

MBC Applied Environmental Sciences. 2001. National Pollutant Discharge Elimination System, 2001 receiving water monitoring report, Reliant Energy Mandalay Generating Station, Ventura County, California. Prepared for Reliant Energy. 58 p. plus appendices.

MBC Applied Environmental Sciences. 2002. National Pollutant Discharge Elimination System, 2002 receiving water monitoring report, Reliant Energy Mandalay Generating Station, Ventura County, California. Prepared for Reliant Energy. 61 p. plus appendices.

MBC Applied Environmental Sciences. 2003. National Pollutant Discharge Elimination System, 2003 receiving water monitoring report, Reliant Energy Mandalay Generating Station, Ventura County, California. Prepared for Reliant Energy. 53 p. plus appendices.

MBC Applied Environmental Sciences. 2004. National Pollutant Discharge Elimination System, 2004 receiving water monitoring report, Reliant Energy Mandalay Generating Station, Ventura County, California. Prepared for Reliant Energy. 60 p. plus appendices.

MBC Applied Environmental Sciences. 2005. National Pollutant Discharge Elimination System, 2005 receiving water monitoring report, Reliant Energy Mandalay Generating Station, Ventura County, California. Prepared for Reliant Energy. 60 p. plus appendices.

MBC Applied Environmental Sciences. 2006a. National Pollutant Discharge Elimination System, 2006 receiving water monitoring report, Reliant Energy Mandalay Generating Station, Ventura County, California. Prepared for Reliant Energy. 72 p. plus appendices.

MBC Applied Environmental Sciences. 2006b. National Pollutant Discharge Elimination System, 2006 receiving water monitoring report, Haynes and AES Alamitos L.L.C. Generating Station, Los Angeles County, California. Prepared for AES Alamitos L.L.C. and Los Angeles Department of Water and Power. 86 p. plus appendices .

MBC Applied Environmental Sciences. 2007a. National Pollutant Discharge Elimination System, 2007 receiving water monitoring report, Reliant Energy Mandalay Generating Station, Ventura County, California. Prepared for Reliant Energy. 78 p. plus appendices.

MBC Applied Environmental Sciences. 2007b. National Pollutant Discharge Elimination System, 2007 receiving water monitoring report, AES Redondo Beach Generating Station L.L.C., Los Angeles County, California. Prepared for AES Redondo Beach L.L.C. 72 p. plus appendices.

MBC Applied Environmental Sciences. 2007c. National Pollutant Discharge Elimination System, 2007 receiving water monitoring report, Harbor Generating Station, Los Angeles County, California. Prepared for City of Los Angeles Department of Water and Power. 62 p. plus appendices.

MBC Applied Environmental Sciences. 2008a. National Pollutant Discharge Elimination System, 2007 receiving water monitoring report, Reliant Energy Mandalay Generating Station, Ventura County, California. Prepared for Reliant Energy. 78 p. plus appendices.

MBC Applied Environmental Sciences. 2008b. National Pollutant Discharge Elimination System, 2008 receiving water monitoring report, Haynes and AES Alamitos L.L.C. Generating Station, Los Angeles County, California. Prepared for AES Alamitos L.L.C., and Los Angeles Department of Water and Power. 76 p. plus appendices.

MBC Applied Environmental Sciences. 2008c. National Pollutant Discharge Elimination System, 2008 receiving water monitoring report, Long Beach Generating Station, Los Angeles County, California. Long Beach Generation L.L.C. 85 p. plus appendices.

MBC Applied Environmental Sciences. 2008d. National Pollutant Discharge Elimination System, 2008 receiving water monitoring report, AES Redondo Beach Generating Station L.L.C., Los Angeles County, California. Prepared for AES Redondo Beach L.L.C. 76 p. plus appendices.

MBC Applied Environmental Sciences. 2008e. National Pollutant Discharge Elimination System, 2008 receiving water monitoring report, Scattergood and El Segundo Generating Stations, Los Angeles County, California. Prepared for Los Angeles Department of Water and Power, Los Angeles, CA and El Segundo Power L.L.C. 72 p. plus appendices.

MBC Applied Environmental Sciences. 2008f. National Pollutant Discharge Elimination System, 2008 receiving water monitoring report, Huntington Beach Generating Station, Orange County, California. Prepared for AES Huntington Beach L.L.C. 67 p. plus appendices.

MBC Applied Environmental Sciences. 2009a. National Pollutant Discharge Elimination System 2009 receiving water monitoring report, RRI Energy Ormond Beach Generating Station, Ventura County, California. Prepared for Reliant Energy. In prep.

MBC Applied Environmental Sciences. 2009b. National Pollutant Discharge Elimination System, 2009 receiving water monitoring report, AES Redondo Beach Generating Station L.L.C., Los Angeles County, California. Prepared for AES Redondo Beach L.L.C. In prep.

MBC Applied Environmental Sciences. 2009c. National Pollutant Discharge Elimination System, 2009 receiving water monitoring report, Scattergood and El Segundo Generating Stations, Los Angeles County, California. Prepared for Los Angeles Department of Water and Power, Los Angeles, CA and El Segundo Power L.L.C. In prep.

MBC Applied Environmental Sciences. 2009d. National Pollutant Discharge Elimination System, 2009 receiving water monitoring report, Haynes and AES Alamitos L.L.C. Generating Station, Los Angeles County, California. Prepared for AES Alamitos L.L.C. and Los Angeles Department of Water and Power. In prep.

Miller, D.J. and R.N. Lea. 1972. Guide to the coastal marine fishes of California. Calif. Dept. Fish Game Fish Bulletin 157: 235 p.

Miller, E.F., D.J. Pondella, II, D.S. Beck, and K.T. Herbinson. in review. Historic population and recruitment trends of California croakers (Family Sciaenidae) and the effects of overfishing, once through cooling, and oceanography. Fisheries Research.

Moore, S. L. and P. W. Wild. 2001. White Croaker. *In*: Leet, W. S., C. M. Dewees, R. Klingbeil, E. J. Larson (eds.) California's Living Marine Resources: A Status Report. University of California Press, Agriculture and Natural Resources Publication SG01-11. 592 p.

Morris, R.H., D.P. Abbott, and E.C. Haderlie. 1980. Intertidal Invertebrates of California. Stanford Univ. Press.

Moyle, P.B. 2002. Inland fishes of California. Univ. Calif. Press, Los Angeles, CA. 502 p.

National Oceanic and Atmospheric Administration. 1991a. National Status and Trends Program - Second summary of data on chemical contaminants in sediments from the National Status and Trends Program. NOAA Tech. Mem. NOS OMA 59. NOAA Office of Ocean. and Marine Assess., Rockville, MD. 29 p. plus append.

National Oceanic and Atmospheric Administration. 1991b. The potential for biological effects of sediment-sorbed contaminants tested in the National Status and Trends Program. NOAA Tech. Mem. NOS OMA 52, Seattle WA. 175 p. plus appendices.

NOAA. See National Oceanic and Atmospheric Administration.

Noblet, J.A., E.Y. Zeng, R. Baird, R.W. Gossett, R.J. Ozretich, and C.R. Phillips. 2003. Southern California Bight 1998 regional monitoring program: VI. Sediment chemistry. Southern California Coastal Water Research Project, Westminster, CA. 152 p. plus appendices.

Odenweller, D. B. 1975. The life history of the shiner surfperch, *Cymatogaster aggregata* Gibbons, in Anaheim Bay, California. *In*: Lane, E. D. and C. W. Hill (eds.), The Marine Resources of Anaheim Bay, Calif. Dept. Fish Game. Fish. Bull., 165: 195 p.

Ogden Environmental and Energy Services Co. 1991. National Pollutant Discharge Elimination Systems reporting and monitoring program, Mandalay Generating Station, Ventura County, California. Prepared for Southern California Edison Company, Rosemead, CA. 91-RD-29. 46 p. plus appendices.

Ogden Environmental and Energy Services Co. 1992. National Pollutant Discharge Elimination Systems reporting and monitoring program, Mandalay Generating Station, Ventura County, California. Prepared for Southern California Edison Company, Rosemead, CA. 92-RD-13. 49 p. plus appendices.

Ogden Environmental and Energy Services Co. 1993. National Pollutant Discharge Elimination Systems reporting and monitoring program, Mandalay Generating Station, Ventura County, California. Prepared for Southern California Edison Company, Rosemead, CA. 93-RD-11. 51 p. plus appendices.

Oliver, J.S., P.N. Slattery, L.W. Hulberg, and J.W. Nybakken. 1980. Relationships between wave disturbance and zonation of benthic invertebrate communities along a subtidal high-energy beach in Monterey Bay, California. Fish. Bull. 78(2):437-454.

Pielou, E.C. 1977. Mathematical ecology. John Wiley and Sons, New York. 384 p.

Ranasinghe, J.A.,S.B. Weisberg, R.W. Smith, D.E.Montagne, B. Thompson, J.M. Oakden, D.D. Huff, D.B. Cadien, R.G. Velarde, and K.J. Ritter. 2007. Evaluation of five indicators of benthic community condition in two California bay and estuary habitats. Southern California Coastal Water Research Project, Technical Report 524. Westminster, CA. 21 p.

Ryan, C., P. Collier, R.A. Fritzsche, G. Harkleroad, P.D. Lam, S. Kennedy, T. Cady, D. Slama, and M. Farmer. 2003. Surfperches *in* C. Ryan and M. Patyten. Annual Status of the Fisheries Report Through 2003. California Department of Fish and Game. Pgs 13-1 - 13-15.

SCAMIT. See Southern California Association of Marine Invertebrate Taxonomists

SCCWRP. See Southern California Coastal Water Research Project and WEB SITES.

Schiff, K.C. and R.W. Gossett. 1998. Southern California Bight 1994 Pilot Project: III. Sediment chemistry. Southern California Coastal Water Research Project, Westminster, CA.

Schiff, K., K. Maruya, and K. Christensen. 2006. Southern California Bight 2003 Regional Monitoring Program: II. Sediment Chemistry. Southern California Coastal Water Research Project. Westminster, CA.

Shannon, C.H. and W. Weaver. 1962. The Mathematical Theory of Communication. Univ. of Illinois Press, Urbana, IL. 117 p.

Siegfried, C.A. 1989. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Southwest)–crangonid shrimp. U.S. Fish Wildl. Serv. Biol. Rep. 82(11.125). U.S. Army Corps of Engineers, TR EL-82-4. 18 p.

Smith, R.W. 1976. Numerical analysis of ecological survey data. Ph.D. Dissertation. University of Southern California, Department of Biology, Los Angeles, CA. 401 p.

Smith, R., A. Ranasinghe, S. Weisberg, D. Montagne, D. Cadien, T. Mikel, R. Velarde, and A. Dalkey. 2003. Extending the Southern California Benthic Response Index to Assess Benthic Conditions in Bays. Southern California Coastal Water Research Project Technical Report 410. December 2003.

Southern California Association of Marine Invertebrate Taxonomists. 2008. A Taxonomic Listing Macro- and Megainvertebrates from Infaunal and Epibenthic Programs in the Southern California Bight, Edition 5. Southern California Association of Marine Invertebrate Taxonomists. Los Angeles, CA. 210 p.

Southern California Coastal Water Research Project. 1973. The ecology of the Southern California Bight: Implications for water quality management. SCCWRP, El Segundo, CA. SCCWRP TR104. 531 p.

Southern California Coastal Water Research Project. 1986. Contaminant levels in the sea-surface microlayer. Pages 6-8 *in* So. Calif. Coastal Water Res. Proj. - 1986. SCCWRP, Long Beach, CA.

State Water Resources Control Board. 1972. Water quality control plan, ocean waters of California, guidelines for technical reports and monitoring programs. 65 p.

State Water Resources Control Board. 1986. California state mussel watch 1984-85. Water Qual. Mon. Rpt. 86-3WQ. 156 p. plus appendices.

State Water Resources Control Board. 1995. State mussel watch program 1987-93 data report. 94-1WQ. 23 p. plus appendices.

State Water Resources Control Board. 2000. State mussel watch program 1995-1997 data report. 23 p. plus appendices.

Stephens, J.S. Jr., P.A. Morris, D.J. Pondella, T.A. Koonce and G.A. Jordan. 1994. Overview of the dynamics of an urban artificial reef fish assemblage at King Harbor, California, USA, 1974-1991: a recruitment driven system. Bull. Mar. Sci. 55:1224-1239.

Stephens, J.S. Jr. and K.E. Zerba. 1981. Factors affecting fish diversity on a temperate reef. Env. Biol. Fish. 6:111-121.

Sverdrup, H.U., M.W. Johnson, and R.H. Fleming. 1942. The Oceans: Their physics, chemistry, and general biology. Prentice-Hall, Inc., Englewood Cliffs, NY. 1060 p. plus appendices.

SWRCB. See State Water Resources Control Board.

Timko, P.L. 1975. High density aggregation in *Dendraster excentricus* (Eschscholtz): analysis of strategies and benefits concerning growth, age structure, feeding, hydrodynamics and reproduction. Dissertation submitted in partial satisfaction of the requirements for the Doctor of Philosophy in Biology, University of California, Los Angeles.

United States Environmental Protection Agency. 1989. Data evaluation, Chapter 5, section 3.3 *in* Risk assessment guidance for Superfund, EPA Solid waste and emergency response OS-230.

Ware, R.R. 1979. The food habits of white croaker *Genyonemus lineatus* and an infaunal analysis near areas of waste discharge in outer Los Angeles Harbor. M. S. thesis, Calif. State Univ., Long Beach, Long Beach, CA. 113 p.

**PERSONAL COMMUNICATION**

Siekiel-Zdzienicki, B.J. 2009. RRI Energy Mandalay Generating Station.

**WEB SITES**

Southern California Coastal Water Research Project. 2009. http://www.SCCWRP.org/pub/download/DOCUMENTS/Technical Reports/524_eval_benthic_community_indicators.pdf.

Weather Underground. 2009. http://www.wunderground.com

# APPENDIX A

## Receiving water monitoring specifications

## V. RECEIVING WATER MONITORING

### A. Receiving Water

1. Pursuant to the Code of Federal Regulations [40 CFR § 122.41(j) and §122.48(b)], the monitoring program for a discharger receiving a NPDES permit must determine compliance with NPDES permit conditions, and demonstrate that State water quality standards are met.

2. Since compliance monitoring focuses on the effects of point source discharge, it is not designed to assess impacts from other sources of pollution (e.g., nonpoint source runoff, aerial fallout) nor to evaluate the current status of important ecological resources on a regional basis.

### B. Regional Database

1. Several efforts are underway to develop and implement a comprehensive regional monitoring program for the Southern California Bight. These efforts

have the support and participation from regulatory agencies, dischargers, and environmental groups. The goal is to establish a regional program to address public health concerns, monitor trends in natural resources and nearshore habitats, and assess regional impacts from all contaminant sources.

2. Two pilot regional monitoring programs were conducted; one during the summer of 1994 and another in 1998. The purpose of the pilot programs were to test an alternative sampling design that combines elements of compliance monitoring with a broader regional assessment approach. The pilot program was designed by USEPA, the State Board, and three Boards (Los Angeles, Santa Ana, and San Diego) in conjunction with the Southern California Coastal Water Research Project and participating discharger agencies.

   The pilot regional monitoring programs included the following components: microbiology; water quality; sediment chemistry; sediment toxicity testing; benthic infauna; demersal fish; and bioaccumulation.

3. The two pilot regional monitoring programs were funded primarily, by resource exchanges with the participating discharger agencies. During the year when pilot regional monitoring was scheduled, USEPA and this Regional Board eliminated portions of the routine compliance monitoring programs for that year, while retaining certain critical compliance monitoring elements. A certain percentage of the traditional sampling sites were also retained to maintain continuity of the historical record and to allow comparison of different sampling designs. The exchanged resources were redirected to complete sampling within the regional monitoring program design. Thus, the Discharger's overall level of effort for the 1994 and 1998 pilot programs remained approximately the same as the compliance monitoring programs.

4. Given the apparent benefits realized by the first two regional monitoring programs, it is probable that similar comprehensive sampling efforts will be repeated for the California Bight at periodic intervals (perhaps every four or five years). At the present time, it appears likely that the next regional monitoring program will be attempted during the summer of 2002 - 2003.

5. We anticipate that future regional monitoring programs will be funded in a similar manner. Revisions to the routine compliance monitoring program will be made under the discretion of the USEPA and this Regional Board as necessary to accomplish this goal; and may include resource exchanges in the number of parameters to be monitored, the frequency of monitoring, or the number, type, and location of samples collected.

6. The compliance monitoring programs for the Mandalay Generating Station, and other major ocean dischargers will serve as the framework for the regional

monitoring program. However, substantial changes to these programs may be required to fulfill the goals of regional monitoring, while retaining the compliance monitoring component required to evaluate the potential impacts from NPDES discharges. Revisions to the existing program will be made under the discretion of the USEPA and this Regional Board as necessary to accomplish this goal; and may include a reduction or increase in the number of parameters to be monitored, the frequency of monitoring, or the number, type, and location of samples collected.

C. Monitoring for Algicide Spraying

The Discharger periodically sprays the banks of the Mandalay Intake Canal with an algicide to control algal growth in the intake canal. The Discharger shall notify the Regional Board at least two weeks prior to each application of algicide. Water samples shall be collected at a minimum of three locations (Wooley Road, $5^{th}$ Street and Unocal Bridge, or other locations subject to approval by the Executive Officer) and analyzed for total residual oxidant concentrations. The Discharger also shall conduct visual observations of the canal following algicide applications to assess the effectiveness of the spraying program in controlling algal growth and to observe any unusual mortality of fish or invertebrates. The Discharger shall report the results of sample analysis and visual observations, as well as a description of the amounts and locations of all algicide applications, in the appropriate monthly monitoring report to the Regional Board.

D. Receiving Water Monitoring

The receiving water monitoring program shall consist of periodic biological surveys of the area surrounding the discharge, and shall include studies of those physical-chemical characteristics of the receiving water which may be impacted by the discharge.

Location of Sampling Stations (see Attached Figure 1):

1. Receiving water stations in the surf zone shall be located as follows:

   a. Station RW1 - 1180 feet upcoast of the discharge channel.

   b. Station RW2 - 1180 feet downcoast of the discharge channel.

   c. Station RW3 - 2360 feet upcoast of the discharge channel.

   d. Station RW4 - 2360 feet downcoast of the discharge channel.

   e. Station RW5 - At the discharge channel.

2. Receiving water stations offshore of the discharge area shall be located as follows:

    a. Station RW6 - directly offshore of station RW13 at a depth of 30 feet.

    b. Station RW7 - directly offshore of station RW16 at a depth of 30 feet.

    c. Station RW8 – directly offshore of station RW11 at a depth of 30 feet.

    d. Station RW9 – directly offshore of station RW17 at a depth of 30 feet.

    e. Station RW10 – directly offshore of station RW12 at a depth of 30 feet.

    f. Station RW11 – directly offshore of station RW5 at a depth of 20 feet.

    g. Station RW12 – directly offshore of station RW4 at a depth of 20 feet.

    h. Station RW13 – directly offshore of station RW3 at a depth of 20 feet.

    i. Station RW14 – 5,910 feet downcoast of the discharge channel at a depth of 20 feet.

    j. Station RW15 – 5,910 feet upcoast of the discharge channel at a depth of of 20 feet.

    k. Station RW16 – directly offshore of station RW1 at a depth of 20 feet.

    l. Station RW17 – directly offshore of station RW2 at a depth of 20 feet.

3. Benthic stations shall be located as follows:

    a. Station B1 shall be located directly beneath Station RW11.

    b. Station B2 shall be located directly beneath Station RW12.

    c. Station B3 shall be located directly beneath Station RW13.

    d. Station B4 shall be located directly beneath Station RW14.

    e. Station B5 shall be located directly beneath Station RW15.

4. Trawling stations shall be located as follows:

   a. Station T1 – Parallel to the shore at a depth of 20 feet, extending equidistant to either side of Station RW15.

   b. Station T2 – Parallel to the shore at a depth of 20 feet, extending equidistant to either side of Station RW16.

   c. Station T3 – Parallel to the shore at a depth of 20 feet, extending equidistant to either side of Station RW17.

   d. Station T4 – Parallel to the shore at a depth of 20 feet, extending equidistant to either side of Station RW14.

E. Type and Frequency of Sampling:

1. Surface temperatures, dissolved oxygen levels and pH shall be measured semiannually (summer and winter) each year at Stations RW1 through RW5. All stations shall be sampled on both a flooding tide and an ebbing tide during each semiannual survey.

2. Temperature profiles shall be measured semiannually (summer and winter) each year at Stations RW6 through RW17 from surface to bottom at a minimum of one-meter intervals. Dissolved oxygen levels and pH shall be measured semiannually at least at the surface, mid-depth and bottom at each station. All stations shall be sampled on both a flooding tide and an ebbing tide during each semiannual survey.

3. Impingement sampling for fish and commercially important macroinvertebrates shall be conducted at least once every two months at intake Serial No. 002. Impingement sampling shall coincide with heat treatments for at least three of the six sampling events during the year.

   Fish and macroinvertebrates shall be identified to the lowest possible taxon. For each intake point, data reported shall include numerical abundance of each fish and macroinvertebrate species, wet weight of each species (when combined weight of individuals in each species exceeds 0.2 kg), number of individuals in each 1-centimeter size class (based on standard length) for each species and total number of species collected. When large numbers of given species are collected, length/weight data need only be recorded for 50 individuals and total number and total weight may be estimated based on aliquots samples. Total fish impinged per heat treatment or sampling event shall be reported and data shall be expressed per unit volume water entrained.

4. Native California mussels (Mytilus Californianus) shall be collected during the summer from the discharge conduit, as close to the point of discharge as possible, for bioaccumulation monitoring. The mussels shall be collected and analyzed as described in Appendix A of the *California State Mussel Watch Marine Water Quality Monitoring Program 1985-86* (Water Quality Monitoring Report No. 87-2WQ). Mussel tissue shall be analyzed for copper, chromium, nickel, and zinc at a minimum.

5. Sampling by otter trawl shall be conducted semiannually (summer and winter) each year along transects at Stations T1 through T4. Trawls are specialized gear used in large open water areas of reservoirs, lakes, large rivers, estuaries, and offshore marine areas. They are used to gain information on a particular species of fish rather than on overall fish populations. The otter trawl is used to capture near-bottom and bottom fishes.

   a. Trawl net dimensions shall be as follows:

      1. At least a 25 ft throat width.

      2. 1.5 in mesh-size (body).

      3. 0.5 in mesh-size (linear in the cod end).

   b. Two replicate trawls shall be conducted at each station for a duration of 10 minutes each at a uniform speed between 2.0 and 2.5 knots.

   c. The identity, size (standard length), wet weight, and number of fish in each trawl shall be reported. The number of fish affected by abnormal growth or disease, such as fin erosion, lesions, and papillomas, shall be reported. Fish species shall be reported in rank order of abundance and frequency of occurrence for each trawl. The Shannon-Wiener diversity index shall also be computed for each trawl.

   d. All commercially important macroinvertibrates shall be identified, enumerated, and reported in the same manner as fish species.

6. Benthic sampling shall be conducted annually during the summer at Stations B1 through B5.

a. One liter sediment core samples shall be collected by divers at each of the benthic stations for biological examination and determination of biomass and diversity, and for sediment analyses. Four replicates shall be obtained at each station for benthic analyses, and each shall be analyzed separately. A fifth sample shall be taken at each station for sediment analyses and general description.

b. Each benthic replicate sample shall be sieved through a 0.5 mm standard mesh screen. All organisms recovered shall be enumerated an identified to the lowest taxon possible. Infaunal organisms shall be reported as concentrations per liter for each replicate and each station. Total abundance, number of species and Shannon-Weiner diversity indices shall be calculated (using natural logs) for each replicate and each station.

Biomass shall be determined as the wet weight in grams or milligrams retained on a 0.5 millimeter screen per unit volume (e.g., 1 liter) of sediment. Biomass shall be reported for each major taxonomic group (e.g., polychaetes, crustaceans, mollusks) for each replicate and each station.

c. Sediment grain size analyses shall be performed on each sediment sample (sufficiently detailed to calculate percent weight in relation to the size). Sub-samples (upper tow centimeters) shall be taken from each sediment sample and analyzed for copper, chromium, nickel and zinc.

7. The following general observations or measurement at receiving water, benthic and trawl stations shall be reported:

a. Tidal stage, time, and date of monitoring.

b. General water conditions.

c. Color of the water.

d. Appearance of oil films or greases, or floatable materials.

e. Extent of visible turbidity or color patches.

f. Direction of tidal flow.

g. Description of odor, if any, of the receiving water.

h. Depth at each station for each sampling period.

i. Presence or absence of red tide.

j. Presence and activity of marine life.

k. Presence of the California Least Tern and California Brown Pelican.

8. During the discharge of calcareous material (excluding heat treatment discharge) to the receiving waters, the following observations or measurements shall be recorded and reported in the next monitoring report:

a. Date and times of discharge(s).

b. Estimate of volume and weigh of discharge(s).

c. Composition of discharge(s).

d. General water conditions and weather conditions.

e. Appearance and extent of any oil films or grease, floatable material or odors.

f. Appearance and extent of visible turbidity or color patches.

g. Presence of marine life.

h. Presence and activity of the California least tern and the California brown pelican.

Reliant Energy Incorporated
Mandalay Generating Station
Monitoring and Reporting Program No. CI-2093

CA0001180

SUMMARY OF RECEIVING WATER MONITORING PROGRAM

| Constituent | Units | Stations | Type of Sample | Minimum Frequency of Analysis |
|---|---|---|---|---|
| Temperature | °C | RW1-RW5 | surface | semiannually (flood, ebb) |
| Temperature | °C | RW6-RW17 | vertical profile | semiannually (flood, ebb) |
| Dissolved oxygen | mg/L | RW1-RW5 | surface | semiannually (flood, ebb) |
| Dissolved oxygen | mg/L | RW6-RW17 | vertical profile | semiannually (flood, ebb) |
| pH | pH Units | RW1-RW5 | surface | semiannually (flood, ebb) |
| pH | pH Units | RW6-RW17 | vertical profile | semiannually (flood, ebb) |
| Fish and macro Invertebrates | ---- | T1-T4 | trawl | semiannually |
| Fish and macro Invertebrates | ---- | Intake Serial No. 002 | impinge-ment | bimonthly |
| Benthic Infauna | ---- | B1-B5 | grab | annually |
| Sediments | ---- | B1-B5 | grab | annually |
| Mussels | ---- | Discharge Serial No. 001 | tissue | annually |

The receiving water monitoring report containing the results of semiannual and annual monitoring shall be received at the Regional Board on March 1 of each year following the calendar year of data collection.

Reliant Energy Incorporated
Mandalay Generating Station
Monitoring and Reporting Program No. CI-2093

CA0001180

## VI. STORM WATER MONITORING AND REPORTING

The Discharger shall implement the Monitoring and Reporting Requirements for individual dischargers contained in the general permit for *Dischargers of Storm Water Associated with Industrial Activities* (State Board Order No. 97-030-DWQ) adopted on April 17, 1997. The monitoring reports shall be received at the Regional Board by July 1 of each year. Indicate in the report the Compliance File CI-2093.

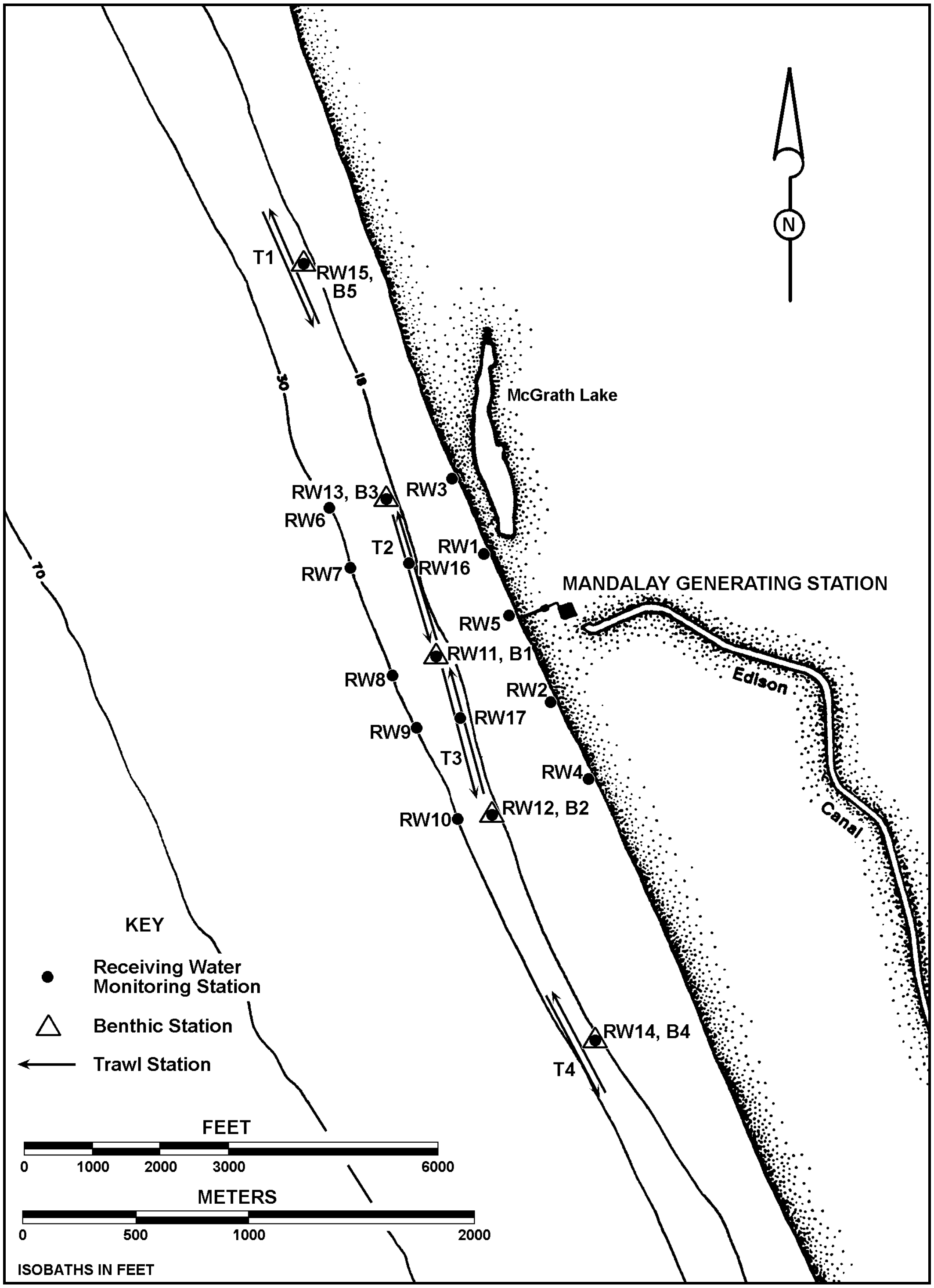
Ordered by: ______________________
Dennis A. Dickinson
Executive Officer

Date: April 26, 2001

/COD

Appendix A. (Cont.).

**Mandalay Generating Station**
**Monitoring and Reporting Program No. CI-2093** **CA0001180**




**Location of the sampling stations. Mandalay Generating Station.**

# APPENDIX B

## Receiving water quality parameters by station

**Appendix B-1. Water quality parameters at each receiving water monitoring station during flood and ebb tides. Mandalay Generating Station NPDES, winter 2009.**

| | | Temp. (°C) | | Oxygen (mg/l) | | pH | | Salinity (psu) | |
|---|---|---|---|---|---|---|---|---|---|
| | Depth (m) | FLOOD | EBB | FLOOD | EBB | FLOOD | EBB | FLOOD | EBB |
| **Surf Zone** | | | | | | | | | |
| RW1 | 0 | 13.09 | 14.52 | 6.37 | 6.34 | 8.04 | 8.17 | 33.5 | 33.5 |
| RW2 | 0 | 14.51 | 14.84 | 6.39 | 6.47 | 8.06 | 8.15 | 33.3 | 33.6 |
| RW3 | 0 | 13.07 | 14.16 | 6.30 | 6.28 | 8.08 | 8.12 | 33.4 | 33.7 |
| RW4 | 0 | 13.03 | 14.57 | 6.36 | 6.37 | 8.07 | 8.14 | 33.4 | 33.5 |
| RW5 | 0 | 16.91 | 17.67 | 7.04 | 6.96 | 7.99 | 8.17 | 32.7 | 33.2 |
| **Offshore** | | | | | | | | | |
| RW6 | 0 | 13.46 | 14.44 | 8.27 | 9.02 | 7.93 | 8.00 | 33.42 | 33.35 |
| | 1 | 13.46 | 14.40 | 8.28 | 9.05 | 7.93 | 8.00 | 33.42 | 33.36 |
| | 2 | 13.48 | 14.10 | 8.28 | 9.09 | 7.93 | 8.00 | 33.42 | 33.39 |
| | 3 | 13.49 | 13.70 | 8.28 | 9.15 | 7.93 | 7.99 | 33.42 | 33.42 |
| | 4 | 13.38 | 13.69 | 8.23 | 9.14 | 7.91 | 8.01 | 33.44 | 33.42 |
| | 5 | 13.20 | 13.66 | 7.95 | 9.26 | 7.89 | 8.01 | 33.46 | 33.42 |
| | 6 | 13.04 | 13.59 | 7.71 | 9.29 | 7.86 | 8.01 | 33.47 | 33.43 |
| | 7 | 12.97 | 13.49 | 7.46 | 9.17 | 7.85 | 8.00 | 33.47 | 33.43 |
| | 8 | 12.77 | 13.41 | 7.37 | 9.00 | 7.83 | 7.98 | 33.49 | 33.43 |
| | 9 | 12.63 | | 7.03 | | 7.80 | | 33.49 | |
| RW7 | 0 | 13.59 | 14.20 | 8.51 | 9.71 | 7.95 | 8.05 | 33.42 | 33.41 |
| | 1 | 13.60 | 14.18 | 8.51 | 9.72 | 7.95 | 8.05 | 33.42 | 33.41 |
| | 2 | 13.61 | 14.10 | 8.52 | 9.68 | 7.95 | 8.04 | 33.42 | 33.42 |
| | 3 | 13.53 | 13.84 | 8.52 | 9.64 | 7.94 | 8.03 | 33.43 | 33.43 |
| | 4 | 13.18 | 13.49 | 8.31 | 9.53 | 7.89 | 7.99 | 33.47 | 33.44 |
| | 5 | 13.12 | 13.23 | 7.73 | 8.88 | 7.87 | 7.94 | 33.46 | 33.46 |
| | 6 | 12.96 | 13.08 | 7.62 | 8.18 | 7.86 | 7.91 | 33.48 | 33.46 |
| | 7 | 12.70 | 13.07 | 7.40 | 7.92 | 7.83 | 7.91 | 33.49 | 33.46 |
| | 8 | 12.61 | 13.08 | 6.98 | 7.85 | 7.80 | 7.90 | 33.49 | 33.45 |
| | 9 | 12.49 | 13.07 | 6.80 | 7.83 | 7.78 | 7.90 | 33.50 | 33.45 |
| | 10 | 12.46 | | 6.61 | | 7.77 | | 33.50 | |
| RW8 | 0 | 13.63 | 14.42 | 8.66 | 8.95 | 7.95 | 8.00 | 33.41 | 33.35 |
| | 1 | 13.65 | 14.07 | 8.65 | 9.12 | 7.95 | 8.01 | 33.41 | 33.40 |
| | 2 | 13.66 | 13.75 | 8.67 | 9.35 | 7.95 | 8.03 | 33.41 | 33.43 |
| | 3 | 13.41 | 13.41 | 8.71 | 9.45 | 7.93 | 8.00 | 33.44 | 33.44 |
| | 4 | 13.11 | 13.23 | 8.24 | 8.94 | 7.87 | 7.96 | 33.47 | 33.44 |
| | 5 | 12.98 | 13.16 | 7.74 | 8.40 | 7.85 | 7.94 | 33.47 | 33.44 |
| | 6 | 12.89 | 13.13 | 7.57 | 8.13 | 7.84 | 7.92 | 33.47 | 33.44 |
| | 7 | 12.59 | 13.12 | 7.36 | 8.00 | 7.81 | 7.92 | 33.49 | 33.45 |
| | 8 | 12.45 | 12.96 | 6.83 | 7.90 | 7.77 | 7.89 | 33.50 | 33.46 |
| | 9 | 12.43 | 12.94 | 6.56 | 7.60 | 7.76 | 7.87 | 33.49 | 33.46 |
| | 10 | 12.46 | | 6.47 | | 7.76 | | 33.49 | |
| RW9 | 0 | 13.74 | 14.47 | 9.15 | 8.78 | 7.98 | 7.97 | 33.41 | 33.32 |
| | 1 | 13.75 | 13.99 | 9.13 | 8.98 | 7.98 | 7.99 | 33.41 | 33.40 |
| | 2 | 13.75 | 13.74 | 9.14 | 9.17 | 7.98 | 8.01 | 33.41 | 33.42 |
| | 3 | 13.75 | 13.56 | 9.16 | 9.18 | 7.98 | 8.00 | 33.41 | 33.43 |
| | 4 | 13.56 | 13.32 | 9.15 | 9.21 | 7.95 | 7.98 | 33.44 | 33.44 |
| | 5 | 13.25 | 13.24 | 8.79 | 8.92 | 7.89 | 7.96 | 33.46 | 33.44 |
| | 6 | 13.11 | 13.07 | 8.18 | 8.49 | 7.87 | 7.93 | 33.46 | 33.46 |
| | 7 | 12.82 | 12.77 | 7.86 | 7.98 | 7.83 | 7.88 | 33.48 | 33.48 |
| | 8 | 12.58 | 12.66 | 7.34 | 7.24 | 7.79 | 7.83 | 33.49 | 33.48 |
| | 9 | 12.46 | 12.62 | 6.88 | 7.04 | 7.77 | 7.83 | 33.49 | 33.48 |

**Appendix B-1. (Cont.).**

| | Depth (m) | Temp. (℃) FLOOD | Temp. (℃) EBB | Oxygen (mg/l) FLOOD | Oxygen (mg/l) EBB | pH FLOOD | pH EBB | Salinity (psu) FLOOD | Salinity (psu) EBB |
|---|---|---|---|---|---|---|---|---|---|
| RW10 | 0 | 13.61 | 13.82 | 8.52 | 9.30 | 7.90 | 8.02 | 33.39 | 33.42 |
| | 1 | 13.65 | 13.72 | 8.51 | 9.32 | 7.90 | 8.02 | 33.38 | 33.43 |
| | 2 | 13.67 | 13.47 | 8.54 | 9.34 | 7.90 | 8.02 | 33.38 | 33.43 |
| | 3 | 13.68 | 13.28 | 8.53 | 9.20 | 7.90 | 7.99 | 33.39 | 33.43 |
| | 4 | 13.56 | 13.27 | 8.55 | 8.82 | 7.90 | 7.97 | 33.42 | 33.43 |
| | 5 | 13.40 | 13.26 | 8.50 | 8.70 | 7.89 | 7.97 | 33.44 | 33.43 |
| | 6 | 13.37 | 13.15 | 8.39 | 8.65 | 7.89 | 7.96 | 33.44 | 33.44 |
| | 7 | 13.21 | 12.90 | 8.36 | 8.03 | 7.87 | 7.91 | 33.45 | 33.47 |
| | 8 | 12.66 | 12.69 | 7.76 | 7.42 | 7.79 | 7.87 | 33.48 | 33.48 |
| | 9 | 12.56 | | 6.92 | | 7.76 | | 33.48 | |
| RW11 | 0 | 13.63 | 14.44 | 8.82 | 9.00 | 7.96 | 7.99 | 33.40 | 33.33 |
| | 1 | 13.65 | 14.31 | 8.83 | 9.05 | 7.96 | 7.99 | 33.40 | 33.34 |
| | 2 | 13.67 | 13.99 | 8.83 | 9.13 | 7.96 | 7.99 | 33.40 | 33.38 |
| | 3 | 13.44 | 13.58 | 8.79 | 9.17 | 7.92 | 8.01 | 33.44 | 33.44 |
| | 4 | 13.24 | 13.41 | 8.28 | 9.13 | 7.89 | 7.98 | 33.45 | 33.44 |
| | 5 | 12.94 | 13.39 | 7.95 | 8.73 | 7.85 | 7.97 | 33.47 | 33.43 |
| | 6 | 12.69 | 13.37 | 7.31 | 8.65 | 7.80 | 7.97 | 33.48 | 33.43 |
| | 7 | 12.72 | | 6.95 | | 7.79 | | 33.47 | |
| RW12 | 0 | 13.57 | 14.46 | 8.42 | 8.59 | 7.90 | 7.96 | 33.38 | 33.30 |
| | 1 | 13.57 | 14.29 | 8.43 | 8.64 | 7.91 | 7.96 | 33.38 | 33.32 |
| | 2 | 13.59 | 13.97 | 8.45 | 8.73 | 7.91 | 7.97 | 33.39 | 33.38 |
| | 3 | 13.61 | 13.73 | 8.49 | 8.87 | 7.91 | 7.99 | 33.40 | 33.43 |
| | 4 | 13.60 | 13.53 | 8.50 | 9.06 | 7.91 | 7.98 | 33.40 | 33.44 |
| | 5 | 13.59 | 13.34 | 8.51 | 8.91 | 7.91 | 7.97 | 33.41 | 33.43 |
| | 6 | 13.38 | 13.32 | 8.54 | 8.79 | 7.90 | 7.97 | 33.44 | 33.43 |
| | 7 | 13.06 | | 8.42 | | 7.86 | | 33.46 | |
| RW13 | 0 | 13.51 | 14.11 | 8.35 | 8.69 | 7.94 | 7.96 | 33.42 | 33.38 |
| | 1 | 13.51 | 14.09 | 8.36 | 8.68 | 7.94 | 7.95 | 33.42 | 33.38 |
| | 2 | 13.51 | 13.93 | 8.37 | 8.63 | 7.94 | 7.93 | 33.42 | 33.39 |
| | 3 | 13.25 | 13.81 | 8.31 | 8.52 | 7.91 | 7.92 | 33.46 | 33.40 |
| | 4 | 13.07 | 13.75 | 7.76 | 8.40 | 7.86 | 7.91 | 33.47 | 33.40 |
| | 5 | 12.83 | 13.74 | 7.43 | 8.32 | 7.84 | 7.91 | 33.48 | 33.39 |
| | 6 | 12.74 | | 7.06 | | 7.81 | | 33.48 | |
| RW14 | 0 | 13.26 | 13.75 | 8.26 | 9.12 | 7.86 | 8.01 | 33.40 | 33.43 |
| | 1 | 13.29 | 13.63 | 8.26 | 9.06 | 7.86 | 8.00 | 33.40 | 33.43 |
| | 2 | 13.31 | 13.48 | 8.28 | 9.02 | 7.86 | 7.99 | 33.40 | 33.44 |
| | 3 | 13.32 | 13.20 | 8.30 | 8.92 | 7.86 | 7.96 | 33.40 | 33.44 |
| | 4 | 13.26 | 13.17 | 8.26 | 8.52 | 7.86 | 7.95 | 33.42 | 33.44 |
| | 5 | 13.00 | 13.00 | 7.99 | 8.38 | 7.82 | 7.94 | 33.45 | 33.47 |
| | 6 | 12.70 | | 7.58 | | 7.78 | | 33.47 | |
| | 7 | 12.63 | | 7.11 | | 7.76 | | 33.47 | |
| RW15 | 0 | 13.50 | 14.20 | 8.21 | 9.53 | 7.94 | 8.03 | 33.42 | 33.39 |
| | 1 | 13.51 | 14.19 | 8.22 | 9.46 | 7.93 | 8.03 | 33.42 | 33.39 |
| | 2 | 13.52 | 14.16 | 8.22 | 9.48 | 7.93 | 8.02 | 33.41 | 33.40 |
| | 3 | 13.51 | 14.04 | 8.24 | 9.43 | 7.93 | 8.01 | 33.41 | 33.41 |
| | 4 | 13.49 | 13.87 | 8.22 | 9.19 | 7.93 | 7.97 | 33.41 | 33.42 |
| | 5 | 13.44 | 13.74 | 8.18 | 8.80 | 7.92 | 7.93 | 33.41 | 33.43 |
| | 6 | 13.40 | 13.31 | 8.12 | 8.65 | 7.91 | 7.91 | 33.43 | 33.47 |

**Appendix B-1. (Cont.).**

| | Depth (m) | Temp. (°C) FLOOD | Temp. (°C) EBB | Oxygen (mg/l) FLOOD | Oxygen (mg/l) EBB | pH FLOOD | pH EBB | Salinity (psu) FLOOD | Salinity (psu) EBB |
|---|---|---|---|---|---|---|---|---|---|
| RW16 | 0 | 13.52 | 14.22 | 8.31 | 9.26 | 7.92 | 8.01 | 33.41 | 33.40 |
| | 1 | 13.50 | 14.17 | 8.28 | 9.27 | 7.91 | 8.01 | 33.42 | 33.39 |
| | 2 | 13.39 | 13.89 | 8.27 | 9.28 | 7.90 | 8.01 | 33.44 | 33.40 |
| | 3 | 13.28 | 13.63 | 8.07 | 9.23 | 7.88 | 8.01 | 33.45 | 33.43 |
| | 4 | 13.06 | 13.45 | 7.88 | 9.25 | 7.87 | 8.00 | 33.47 | 33.44 |
| | 5 | 12.92 | 13.30 | 7.52 | 8.96 | 7.83 | 7.96 | 33.48 | 33.44 |
| | 6 | 12.79 | 13.29 | 7.36 | 8.44 | 7.80 | 7.95 | 33.47 | 33.44 |
| | 7 | | 13.29 | | 8.39 | | 7.95 | | 33.43 |
| RW17 | 0 | 13.79 | 14.16 | 8.77 | 8.75 | 7.94 | 7.97 | 33.38 | 33.35 |
| | 1 | 13.77 | 14.17 | 8.87 | 8.74 | 7.95 | 7.97 | 33.39 | 33.35 |
| | 2 | 13.75 | 13.87 | 8.97 | 8.79 | 7.97 | 7.97 | 33.41 | 33.39 |
| | 3 | 13.62 | 13.54 | 9.05 | 8.83 | 7.94 | 7.99 | 33.43 | 33.43 |
| | 4 | 13.40 | 13.30 | 8.67 | 8.95 | 7.91 | 7.97 | 33.44 | 33.44 |
| | 5 | 13.22 | 13.22 | 8.31 | 8.70 | 7.88 | 7.96 | 33.45 | 33.44 |
| | 6 | 12.97 | 12.96 | 8.05 | 8.35 | 7.85 | 7.89 | 33.47 | 33.46 |
| | 7 | 12.66 | | 7.46 | | 7.79 | | 33.48 | |

**Appendix B-2. Water quality parameters at each receiving water monitoring station during flood and ebb tides. Mandalay Generating Station NPDES, summer 2009.**

| | | Temp. (℃) | | Oxygen (mg/l) | | pH | | Salinity (psu) | |
|---|---|---|---|---|---|---|---|---|---|
| | Depth (m) | FLOOD | EBB | FLOOD | EBB | FLOOD | EBB | FLOOD | EBB |
| **Surf Zone** | | | | | | | | | |
| RW1 | 0 | 15.56 | 17.85 | 7.13 | 6.96 | 8.05 | 8.14 | 33.7 | 33.7 |
| RW2 | 0 | 17.00 | 18.42 | 6.74 | 6.69 | 7.99 | 8.08 | 33.6 | 33.7 |
| RW3 | 0 | 15.50 | 18.27 | 7.10 | 6.86 | 7.98 | 8.11 | 33.7 | 33.6 |
| RW4 | 0 | 16.86 | 18.74 | 6.87 | 6.81 | 8.01 | 8.07 | 33.6 | 33.7 |
| RW5 | 0 | 16.88 | 19.21 | 7.06 | 8.17 | 7.96 | 8.04 | 33.7 | 33.7 |
| **Offshore** | | | | | | | | | |
| RW6 | 0 | 15.86 | 16.73 | 7.31 | 8.00 | 7.88 | 7.93 | 33.46 | 33.49 |
| | 1 | 15.91 | 16.71 | 7.30 | 8.01 | 7.88 | 7.93 | 33.45 | 33.49 |
| | 2 | 15.68 | 16.70 | 7.33 | 8.01 | 7.88 | 7.93 | 33.48 | 33.49 |
| | 3 | 14.99 | 16.20 | 7.37 | 8.06 | 7.87 | 7.93 | 33.52 | 33.50 |
| | 4 | 14.81 | 15.64 | 7.27 | 8.06 | 7.88 | 7.92 | 33.52 | 33.51 |
| | 5 | 14.71 | 14.67 | 7.36 | 8.05 | 7.88 | 7.91 | 33.52 | 33.52 |
| | 6 | 14.55 | 14.42 | 7.32 | 7.82 | 7.87 | 7.89 | 33.51 | 33.51 |
| | 7 | 14.30 | 14.37 | 7.34 | 7.62 | 7.86 | 7.88 | 33.51 | 33.51 |
| | 8 | 14.11 | 14.31 | 7.28 | 7.56 | 7.86 | 7.88 | 33.51 | 33.50 |
| | 9 | 14.10 | 14.29 | 7.22 | 7.51 | 7.85 | 7.88 | 33.51 | 33.50 |
| | 10 | 14.11 | 14.30 | 7.20 | 7.48 | 7.85 | 7.88 | 33.51 | 33.49 |
| RW7 | 0 | 15.98 | 16.66 | 7.45 | 7.95 | 7.88 | 7.93 | 33.45 | 33.49 |
| | 1 | 15.99 | 16.65 | 7.44 | 7.95 | 7.88 | 7.93 | 33.45 | 33.49 |
| | 2 | 15.67 | 16.58 | 7.48 | 7.95 | 7.87 | 7.93 | 33.49 | 33.50 |
| | 3 | 15.11 | 16.14 | 7.50 | 7.99 | 7.88 | 7.92 | 33.52 | 33.50 |
| | 4 | 14.99 | 15.20 | 7.55 | 8.02 | 7.88 | 7.91 | 33.52 | 33.50 |
| | 5 | 14.65 | 14.54 | 7.58 | 7.93 | 7.88 | 7.89 | 33.52 | 33.52 |
| | 6 | 14.37 | 14.31 | 7.58 | 7.68 | 7.87 | 7.88 | 33.52 | 33.51 |
| | 7 | 14.19 | 14.32 | 7.45 | 7.51 | 7.85 | 7.88 | 33.51 | 33.50 |
| | 8 | 14.23 | 14.33 | 7.30 | 7.48 | 7.85 | 7.87 | 33.51 | 33.50 |
| | 9 | 14.19 | 14.34 | 7.32 | 7.46 | 7.85 | 7.87 | 33.51 | 33.49 |
| RW8 | 0 | 16.22 | 16.63 | 7.24 | 7.92 | 7.86 | 7.93 | 33.42 | 33.49 |
| | 1 | 16.22 | 16.64 | 7.23 | 7.92 | 7.86 | 7.93 | 33.42 | 33.49 |
| | 2 | 16.10 | 16.62 | 7.23 | 7.92 | 7.87 | 7.92 | 33.46 | 33.49 |
| | 3 | 15.77 | 16.05 | 7.44 | 7.97 | 7.90 | 7.92 | 33.52 | 33.50 |
| | 4 | 15.55 | 14.64 | 7.75 | 8.05 | 7.90 | 7.90 | 33.52 | 33.52 |
| | 5 | 15.10 | 14.25 | 7.77 | 7.80 | 7.90 | 7.88 | 33.53 | 33.51 |
| | 6 | 14.69 | 14.22 | 7.76 | 7.57 | 7.89 | 7.87 | 33.52 | 33.50 |
| | 7 | 14.48 | 14.21 | 7.64 | 7.48 | 7.88 | 7.87 | 33.52 | 33.50 |
| | 8 | 14.18 | 14.19 | 7.60 | 7.43 | 7.86 | 7.87 | 33.51 | 33.50 |
| | 9 | 14.25 | 14.17 | 7.41 | 7.42 | 7.86 | 7.87 | 33.51 | 33.49 |
| | 10 | 14.17 | 14.19 | 7.42 | 7.39 | 7.86 | 7.87 | 33.51 | 33.49 |
| RW9 | 0 | 16.51 | 16.65 | 7.35 | 7.89 | 7.84 | 7.92 | 33.36 | 33.50 |
| | 1 | 16.55 | 16.66 | 7.35 | 7.89 | 7.84 | 7.92 | 33.33 | 33.50 |
| | 2 | 16.35 | 16.60 | 7.38 | 7.88 | 7.86 | 7.92 | 33.42 | 33.50 |
| | 3 | 15.72 | 16.36 | 7.55 | 7.91 | 7.90 | 7.92 | 33.53 | 33.50 |
| | 4 | 15.41 | 15.53 | 7.91 | 7.97 | 7.91 | 7.91 | 33.53 | 33.50 |
| | 5 | 15.00 | 14.58 | 7.91 | 7.91 | 7.90 | 7.89 | 33.53 | 33.51 |
| | 6 | 14.88 | 14.34 | 7.83 | 7.65 | 7.89 | 7.88 | 33.53 | 33.50 |
| | 7 | 14.48 | 14.24 | 7.80 | 7.53 | 7.88 | 7.88 | 33.52 | 33.49 |
| | 8 | 14.45 | 14.27 | 7.61 | 7.49 | 7.86 | 7.88 | 33.51 | 33.50 |
| | 9 | 14.44 | 14.21 | 7.55 | 7.50 | 7.86 | 7.87 | 33.51 | 33.49 |

**Appendix B-2. (Cont.).**

| | Depth (m) | Temp. (℃) FLOOD | Temp. (℃) EBB | Oxygen (mg/l) FLOOD | Oxygen (mg/l) EBB | pH FLOOD | pH EBB | Salinity (psu) FLOOD | Salinity (psu) EBB |
|---|---|---|---|---|---|---|---|---|---|
| RW10 | 0 | 16.27 | 16.69 | 7.48 | 7.85 | 7.88 | 7.92 | 33.45 | 33.50 |
| | 1 | 16.26 | 16.69 | 7.46 | 7.84 | 7.88 | 7.92 | 33.46 | 33.50 |
| | 2 | 16.22 | 16.61 | 7.49 | 7.86 | 7.89 | 7.92 | 33.48 | 33.50 |
| | 3 | 16.07 | 16.33 | 7.63 | 7.89 | 7.91 | 7.92 | 33.52 | 33.50 |
| | 4 | 15.56 | 15.83 | 7.98 | 7.96 | 7.92 | 7.92 | 33.53 | 33.51 |
| | 5 | 15.29 | 14.96 | 8.07 | 8.05 | 7.92 | 7.90 | 33.53 | 33.54 |
| | 6 | 15.21 | 14.26 | 7.94 | 7.82 | 7.90 | 7.88 | 33.53 | 33.51 |
| | 7 | 14.72 | 14.21 | 7.98 | 7.53 | 7.90 | 7.87 | 33.52 | 33.50 |
| | 8 | 14.67 | 14.20 | 7.80 | 7.46 | 7.89 | 7.87 | 33.52 | 33.50 |
| | 9 | 14.43 | 14.18 | 7.74 | 7.42 | 7.88 | 7.87 | 33.51 | 33.49 |
| | 10 | 14.44 | | 7.57 | | 7.87 | | 33.51 | |
| RW11 | 0 | 16.18 | 16.74 | 7.43 | 7.92 | 7.87 | 7.92 | 33.44 | 33.46 |
| | 1 | 15.98 | 16.73 | 7.48 | 7.92 | 7.87 | 7.92 | 33.48 | 33.46 |
| | 2 | 15.72 | 16.69 | 7.64 | 7.92 | 7.89 | 7.92 | 33.51 | 33.46 |
| | 3 | 15.32 | 16.35 | 7.71 | 7.95 | 7.88 | 7.92 | 33.52 | 33.47 |
| | 4 | 14.99 | 15.04 | 7.63 | 8.06 | 7.88 | 7.91 | 33.52 | 33.51 |
| | 5 | 14.91 | 14.62 | 7.62 | 7.83 | 7.88 | 7.89 | 33.52 | 33.51 |
| | 6 | 14.94 | 14.79 | 7.52 | 7.63 | 7.87 | 7.89 | 33.51 | 33.49 |
| RW12 | 0 | 16.08 | 16.64 | 7.54 | 7.82 | 7.87 | 7.92 | 33.46 | 33.50 |
| | 1 | 16.06 | 16.65 | 7.52 | 7.79 | 7.87 | 7.92 | 33.48 | 33.50 |
| | 2 | 15.84 | 16.62 | 7.65 | 7.81 | 7.89 | 7.92 | 33.50 | 33.50 |
| | 3 | 15.44 | 16.47 | 7.75 | 7.84 | 7.89 | 7.92 | 33.52 | 33.49 |
| | 4 | 15.00 | 16.21 | 7.79 | 7.90 | 7.88 | 7.92 | 33.52 | 33.48 |
| | 5 | 14.88 | 15.91 | 7.68 | 7.97 | 7.88 | 7.92 | 33.52 | 33.48 |
| | 6 | 14.90 | 15.61 | 7.64 | 8.01 | 7.87 | 7.92 | 33.51 | 33.50 |
| RW13 | 0 | 15.54 | 16.76 | 7.32 | 7.94 | 7.86 | 7.93 | 33.48 | 33.49 |
| | 1 | 15.54 | 16.74 | 7.32 | 7.93 | 7.86 | 7.93 | 33.48 | 33.49 |
| | 2 | 15.52 | 16.74 | 7.29 | 7.93 | 7.86 | 7.93 | 33.48 | 33.48 |
| | 3 | 15.47 | 16.50 | 7.26 | 7.95 | 7.85 | 7.93 | 33.48 | 33.48 |
| | 4 | 15.11 | 15.16 | 7.25 | 8.07 | 7.85 | 7.92 | 33.51 | 33.52 |
| | 5 | 14.83 | 14.91 | 7.11 | 7.86 | 7.84 | 7.91 | 33.52 | 33.52 |
| | 6 | 14.77 | 14.86 | 7.12 | 7.78 | 7.86 | 7.91 | 33.52 | 33.51 |
| | 7 | 14.73 | 14.85 | 7.17 | 7.74 | 7.85 | 7.90 | 33.51 | 33.51 |
| RW14 | 0 | 16.35 | 16.33 | 7.49 | 7.75 | 7.87 | 7.92 | 33.45 | 33.50 |
| | 1 | 16.34 | 16.33 | 7.49 | 7.73 | 7.87 | 7.92 | 33.45 | 33.50 |
| | 2 | 16.19 | 16.32 | 7.56 | 7.74 | 7.89 | 7.92 | 33.49 | 33.50 |
| | 3 | 15.91 | 16.25 | 7.90 | 7.76 | 7.93 | 7.91 | 33.53 | 33.50 |
| | 4 | 15.62 | 16.07 | 8.18 | 7.76 | 7.91 | 7.91 | 33.52 | 33.50 |
| | 5 | 15.50 | 15.05 | 7.89 | 7.87 | 7.89 | 7.90 | 33.52 | 33.49 |
| | 6 | 15.33 | 15.37 | 7.86 | 7.64 | 7.89 | 7.89 | 33.52 | 33.49 |
| RW15 | 0 | 15.48 | 16.93 | 7.43 | 8.22 | 7.86 | 7.96 | 33.38 | 33.50 |
| | 1 | 15.48 | 16.95 | 7.41 | 8.20 | 7.86 | 7.96 | 33.37 | 33.50 |
| | 2 | 15.37 | 16.94 | 7.33 | 8.20 | 7.85 | 7.96 | 33.43 | 33.50 |
| | 3 | 14.96 | 16.70 | 7.07 | 8.25 | 7.84 | 7.95 | 33.50 | 33.51 |
| | 4 | 14.65 | 16.25 | 7.04 | 8.22 | 7.85 | 7.94 | 33.53 | 33.51 |
| | 5 | 14.58 | 15.27 | 7.02 | 8.19 | 7.85 | 7.92 | 33.53 | 33.53 |
| | 6 | 14.47 | 14.93 | 6.97 | 7.93 | 7.83 | 7.90 | 33.52 | 33.53 |
| | 7 | | 14.92 | | 7.77 | | 7.90 | | 33.52 |

**Appendix B-2. (Cont.).**

| | Depth (m) | Temp. (℃) FLOOD | Temp. (℃) EBB | Oxygen (mg/l) FLOOD | Oxygen (mg/l) EBB | pH FLOOD | pH EBB | Salinity (psu) FLOOD | Salinity (psu) EBB |
|---|---|---|---|---|---|---|---|---|---|
| RW16 | 0 | 15.67 | 16.65 | 7.54 | 7.90 | 7.88 | 7.93 | 33.47 | 33.49 |
| | 1 | 15.60 | 16.61 | 7.53 | 7.90 | 7.88 | 7.93 | 33.49 | 33.49 |
| | 2 | 15.45 | 16.63 | 7.57 | 7.90 | 7.89 | 7.93 | 33.51 | 33.49 |
| | 3 | 15.10 | 16.51 | 7.59 | 7.95 | 7.89 | 7.93 | 33.52 | 33.49 |
| | 4 | 14.86 | 16.17 | 7.54 | 7.94 | 7.89 | 7.92 | 33.52 | 33.49 |
| | 5 | 14.85 | 14.97 | 7.52 | 8.03 | 7.89 | 7.92 | 33.52 | 33.52 |
| | 6 | 14.85 | 14.72 | 7.51 | 7.83 | 7.88 | 7.90 | 33.51 | 33.52 |
| | 7 | | 14.57 | | 7.67 | | 7.89 | | 33.51 |
| RW17 | 0 | 16.13 | 16.59 | 7.55 | 7.91 | 7.86 | 7.92 | 33.41 | 33.48 |
| | 1 | 16.14 | 16.60 | 7.52 | 7.90 | 7.86 | 7.92 | 33.41 | 33.48 |
| | 2 | 15.77 | 16.62 | 7.61 | 7.90 | 7.88 | 7.92 | 33.48 | 33.49 |
| | 3 | 15.39 | 16.56 | 7.69 | 7.91 | 7.89 | 7.92 | 33.52 | 33.48 |
| | 4 | 15.05 | 16.07 | 7.73 | 7.96 | 7.88 | 7.91 | 33.52 | 33.49 |
| | 5 | 14.80 | 14.54 | 7.65 | 8.04 | 7.88 | 7.89 | 33.52 | 33.52 |
| | 6 | 14.74 | | 7.62 | | 7.88 | | 33.52 | |

# APPENDIX C

## Sediment grain size techniques and statistical parameters by station

**Appendix C-1. Grain size techniques.**

Sediment Grain Size Analysis

Analysis of sediment samples for size distribution characteristics are performed using two techniques. Sediments in the gravel size range (> 2.0 mm in diameter) are analyzed using a series of standard sieves having screen openings of 0.5 phi increments (diameter in phi units = $-\log_2$ diameter in mm, or = -ln diameter in mm ÷ ln 2). The sand-silt-clay fraction of sediments [-1 phi through 4 phi (2.0 mm through 0.0625 mm) for sand], [4 phi through 8 phi (0.0625 mm through 0.004 mm) for silt, 8 phi and greater for clay (0.0039 mm and smaller)] is analyzed by laser light diffraction. The sample is suspended in a suspension column and continuously circulated through the laser beam. The laser beam passes through the sample where the suspended particles scatter incident light. Fourier optics collect diffracted light and focus it on to three sets of detectors. A composite, time-averaged diffraction pattern is measured by 126 detectors. Sizes are computed and summed into normal distribution classifications.

Laboratory data from the two methods are mathematically combined and entered into a computer program which calculates and prints size-distribution characteristics and plots both interval and cumulative frequency distribution curves.

Analysis of the plotted cumulative size frequency curves is performed as described by Inman (1952). The median, 5th, 16th, 84th, and 95th percentiles (converted to phi notation) of the sediment distribution curve is used to calculate mean grain size diameter, sorting coefficient, and measures of skewness and kurtosis. Where sediment distribution coincides with a normal distribution curve, the 16th and 84th percentiles represent diameters one standard deviation on either side of the mean. The following formulas are used in the calculations:

1. Mean Diameter ($M_\phi$) is the average particle size in the central 68% of the distribution.

$$M_\phi = (\phi_{16} + \phi_{50} + \phi_{84}) \ / \ 3$$

2. Sorting ($\sigma_\phi$) measures the uniformity (or non-uniformity) of particle quantities in each size category of the sediment distribution. A $\sigma_\phi$ value under 0.35ϕ indicates that particles are very well sorted (i.e. sediments are primarily composed of a narrow range of size classes, or a single size class), while a value of over 4.0ϕ indicates that the sediments are extremely poorly sorted, or evenly distributed among size classes.

$$\sigma_\phi = \frac{\phi_{84} - \phi_{16}}{4} + \frac{\phi_{95} - \phi_5}{6.6}$$

3. Skewness ($\alpha_\phi$) is a measure of the direction and extent of departure of the mean from the median (in a normal or symmetrical curve they coincide). In symmetrical curves, $\alpha_\phi$=0.00 with limits of -1.00 and +1.00. Negative values indicate the particle distribution is skewed toward larger particle diameters, while positive values indicate the distribution is skewed toward smaller particle diameters.

$$\alpha_\phi = \frac{\phi_{16} + \phi_{84} - 2\phi_{50}}{2(\phi_{84} - \phi_{16})} + \frac{\phi_5 + \phi_{95} - 2\phi_{50}}{2(\phi_{95} - \phi_5)}$$

4. Kurtosis ($\beta_\phi$) is a measure of how far the sediment distribution curve departs from a normal Gaussian shape at its peak. Curves with greater than normal amounts of sediment at their modes will be sharp or leptokurtic ($\beta_\phi$ > 1). Those with fatter tails and lower peaks than expected are termed platykurtic ($\beta_\phi$ < 1). $\beta_\phi$ = 1.00 for a normal curve. Curve category interpretations are based on Folk (1974).

$$\beta_\phi = \frac{\phi_{95} - \phi_5}{2.44(\phi_{75} - \phi_{25})}$$

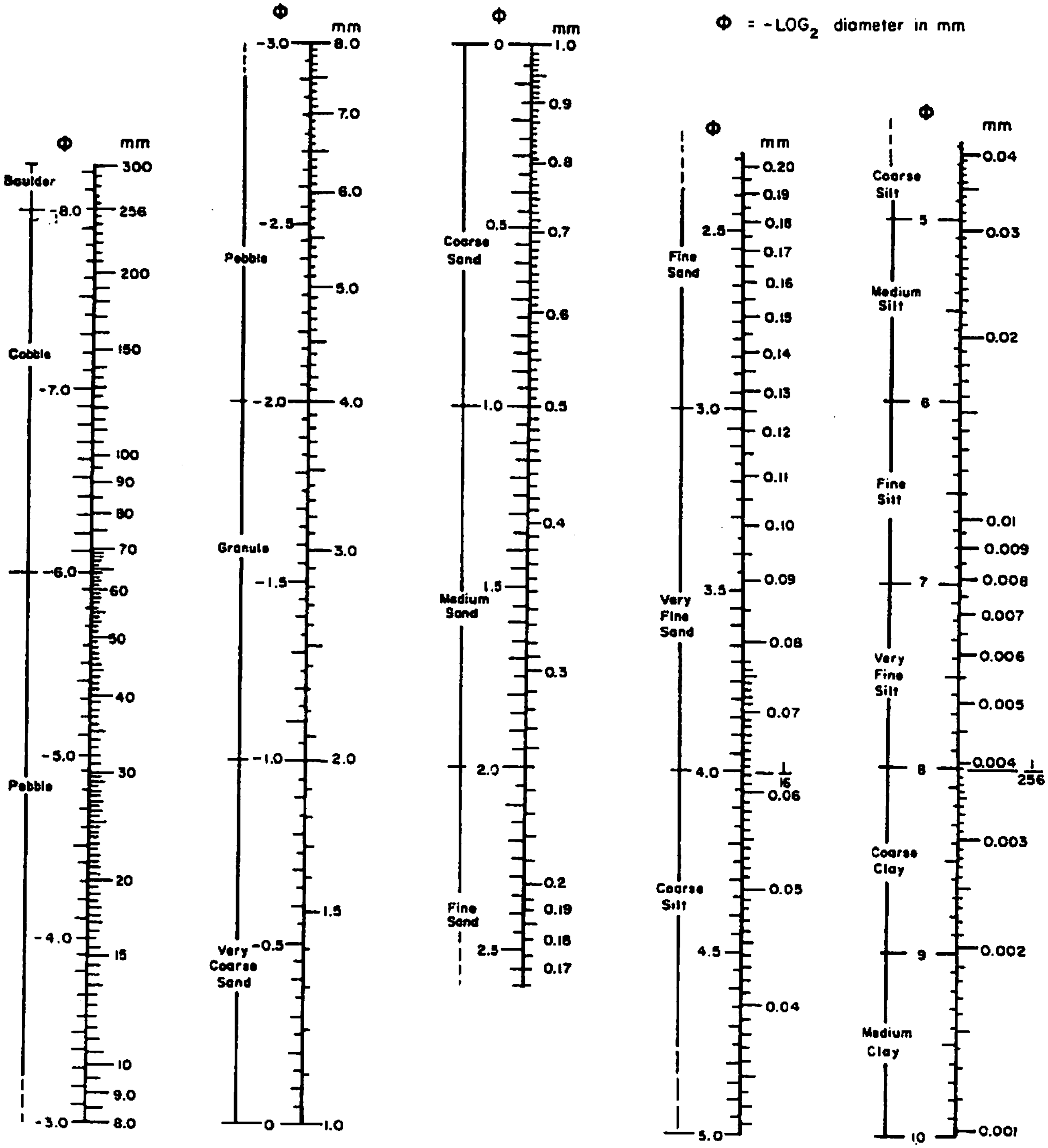
LITERATURE CITED

Folk, R. L. 1974. Petrology of sedimentary rocks. Hemphill Publishing Co., Austin, TX. 182 p.

Inman, D. L. 1952. Measures for describing the size distribution of sediments. J. Sed. Pet. 22:125-145.

Appendix C-1. (Cont.).

**Phi - Millimeter Conversion Figure**




Measurement sorting values for a large number of sediments has suggested the following verbal classification scale for sorting:

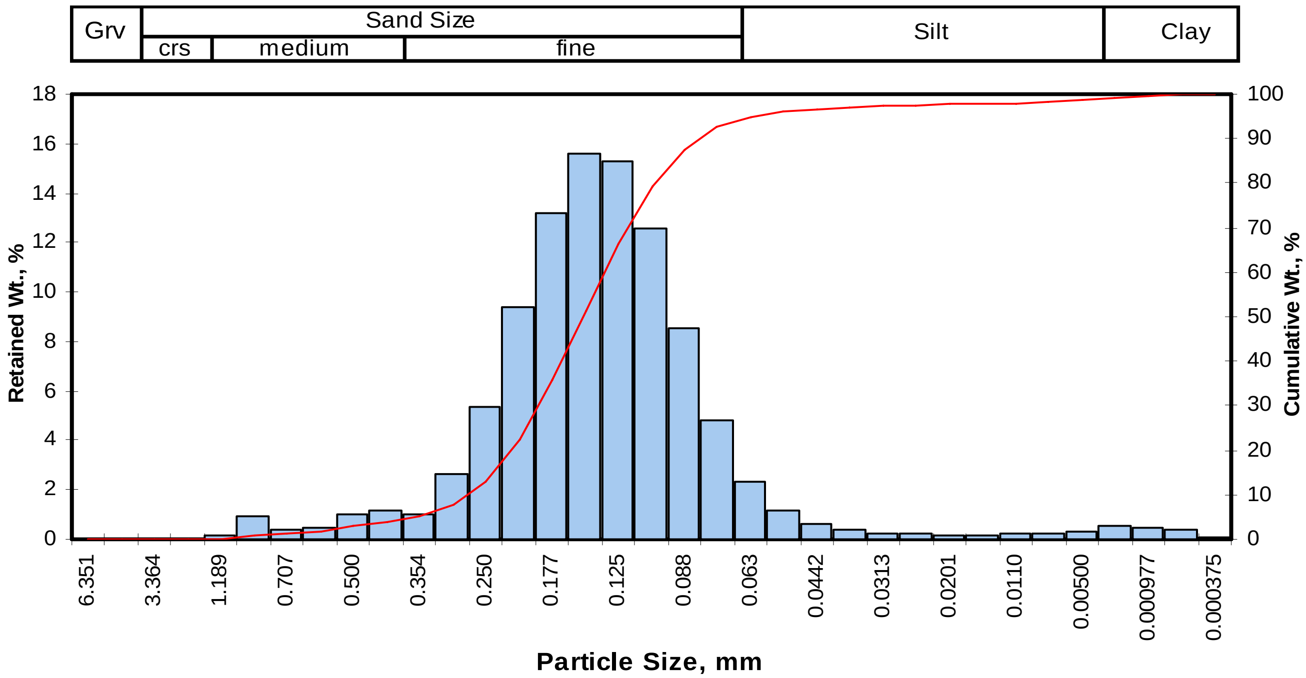
| | | |
|---|---|---|
| $\sigma_I$ under | .35 φ. | very well sorted |
| | .35-.50 φ. | well sorted |
| | .50-.71 φ. | moderately well sorted |
| | .71-1.0 φ | moderately sorted |
| | 1.0-2.0 φ. | poorly sorted |
| | 2.0-4.0 φ. | very poorly sorted |
| | over 4.0 φ. | extremely poorly sorted |

Appendix C-2. Sediment grain size distribution and statistical parameters by station. Mandalay Generating Station NPDES, 2009.

**PTS** Laboratories, Inc.

**Particle Size Analysis - ASTM D4464M**

| | | | |
|---|---|---|---|
| **Client:** | Calscience | **PTS File No:** | 39723 |
| **Project:** | N/A | **Sample ID:** | MGS B1 |
| **Project No:** | 09-08-2258 | **Depth, ft:** | N/A |




| Opening Inches | Opening Millimeters | Phi of Screen | U.S. No. | Sample Weight, grams | Increment Weight, percent | Cumulative Weight, percent |
|---|---|---|---|---|---|---|
| 0.2500 | 6.351 | -2.67 | 1/4 | 0.00 | 0.00 | 0.00 |
| 0.1873 | 4.757 | -2.25 | 4 | 0.00 | 0.00 | 0.00 |
| 0.1324 | 3.364 | -1.75 | 6 | 0.00 | 0.00 | 0.00 |
| 0.0787 | 2.000 | -1.00 | 10 | 0.00 | 0.00 | 0.00 |
| 0.0468 | 1.189 | -0.25 | 16 | 0.12 | 0.12 | 0.12 |
| 0.0331 | 0.841 | 0.25 | 20 | 0.90 | 0.90 | 1.02 |
| 0.0278 | 0.707 | 0.50 | 25 | 0.41 | 0.41 | 1.43 |
| 0.0234 | 0.595 | 0.75 | 30 | 0.48 | 0.48 | 1.91 |
| 0.0197 | 0.500 | 1.00 | 35 | 1.00 | 1.00 | 2.91 |
| 0.0166 | 0.420 | 1.25 | 40 | 1.17 | 1.17 | 4.08 |
| 0.0139 | 0.354 | 1.50 | 45 | 0.97 | 0.97 | 5.05 |
| 0.0117 | 0.297 | 1.75 | 50 | 2.62 | 2.62 | 7.67 |
| 0.0098 | 0.250 | 2.00 | 60 | 5.36 | 5.36 | 13.03 |
| 0.0083 | 0.210 | 2.25 | 70 | 9.41 | 9.41 | 22.44 |
| 0.0070 | 0.177 | 2.50 | 80 | 13.20 | 13.20 | 35.64 |
| 0.0059 | 0.149 | 2.75 | 100 | 15.60 | 15.60 | 51.24 |
| 0.0049 | 0.125 | 3.00 | 120 | 15.30 | 15.30 | 66.55 |
| 0.0041 | 0.105 | 3.25 | 140 | 12.60 | 12.60 | 79.15 |
| 0.0035 | 0.088 | 3.50 | 170 | 8.54 | 8.54 | 87.69 |
| 0.0029 | 0.074 | 3.75 | 200 | 4.80 | 4.80 | 92.49 |
| 0.0025 | 0.063 | 4.00 | 230 | 2.36 | 2.36 | 94.85 |
| 0.0021 | 0.053 | 4.25 | 270 | 1.16 | 1.16 | 96.01 |
| 0.00174 | 0.0442 | 4.50 | 325 | 0.62 | 0.62 | 96.63 |
| 0.00146 | 0.0372 | 4.75 | 400 | 0.37 | 0.37 | 97.00 |
| 0.00123 | 0.0313 | 5.00 | 450 | 0.24 | 0.24 | 97.24 |
| 0.000986 | 0.0250 | 5.32 | 500 | 0.23 | 0.23 | 97.47 |
| 0.000790 | 0.0201 | 5.64 | 635 | 0.18 | 0.18 | 97.65 |
| 0.000615 | 0.0156 | 6.00 | | 0.18 | 0.18 | 97.83 |
| 0.000435 | 0.0110 | 6.50 | | 0.22 | 0.22 | 98.05 |
| 0.000308 | 0.00781 | 7.00 | | 0.22 | 0.22 | 98.27 |
| 0.000197 | 0.00500 | 7.65 | | 0.28 | 0.28 | 98.55 |
| 0.000077 | 0.00195 | 9.00 | | 0.55 | 0.55 | 99.10 |
| 0.000038 | 0.000977 | 10.00 | | 0.47 | 0.47 | 99.57 |
| 0.000019 | 0.000488 | 11.00 | | 0.39 | 0.39 | 99.96 |
| 0.000015 | 0.000375 | 11.38 | | 0.04 | 0.04 | 100.00 |
| **TOTALS** | | | | **100.00** | **100.00** | **100.00** |

| Cumulative Weight Percent greater than | | | |
|---|---|---|---|
| **Weight percent** | **Phi Value** | **Particle Size Inches** | **Particle Size Millimeters** |
| 5 | 1.49 | 0.0140 | 0.357 |
| 10 | 1.86 | 0.0109 | 0.276 |
| 16 | 2.08 | 0.0093 | 0.237 |
| 25 | 2.30 | 0.0080 | 0.203 |
| 40 | 2.57 | 0.0066 | 0.168 |
| 50 | 2.73 | 0.0059 | 0.151 |
| 60 | 2.89 | 0.0053 | 0.135 |
| 75 | 3.17 | 0.0044 | 0.111 |
| 84 | 3.39 | 0.0038 | 0.095 |
| 90 | 3.62 | 0.0032 | 0.081 |
| 95 | 4.03 | 0.0024 | 0.061 |

| Measure | Trask | Inman | Folk-Ward |
|---|---|---|---|
| Median, phi | 2.73 | 2.73 | 2.73 |
| Median, in. | 0.0059 | 0.0059 | 0.0059 |
| Median, mm | 0.151 | 0.151 | 0.151 |
| Mean, phi | 2.67 | 2.74 | 2.73 |
| Mean, in. | 0.0062 | 0.0059 | 0.0059 |
| Mean, mm | 0.157 | 0.150 | 0.150 |
| Sorting | 1.352 | 0.657 | 0.714 |
| Skewness | 0.998 | 0.008 | 0.016 |
| Kurtosis | 0.237 | 0.939 | 1.200 |
| **Grain Size Description** (ASTM-USCS Scale) | Fine sand (based on Mean from Trask) | | |

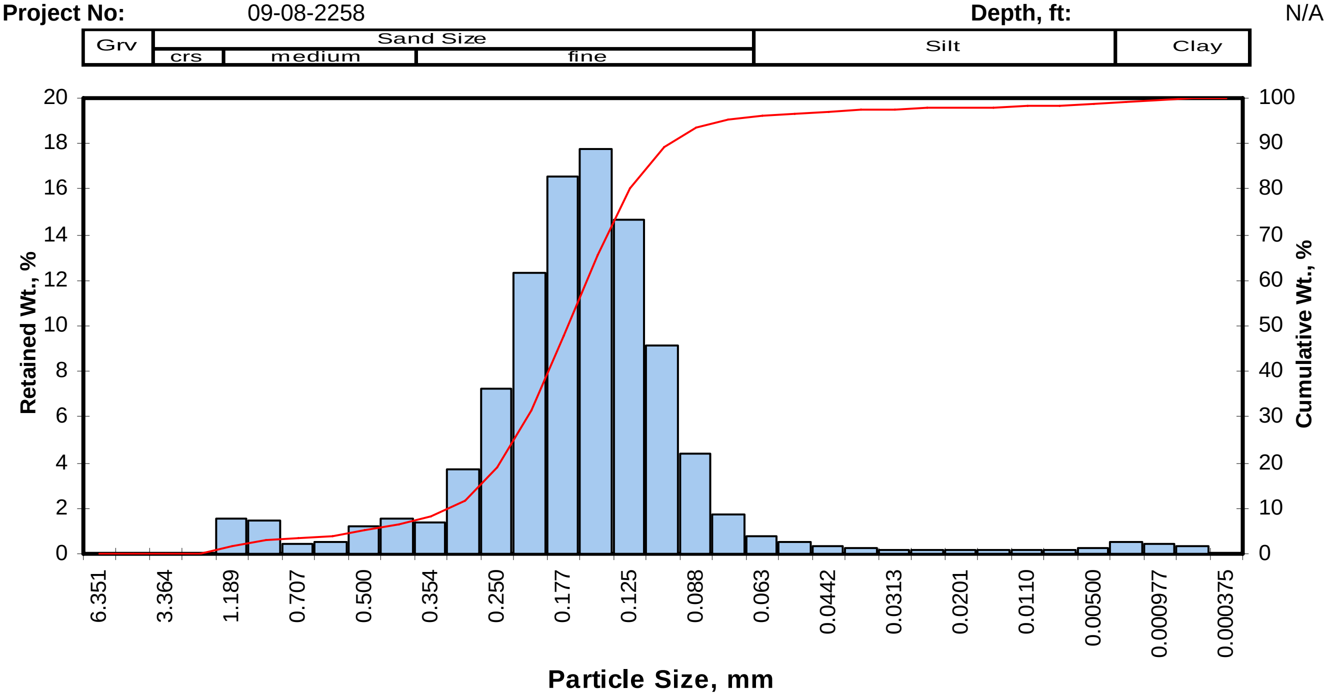
| Description | Retained on Sieve # | Weight Percent |
|---|---|---|
| Gravel | 4 | 0.00 |
| Coarse Sand | 10 | 0.00 |
| Medium Sand | 40 | 4.08 |
| Fine Sand | 200 | 88.41 |
| Silt | >0.005 mm | 6.06 |
| Clay | <0.005 mm | 1.45 |
| | **Total** | **100** |

Appendix C-2. (Cont.).

**PTS** Laboratories, Inc.

**Particle Size Analysis - ASTM D4464M**

| | | | |
|---|---|---|---|
| **Client:** | Calscience | **PTS File No:** | 39723 |
| **Project:** | N/A | **Sample ID:** | MGS B2 |
| **Project No:** | 09-08-2258 | **Depth, ft:** | N/A |




| Opening Inches | Opening Millimeters | Phi of Screen | U.S. No. | Sample Weight, grams | Increment Weight, percent | Cumulative Weight, percent |
|---|---|---|---|---|---|---|
| 0.2500 | 6.351 | -2.67 | 1/4 | 0.00 | 0.00 | 0.00 |
| 0.1873 | 4.757 | -2.25 | 4 | 0.00 | 0.00 | 0.00 |
| 0.1324 | 3.364 | -1.75 | 6 | 0.00 | 0.00 | 0.00 |
| 0.0787 | 2.000 | -1.00 | 10 | 0.00 | 0.00 | 0.00 |
| 0.0468 | 1.189 | -0.25 | 16 | 1.58 | 1.58 | 1.58 |
| 0.0331 | 0.841 | 0.25 | 20 | 1.44 | 1.44 | 3.02 |
| 0.0278 | 0.707 | 0.50 | 25 | 0.41 | 0.41 | 3.43 |
| 0.0234 | 0.595 | 0.75 | 30 | 0.48 | 0.48 | 3.91 |
| 0.0197 | 0.500 | 1.00 | 35 | 1.17 | 1.17 | 5.08 |
| 0.0166 | 0.420 | 1.25 | 40 | 1.52 | 1.52 | 6.61 |
| 0.0139 | 0.354 | 1.50 | 45 | 1.41 | 1.41 | 8.02 |
| 0.0117 | 0.297 | 1.75 | 50 | 3.71 | 3.71 | 11.73 |
| 0.0098 | 0.250 | 2.00 | 60 | 7.22 | 7.23 | 18.96 |
| 0.0083 | 0.210 | 2.25 | 70 | 12.30 | 12.31 | 31.27 |
| 0.0070 | 0.177 | 2.50 | 80 | 16.50 | 16.52 | 47.78 |
| 0.0059 | 0.149 | 2.75 | 100 | 17.70 | 17.72 | 65.50 |
| 0.0049 | 0.125 | 3.00 | 120 | 14.60 | 14.61 | 80.12 |
| 0.0041 | 0.105 | 3.25 | 140 | 9.17 | 9.18 | 89.29 |
| 0.0035 | 0.088 | 3.50 | 170 | 4.38 | 4.38 | 93.68 |
| 0.0029 | 0.074 | 3.75 | 200 | 1.76 | 1.76 | 95.44 |
| 0.0025 | 0.063 | 4.00 | 230 | 0.81 | 0.81 | 96.25 |
| 0.0021 | 0.053 | 4.25 | 270 | 0.51 | 0.51 | 96.76 |
| 0.00174 | 0.0442 | 4.50 | 325 | 0.33 | 0.33 | 97.09 |
| 0.00146 | 0.0372 | 4.75 | 400 | 0.22 | 0.22 | 97.31 |
| 0.00123 | 0.0313 | 5.00 | 450 | 0.17 | 0.17 | 97.48 |
| 0.000986 | 0.0250 | 5.32 | 500 | 0.20 | 0.20 | 97.68 |
| 0.000790 | 0.0201 | 5.64 | 635 | 0.18 | 0.18 | 97.86 |
| 0.000615 | 0.0156 | 6.00 | | 0.17 | 0.17 | 98.03 |
| 0.000435 | 0.0110 | 6.50 | | 0.21 | 0.21 | 98.24 |
| 0.000308 | 0.00781 | 7.00 | | 0.21 | 0.21 | 98.45 |
| 0.000197 | 0.00500 | 7.65 | | 0.26 | 0.26 | 98.71 |
| 0.000077 | 0.00195 | 9.00 | | 0.50 | 0.50 | 99.21 |
| 0.000038 | 0.000977 | 10.00 | | 0.41 | 0.41 | 99.62 |
| 0.000019 | 0.000488 | 11.00 | | 0.34 | 0.34 | 99.96 |
| 0.000015 | 0.000375 | 11.38 | | 0.04 | 0.04 | 100.00 |
| **TOTALS** | | | | **99.90** | **100.00** | **100.00** |

**Cumulative Weight Percent greater than**

| Weight percent | Phi Value | Particle Size Inches | Particle Size Millimeters |
|---|---|---|---|
| 5 | 0.98 | 0.0199 | 0.506 |
| 10 | 1.63 | 0.0127 | 0.322 |
| 16 | 1.90 | 0.0106 | 0.268 |
| 25 | 2.12 | 0.0090 | 0.230 |
| 40 | 2.38 | 0.0076 | 0.192 |
| 50 | 2.53 | 0.0068 | 0.173 |
| 60 | 2.67 | 0.0062 | 0.157 |
| 75 | 2.91 | 0.0052 | 0.133 |
| 84 | 3.11 | 0.0046 | 0.116 |
| 90 | 3.29 | 0.0040 | 0.102 |
| 95 | 3.69 | 0.0031 | 0.078 |

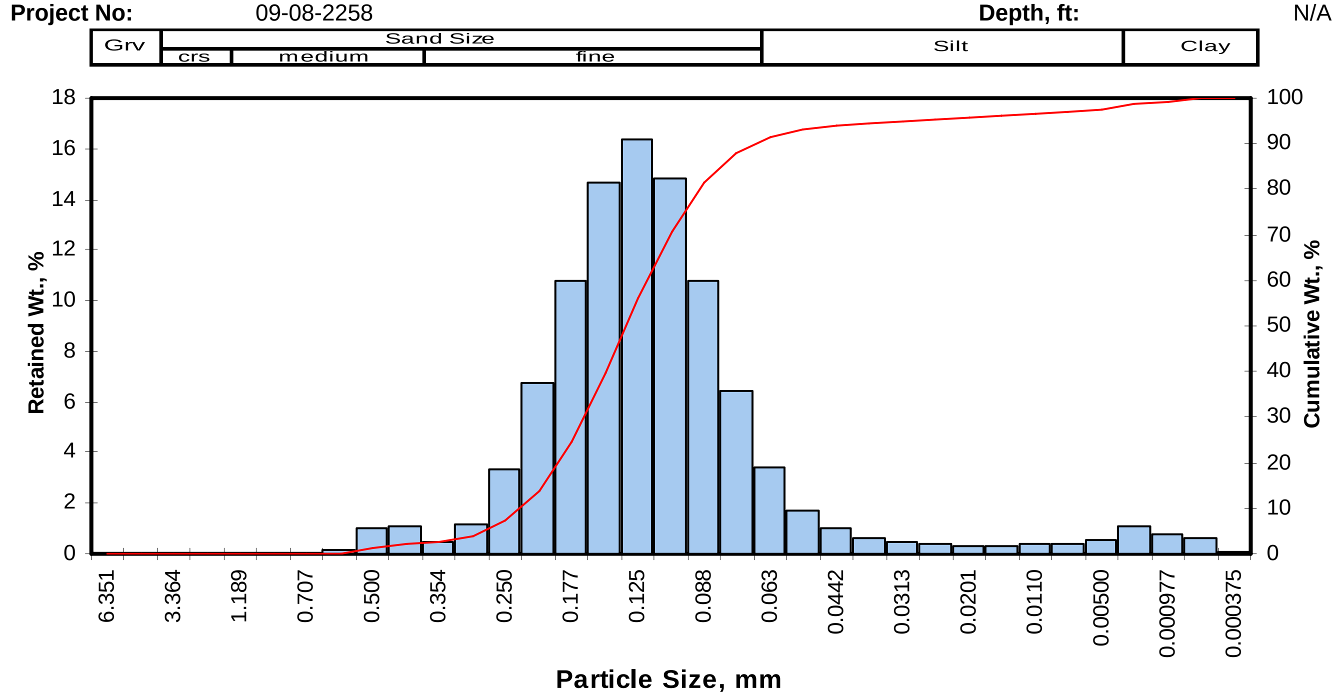
| Measure | Trask | Inman | Folk-Ward |
|---|---|---|---|
| Median, phi | 2.53 | 2.53 | 2.53 |
| Median, in. | 0.0068 | 0.0068 | 0.0068 |
| Median, mm | 0.173 | 0.173 | 0.173 |
| Mean, phi | 2.46 | 2.50 | 2.51 |
| Mean, in. | 0.0071 | 0.0070 | 0.0069 |
| Mean, mm | 0.181 | 0.177 | 0.175 |
| Sorting | 1.315 | 0.604 | 0.712 |
| Skewness | 1.010 | -0.049 | -0.097 |
| Kurtosis | 0.220 | 1.240 | 1.404 |

| | |
|---|---|
| **Grain Size Description** (ASTM-USCS Scale) | Fine sand (based on Mean from Trask) |

| Description | Retained on Sieve # | Weight Percent |
|---|---|---|
| Gravel | 4 | 0.00 |
| Coarse Sand | 10 | 0.00 |
| Medium Sand | 40 | 6.61 |
| Fine Sand | 200 | 88.83 |
| Silt | >0.005 mm | 3.27 |
| Clay | <0.005 mm | 1.29 |
| | **Total** | **100** |

**PTS** Laboratories, Inc. — **Particle Size Analysis - ASTM D4464M**

| | | | |
|---|---|---|---|
| **Client:** | Calscience | **PTS File No:** | 39723 |
| **Project:** | N/A | **Sample ID:** | MGS B3 |
| **Project No:** | 09-08-2258 | **Depth, ft:** | N/A |




| Opening Inches | Opening Millimeters | Phi of Screen | U.S. No. | Sample Weight, grams | Increment Weight, percent | Cumulative Weight, percent |
|---|---|---|---|---|---|---|
| 0.2500 | 6.351 | -2.67 | 1/4 | 0.00 | 0.00 | 0.00 |
| 0.1873 | 4.757 | -2.25 | 4 | 0.00 | 0.00 | 0.00 |
| 0.1324 | 3.364 | -1.75 | 6 | 0.00 | 0.00 | 0.00 |
| 0.0787 | 2.000 | -1.00 | 10 | 0.00 | 0.00 | 0.00 |
| 0.0468 | 1.189 | -0.25 | 16 | 0.00 | 0.00 | 0.00 |
| 0.0331 | 0.841 | 0.25 | 20 | 0.00 | 0.00 | 0.00 |
| 0.0278 | 0.707 | 0.50 | 25 | 0.00 | 0.00 | 0.00 |
| 0.0234 | 0.595 | 0.75 | 30 | 0.13 | 0.13 | 0.13 |
| 0.0197 | 0.500 | 1.00 | 35 | 1.00 | 1.00 | 1.13 |
| 0.0166 | 0.420 | 1.25 | 40 | 1.09 | 1.09 | 2.22 |
| 0.0139 | 0.354 | 1.50 | 45 | 0.48 | 0.48 | 2.70 |
| 0.0117 | 0.297 | 1.75 | 50 | 1.19 | 1.19 | 3.89 |
| 0.0098 | 0.250 | 2.00 | 60 | 3.34 | 3.34 | 7.22 |
| 0.0083 | 0.210 | 2.25 | 70 | 6.78 | 6.77 | 14.00 |
| 0.0070 | 0.177 | 2.50 | 80 | 10.80 | 10.79 | 24.78 |
| 0.0059 | 0.149 | 2.75 | 100 | 14.70 | 14.68 | 39.47 |
| 0.0049 | 0.125 | 3.00 | 120 | 16.40 | 16.38 | 55.85 |
| 0.0041 | 0.105 | 3.25 | 140 | 14.80 | 14.78 | 70.63 |
| 0.0035 | 0.088 | 3.50 | 170 | 10.80 | 10.79 | 81.42 |
| 0.0029 | 0.074 | 3.75 | 200 | 6.47 | 6.46 | 87.89 |
| 0.0025 | 0.063 | 4.00 | 230 | 3.38 | 3.38 | 91.26 |
| 0.0021 | 0.053 | 4.25 | 270 | 1.73 | 1.73 | 92.99 |
| 0.00174 | 0.0442 | 4.50 | 325 | 0.98 | 0.98 | 93.97 |
| 0.00146 | 0.0372 | 4.75 | 400 | 0.62 | 0.62 | 94.59 |
| 0.00123 | 0.0313 | 5.00 | 450 | 0.43 | 0.43 | 95.02 |
| 0.000986 | 0.0250 | 5.32 | 500 | 0.41 | 0.41 | 95.43 |
| 0.000790 | 0.0201 | 5.64 | 635 | 0.33 | 0.33 | 95.76 |
| 0.000615 | 0.0156 | 6.00 | | 0.33 | 0.33 | 96.09 |
| 0.000435 | 0.0110 | 6.50 | | 0.42 | 0.42 | 96.51 |
| 0.000308 | 0.00781 | 7.00 | | 0.42 | 0.42 | 96.93 |
| 0.000197 | 0.00500 | 7.65 | | 0.55 | 0.55 | 97.48 |
| 0.000077 | 0.00195 | 9.00 | | 1.08 | 1.08 | 98.55 |
| 0.000038 | 0.000977 | 10.00 | | 0.77 | 0.77 | 99.32 |
| 0.000019 | 0.000488 | 11.00 | | 0.61 | 0.61 | 99.93 |
| 0.000015 | 0.000375 | 11.38 | | 0.07 | 0.07 | 100.00 |
| **TOTALS** | | | | **100.10** | **100.00** | **100.00** |

**Cumulative Weight Percent greater than**

| Weight percent | Phi Value | Particle Size Inches | Particle Size Millimeters |
|---|---|---|---|
| 5 | 1.83 | 0.0110 | 0.281 |
| 10 | 2.10 | 0.0092 | 0.233 |
| 16 | 2.30 | 0.0080 | 0.204 |
| 25 | 2.50 | 0.0069 | 0.176 |
| 40 | 2.76 | 0.0058 | 0.148 |
| 50 | 2.91 | 0.0052 | 0.133 |
| 60 | 3.07 | 0.0047 | 0.119 |
| 75 | 3.35 | 0.0039 | 0.098 |
| 84 | 3.60 | 0.0032 | 0.082 |
| 90 | 3.91 | 0.0026 | 0.067 |
| 95 | 4.99 | 0.0012 | 0.031 |

| Measure | Trask | Inman | Folk-Ward |
|---|---|---|---|
| Median, phi | 2.91 | 2.91 | 2.91 |
| Median, in. | 0.0052 | 0.0052 | 0.0052 |
| Median, mm | 0.133 | 0.133 | 0.133 |
| Mean, phi | 2.87 | 2.95 | 2.94 |
| Mean, in. | 0.0054 | 0.0051 | 0.0051 |
| Mean, mm | 0.137 | 0.130 | 0.131 |
| Sorting | 1.341 | 0.652 | 0.804 |
| Skewness | 0.988 | 0.057 | 0.187 |
| Kurtosis | 0.236 | 1.422 | 1.526 |

| | |
|---|---|
| **Grain Size Description** (ASTM-USCS Scale) | Fine sand (based on Mean from Trask) |

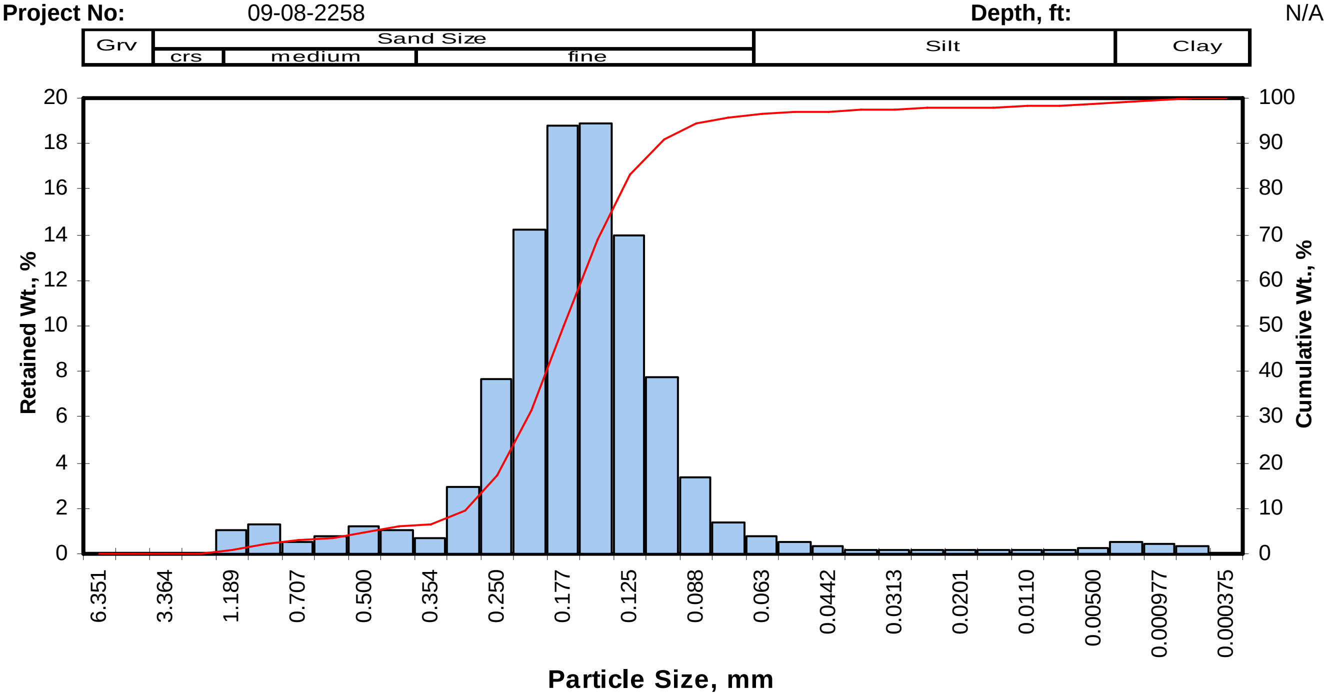
| Description | Retained on Sieve # | Weight Percent |
|---|---|---|
| Gravel | 4 | 0.00 |
| Coarse Sand | 10 | 0.00 |
| Medium Sand | 40 | 2.22 |
| Fine Sand | 200 | 85.67 |
| Silt | >0.005 mm | 9.59 |
| Clay | <0.005 mm | 2.52 |
| | **Total** | **100** |

Appendix C-2. (Cont.).

**PTS** Laboratories, Inc.

## Particle Size Analysis - ASTM D4464M

| | | | |
|---|---|---|---|
| **Client:** | Calscience | **PTS File No:** | 39723 |
| **Project:** | N/A | **Sample ID:** | MGS B4 |
| **Project No:** | 09-08-2258 | **Depth, ft:** | N/A |




| Opening Inches | Opening Millimeters | Phi of Screen | U.S. No. | Sample Weight, grams | Increment Weight, percent | Cumulative Weight, percent |
|---|---|---|---|---|---|---|
| 0.2500 | 6.351 | -2.67 | 1/4 | 0.00 | 0.00 | 0.00 |
| 0.1873 | 4.757 | -2.25 | 4 | 0.00 | 0.00 | 0.00 |
| 0.1324 | 3.364 | -1.75 | 6 | 0.00 | 0.00 | 0.00 |
| 0.0787 | 2.000 | -1.00 | 10 | 0.00 | 0.00 | 0.00 |
| 0.0468 | 1.189 | -0.25 | 16 | 1.04 | 1.04 | 1.04 |
| 0.0331 | 0.841 | 0.25 | 20 | 1.30 | 1.30 | 2.34 |
| 0.0278 | 0.707 | 0.50 | 25 | 0.55 | 0.55 | 2.89 |
| 0.0234 | 0.595 | 0.75 | 30 | 0.75 | 0.75 | 3.64 |
| 0.0197 | 0.500 | 1.00 | 35 | 1.21 | 1.21 | 4.85 |
| 0.0166 | 0.420 | 1.25 | 40 | 1.04 | 1.04 | 5.89 |
| 0.0139 | 0.354 | 1.50 | 45 | 0.70 | 0.70 | 6.59 |
| 0.0117 | 0.297 | 1.75 | 50 | 2.91 | 2.91 | 9.50 |
| 0.0098 | 0.250 | 2.00 | 60 | 7.67 | 7.67 | 17.16 |
| 0.0083 | 0.210 | 2.25 | 70 | 14.20 | 14.20 | 31.36 |
| 0.0070 | 0.177 | 2.50 | 80 | 18.80 | 18.79 | 50.15 |
| 0.0059 | 0.149 | 2.75 | 100 | 18.90 | 18.89 | 69.05 |
| 0.0049 | 0.125 | 3.00 | 120 | 14.00 | 14.00 | 83.04 |
| 0.0041 | 0.105 | 3.25 | 140 | 7.78 | 7.78 | 90.82 |
| 0.0035 | 0.088 | 3.50 | 170 | 3.37 | 3.37 | 94.19 |
| 0.0029 | 0.074 | 3.75 | 200 | 1.39 | 1.39 | 95.58 |
| 0.0025 | 0.063 | 4.00 | 230 | 0.76 | 0.76 | 96.34 |
| 0.0021 | 0.053 | 4.25 | 270 | 0.50 | 0.50 | 96.84 |
| 0.00174 | 0.0442 | 4.50 | 325 | 0.31 | 0.31 | 97.15 |
| 0.00146 | 0.0372 | 4.75 | 400 | 0.21 | 0.21 | 97.36 |
| 0.00123 | 0.0313 | 5.00 | 450 | 0.16 | 0.16 | 97.52 |
| 0.000986 | 0.0250 | 5.32 | 500 | 0.18 | 0.18 | 97.70 |
| 0.000790 | 0.0201 | 5.64 | 635 | 0.16 | 0.16 | 97.86 |
| 0.000615 | 0.0156 | 6.00 | | 0.16 | 0.16 | 98.02 |
| 0.000435 | 0.0110 | 6.50 | | 0.21 | 0.21 | 98.23 |
| 0.000308 | 0.00781 | 7.00 | | 0.21 | 0.21 | 98.44 |
| 0.000197 | 0.00500 | 7.65 | | 0.27 | 0.27 | 98.71 |
| 0.000077 | 0.00195 | 9.00 | | 0.51 | 0.51 | 99.22 |
| 0.000038 | 0.000977 | 10.00 | | 0.42 | 0.42 | 99.64 |
| 0.000019 | 0.000488 | 11.00 | | 0.33 | 0.33 | 99.97 |
| 0.000015 | 0.000375 | 11.38 | | 0.04 | 0.03 | 100.00 |
| **TOTALS** | | | | **100.00** | **100.00** | **100.00** |

| Cumulative Weight Percent greater than | | | |
|---|---|---|---|
| **Weight percent** | **Phi Value** | **Particle Size Inches** | **Particle Size Millimeters** |
| 5 | 1.04 | 0.0192 | 0.488 |
| 10 | 1.77 | 0.0116 | 0.294 |
| 16 | 1.96 | 0.0101 | 0.257 |
| 25 | 2.14 | 0.0089 | 0.227 |
| 40 | 2.36 | 0.0076 | 0.194 |
| 50 | 2.50 | 0.0070 | 0.177 |
| 60 | 2.63 | 0.0064 | 0.162 |
| 75 | 2.86 | 0.0054 | 0.138 |
| 84 | 3.03 | 0.0048 | 0.122 |
| 90 | 3.22 | 0.0042 | 0.107 |
| 95 | 3.65 | 0.0031 | 0.080 |

| Measure | Trask | Inman | Folk-Ward |
|---|---|---|---|
| Median, phi | 2.50 | 2.50 | 2.50 |
| Median, in. | 0.0070 | 0.0070 | 0.0070 |
| Median, mm | 0.177 | 0.177 | 0.177 |
| Mean, phi | 2.45 | 2.50 | 2.50 |
| Mean, in. | 0.0072 | 0.0070 | 0.0070 |
| Mean, mm | 0.183 | 0.177 | 0.177 |
| Sorting | 1.283 | 0.534 | 0.663 |
| Skewness | 1.001 | -0.003 | -0.061 |
| Kurtosis | 0.238 | 1.442 | 1.489 |

| | |
|---|---|
| **Grain Size Description** (ASTM-USCS Scale) | Fine sand (based on Mean from Trask) |

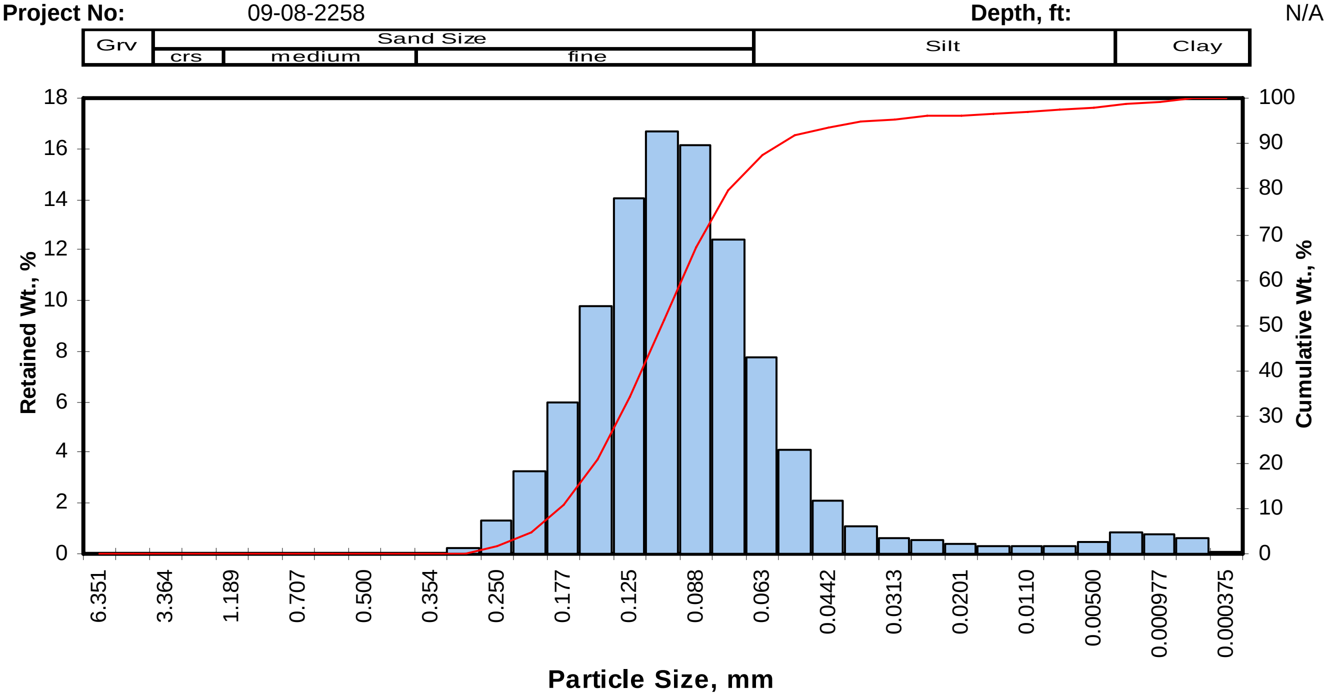
| Description | Retained on Sieve # | Weight Percent |
|---|---|---|
| Gravel | 4 | 0.00 |
| Coarse Sand | 10 | 0.00 |
| Medium Sand | 40 | 5.89 |
| Fine Sand | 200 | 89.69 |
| Silt | >0.005 mm | 3.13 |
| Clay | <0.005 mm | 1.29 |
| | **Total** | **100** |

Appendix C-2. (Cont.).

**PTS** Laboratories, Inc.

**Particle Size Analysis - ASTM D4464M**

| | | | |
|---|---|---|---|
| **Client:** | Calscience | **PTS File No:** | 39723 |
| **Project:** | N/A | **Sample ID:** | MGS B5 |
| **Project No:** | 09-08-2258 | **Depth, ft:** | N/A |




| Opening Inches | Opening Millimeters | Phi of Screen | U.S. No. | Sample Weight, grams | Increment Weight, percent | Cumulative Weight, percent |
|---|---|---|---|---|---|---|
| 0.2500 | 6.351 | -2.67 | 1/4 | 0.00 | 0.00 | 0.00 |
| 0.1873 | 4.757 | -2.25 | 4 | 0.00 | 0.00 | 0.00 |
| 0.1324 | 3.364 | -1.75 | 6 | 0.00 | 0.00 | 0.00 |
| 0.0787 | 2.000 | -1.00 | 10 | 0.00 | 0.00 | 0.00 |
| 0.0468 | 1.189 | -0.25 | 16 | 0.00 | 0.00 | 0.00 |
| 0.0331 | 0.841 | 0.25 | 20 | 0.00 | 0.00 | 0.00 |
| 0.0278 | 0.707 | 0.50 | 25 | 0.00 | 0.00 | 0.00 |
| 0.0234 | 0.595 | 0.75 | 30 | 0.00 | 0.00 | 0.00 |
| 0.0197 | 0.500 | 1.00 | 35 | 0.00 | 0.00 | 0.00 |
| 0.0166 | 0.420 | 1.25 | 40 | 0.00 | 0.00 | 0.00 |
| 0.0139 | 0.354 | 1.50 | 45 | 0.00 | 0.00 | 0.00 |
| 0.0117 | 0.297 | 1.75 | 50 | 0.20 | 0.20 | 0.20 |
| 0.0098 | 0.250 | 2.00 | 60 | 1.31 | 1.31 | 1.51 |
| 0.0083 | 0.210 | 2.25 | 70 | 3.28 | 3.28 | 4.79 |
| 0.0070 | 0.177 | 2.50 | 80 | 5.94 | 5.94 | 10.74 |
| 0.0059 | 0.149 | 2.75 | 100 | 9.80 | 9.81 | 20.54 |
| 0.0049 | 0.125 | 3.00 | 120 | 14.00 | 14.01 | 34.55 |
| 0.0041 | 0.105 | 3.25 | 140 | 16.70 | 16.71 | 51.26 |
| 0.0035 | 0.088 | 3.50 | 170 | 16.10 | 16.11 | 67.37 |
| 0.0029 | 0.074 | 3.75 | 200 | 12.40 | 12.41 | 79.78 |
| 0.0025 | 0.063 | 4.00 | 230 | 7.72 | 7.72 | 87.50 |
| 0.0021 | 0.053 | 4.25 | 270 | 4.12 | 4.12 | 91.63 |
| 0.00174 | 0.0442 | 4.50 | 325 | 2.08 | 2.08 | 93.71 |
| 0.00146 | 0.0372 | 4.75 | 400 | 1.10 | 1.10 | 94.81 |
| 0.00123 | 0.0313 | 5.00 | 450 | 0.63 | 0.63 | 95.44 |
| 0.000986 | 0.0250 | 5.32 | 500 | 0.51 | 0.51 | 95.95 |
| 0.000790 | 0.0201 | 5.64 | 635 | 0.35 | 0.35 | 96.30 |
| 0.000615 | 0.0156 | 6.00 | | 0.29 | 0.29 | 96.59 |
| 0.000435 | 0.0110 | 6.50 | | 0.34 | 0.34 | 96.93 |
| 0.000308 | 0.00781 | 7.00 | | 0.33 | 0.33 | 97.26 |
| 0.000197 | 0.00500 | 7.65 | | 0.43 | 0.43 | 97.69 |
| 0.000077 | 0.00195 | 9.00 | | 0.88 | 0.88 | 98.57 |
| 0.000038 | 0.000977 | 10.00 | | 0.74 | 0.74 | 99.31 |
| 0.000019 | 0.000488 | 11.00 | | 0.62 | 0.62 | 99.93 |
| 0.000015 | 0.000375 | 11.38 | | 0.07 | 0.07 | 100.00 |
| **TOTALS** | | | | **99.90** | **100.00** | **100.00** |

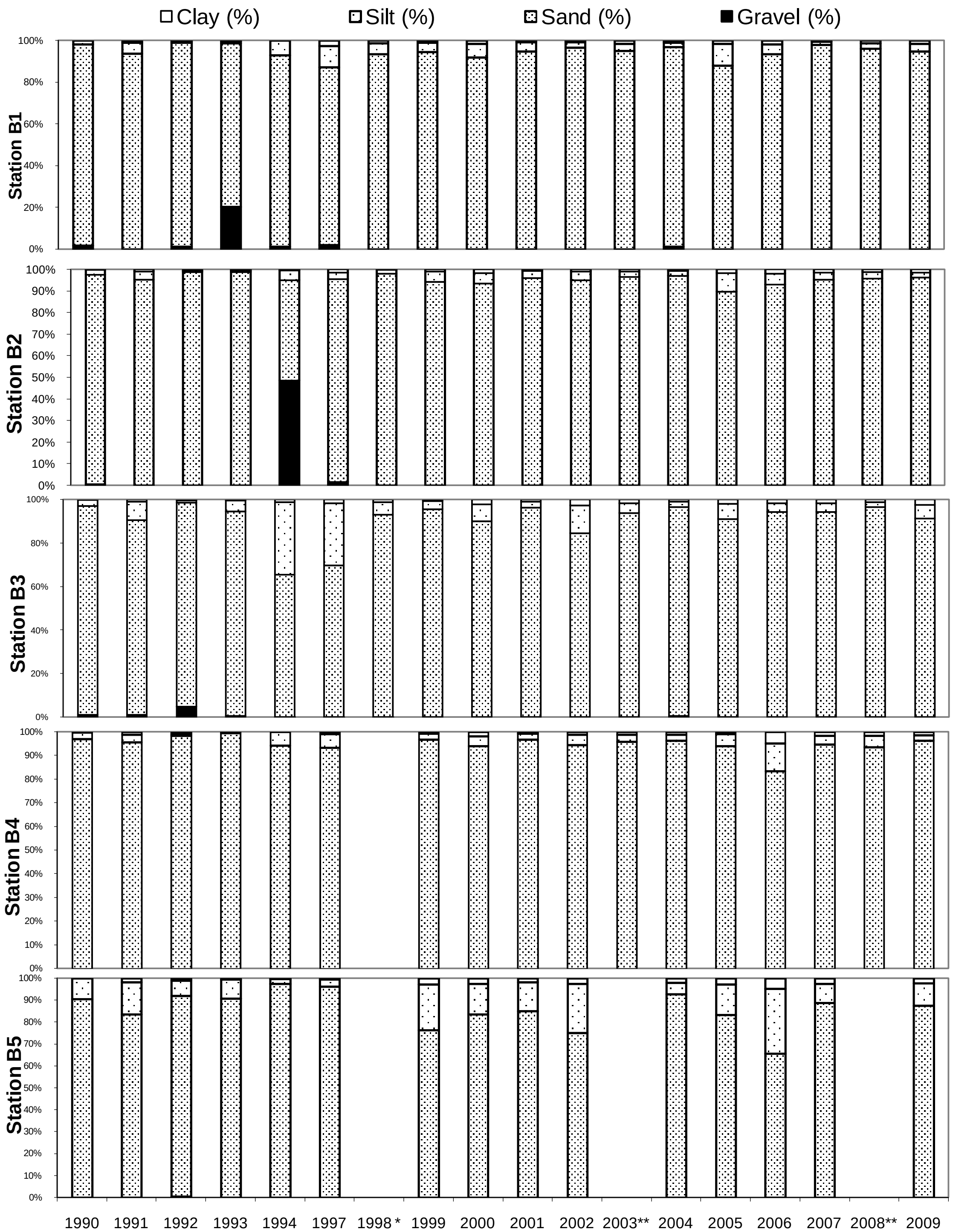
| Cumulative Weight Percent greater than | | | |
|---|---|---|---|
| **Weight percent** | **Phi Value** | **Particle Size Inches** | **Particle Size Millimeters** |
| 5 | 2.26 | 0.0082 | 0.209 |
| 10 | 2.47 | 0.0071 | 0.181 |
| 16 | 2.63 | 0.0063 | 0.161 |
| 25 | 2.83 | 0.0055 | 0.141 |
| 40 | 3.08 | 0.0047 | 0.118 |
| 50 | 3.23 | 0.0042 | 0.106 |
| 60 | 3.39 | 0.0038 | 0.096 |
| 75 | 3.65 | 0.0031 | 0.079 |
| 84 | 3.89 | 0.0027 | 0.068 |
| 90 | 4.15 | 0.0022 | 0.056 |
| 95 | 4.83 | 0.0014 | 0.035 |

| Measure | Trask | Inman | Folk-Ward |
|---|---|---|---|
| Median, phi | 3.23 | 3.23 | 3.23 |
| Median, in. | 0.0042 | 0.0042 | 0.0042 |
| Median, mm | 0.106 | 0.106 | 0.106 |
| Mean, phi | 3.18 | 3.26 | 3.25 |
| Mean, in. | 0.0043 | 0.0041 | 0.0041 |
| Mean, mm | 0.110 | 0.104 | 0.105 |
| Sorting | 1.331 | 0.626 | 0.702 |
| Skewness | 0.993 | 0.047 | 0.145 |
| Kurtosis | 0.246 | 1.050 | 1.277 |

| Grain Size Description (ASTM-USCS Scale) | Fine sand (based on Mean from Trask) |
|---|---|

| Description | Retained on Sieve # | Weight Percent |
|---|---|---|
| Gravel | 4 | 0.00 |
| Coarse Sand | 10 | 0.00 |
| Medium Sand | 40 | 0.00 |
| Fine Sand | 200 | 79.78 |
| Silt | >0.005 mm | 17.91 |
| Clay | <0.005 mm | 2.31 |
| | **Total** | **100** |

**Appendix C-3. Long-term sediment composition by size catagory, 1990 - 2009. Mandalay Generating Station NPDES, 2009.**




Regional Monitoring Years: *1998 only three stations required; **2003 and 2008 only four stations required

# APPENDIX D

## Sediment chemistry by station

Calscience Environmental Laboratories, Inc.

## Analytical Report

MBC Applied Environmental Sciences
3000 Redhill Avenue
Costa Mesa, CA 92626-4524

Project: MGS 09205A

| | |
|---|---|
| Date Received: | 07/24/09 |
| Work Order No: | 09-07-2037 |
| Preparation: | EPA 3050B |
| Method: | EPA 6020 |
| Units: | mg/kg |
| | Page 1 of 1 |

| Client Sample Number | Lab Sample Number | Date /Time Collected | Matrix | Instrument | Date Prepared | Date/Time Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **B1-(I, II, III)** | **09-07-2037-16-A** | **07/22/09 11:00** | **Solid** | **ICP/MS 03** | **07/28/09** | **07/29/09 12:14** | **090728L01** |

Comment(s): -Results are reported on a dry weight basis.

| Parameter | Result | RL | DF | Qual | Parameter | Result | RL | DF | Qual |
|---|---|---|---|---|---|---|---|---|---|
| Chromium | 8.52 | 0.128 | 1 | | Nickel | 8.01 | 0.128 | 1 | |
| Copper | 5.08 | 0.128 | 1 | | Zinc | 25.4 | 1.28 | 1 | |

| Client Sample Number | Lab Sample Number | Date /Time Collected | Matrix | Instrument | Date Prepared | Date/Time Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **B2-(I, II, III)** | **09-07-2037-17-A** | **07/22/09 10:22** | **Solid** | **ICP/MS 03** | **07/28/09** | **07/29/09 12:18** | **090728L01** |

Comment(s): -Results are reported on a dry weight basis.

| Parameter | Result | RL | DF | Qual | Parameter | Result | RL | DF | Qual |
|---|---|---|---|---|---|---|---|---|---|
| Chromium | 9.71 | 0.132 | 1 | | Nickel | 8.64 | 0.132 | 1 | |
| Copper | 4.90 | 0.132 | 1 | | Zinc | 27.2 | 1.32 | 1 | |

| Client Sample Number | Lab Sample Number | Date /Time Collected | Matrix | Instrument | Date Prepared | Date/Time Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **B3-(I, II, III)** | **09-07-2037-18-A** | **07/22/09 11:27** | **Solid** | **ICP/MS 03** | **07/28/09** | **07/29/09 12:22** | **090728L01** |

Comment(s): -Results are reported on a dry weight basis.

| Parameter | Result | RL | DF | Qual | Parameter | Result | RL | DF | Qual |
|---|---|---|---|---|---|---|---|---|---|
| Chromium | 9.67 | 0.137 | 1 | | Nickel | 8.86 | 0.137 | 1 | |
| Copper | 5.99 | 0.137 | 1 | | Zinc | 30.4 | 1.37 | 1 | |

| Client Sample Number | Lab Sample Number | Date /Time Collected | Matrix | Instrument | Date Prepared | Date/Time Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **B4-(I, II, III)** | **09-07-2037-19-A** | **07/22/09 09:58** | **Solid** | **ICP/MS 03** | **07/28/09** | **07/29/09 12:26** | **090728L01** |

Comment(s): -Results are reported on a dry weight basis.

| Parameter | Result | RL | DF | Qual | Parameter | Result | RL | DF | Qual |
|---|---|---|---|---|---|---|---|---|---|
| Chromium | 8.46 | 0.130 | 1 | | Nickel | 8.52 | 0.130 | 1 | |
| Copper | 4.63 | 0.130 | 1 | | Zinc | 23.4 | 1.30 | 1 | |

| Client Sample Number | Lab Sample Number | Date /Time Collected | Matrix | Instrument | Date Prepared | Date/Time Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **B5-(I, II, III)** | **09-07-2037-20-A** | **07/22/09 11:58** | **Solid** | **ICP/MS 03** | **07/28/09** | **07/29/09 12:30** | **090728L01** |

Comment(s): -Results are reported on a dry weight basis.

| Parameter | Result | RL | DF | Qual | Parameter | Result | RL | DF | Qual |
|---|---|---|---|---|---|---|---|---|---|
| Chromium | 9.26 | 0.136 | 1 | | Nickel | 8.15 | 0.136 | 1 | |
| Copper | 6.28 | 0.136 | 1 | | Zinc | 34.3 | 1.36 | 1 | |

| Client Sample Number | Lab Sample Number | Date /Time Collected | Matrix | Instrument | Date Prepared | Date/Time Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **Method Blank** | **096-10-002-1,554** | **N/A** | **Solid** | **ICP/MS 03** | **07/28/09** | **07/28/09 20:14** | **090728L01** |

| Parameter | Result | RL | DF | Qual | Parameter | Result | RL | DF | Qual |
|---|---|---|---|---|---|---|---|---|---|
| Chromium | ND | 0.100 | 1 | | Nickel | ND | 0.100 | 1 | |
| Copper | ND | 0.100 | 1 | | Zinc | ND | 1.00 | 1 | |

RL - Reporting Limit , DF - Dilution Factor , Qual - Qualifiers

7440 Lincoln Way, Garden Grove, CA 92841-1427 • TEL:(714) 895-5494 • FAX: (714) 894-7501

Calscience Environmental Laboratories, Inc.

# Analytical Report

| | |
|---|---|
| MBC Applied Environmental Sciences | Date Received: 07/24/09 |
| 3000 Redhill Avenue | Work Order No: 09-07-2037 |
| Costa Mesa, CA 92626-4524 | |

Project: MGS 09205A



| Client Sample Number | Lab Sample Number | Date Collected | Matrix |
|---|---|---|---|
| **B1-(I, II, III)** | **09-07-2037-16** | **07/22/09** | **Solid** |

| Parameter | Result | RL | DF | Qual | Units | Date Prepared | Date Analyzed | Method |
|---|---|---|---|---|---|---|---|---|
| Solids, Total | 77.9 | 0.100 | 1 | | % | 07/30/09 | 07/30/09 | SM 2540 B |

| | | | |
|---|---|---|---|
| **B2-(I, II, III)** | **09-07-2037-17** | **07/22/09** | **Solid** |

| Parameter | Result | RL | DF | Qual | Units | Date Prepared | Date Analyzed | Method |
|---|---|---|---|---|---|---|---|---|
| Solids, Total | 75.8 | 0.100 | 1 | | % | 07/30/09 | 07/30/09 | SM 2540 B |

| | | | |
|---|---|---|---|
| **B3-(I, II, III)** | **09-07-2037-18** | **07/22/09** | **Solid** |

| Parameter | Result | RL | DF | Qual | Units | Date Prepared | Date Analyzed | Method |
|---|---|---|---|---|---|---|---|---|
| Solids, Total | 72.8 | 0.100 | 1 | | % | 07/30/09 | 07/30/09 | SM 2540 B |

| | | | |
|---|---|---|---|
| **B4-(I, II, III)** | **09-07-2037-19** | **07/22/09** | **Solid** |

| Parameter | Result | RL | DF | Qual | Units | Date Prepared | Date Analyzed | Method |
|---|---|---|---|---|---|---|---|---|
| Solids, Total | 76.9 | 0.100 | 1 | | % | 07/30/09 | 07/30/09 | SM 2540 B |

| | | | |
|---|---|---|---|
| **B5-(I, II, III)** | **09-07-2037-20** | **07/22/09** | **Solid** |

| Parameter | Result | RL | DF | Qual | Units | Date Prepared | Date Analyzed | Method |
|---|---|---|---|---|---|---|---|---|
| Solids, Total | 73.5 | 0.100 | 1 | | % | 07/30/09 | 07/30/09 | SM 2540 B |

RL - Reporting Limit , DF - Dilution Factor , Qual - Qualifiers

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Calscience Environmental Laboratories, Inc.

## Analytical Report

MBC Applied Environmental Sciences
3000 Redhill Avenue
Costa Mesa, CA 92626-4524

Date Received: 07/24/09
Work Order No: 09-07-2037

Project: MGS 09205A



| Client Sample Number | Lab Sample Number | Date Collected | Matrix |
|---|---|---|---|
| **Method Blank** | | **N/A** | **Solid** |

| Parameter | Result | RL | DF | Qual | Units | Date Prepared | Date Analyzed | Method |
|---|---|---|---|---|---|---|---|---|
| Solids, Total | ND | 0.100 | 1 | | % | 07/30/09 | 07/30/09 | SM 2540 B |

RL - Reporting Limit , DF - Dilution Factor , Qual - Qualifiers

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**Calscience Environmental Laboratories, Inc.**

## Quality Control - Spike/Spike Duplicate

MBC Applied Environmental Sciences
3000 Redhill Avenue
Costa Mesa, CA 92626-4524

Date Received: 07/24/09
Work Order No: 09-07-2037
Preparation: EPA 3050B
Method: EPA 6020

Project MGS 09205A

| Quality Control Sample ID | Matrix | Instrument | Date Prepared | Date Analyzed | MS/MSD Batch Number |
|---|---|---|---|---|---|
| **09-07-2181-5** | **Solid** | **ICP/MS 03** | **07/28/09** | **07/28/09** | **090728S01** |

| Parameter | MS %REC | MSD %REC | %REC CL | RPD | RPD CL | Qualifiers |
|---|---|---|---|---|---|---|
| Chromium | 124 | 110 | 20-182 | 10 | 0-15 | |
| Copper | 118 | 97 | 25-157 | 11 | 0-22 | |
| Nickel | 120 | 105 | 46-154 | 11 | 0-15 | |
| Zinc | 28 | 28 | 23-173 | 0 | 0-18 | |

RPD - Relative Percent Difference , CL - Control Limit

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# Quality Control - PDS / PDSD

| | |
|---|---|
| MBC Applied Environmental Sciences | Date Received: 07/24/09 |
| 3000 Redhill Avenue | Work Order No: 09-07-2037 |
| Costa Mesa, CA 92626-4524 | Preparation: EPA 3050B |
| | Method: EPA 6020 |

Project: MGS 09205A

| Quality Control Sample ID | Matrix | Instrument | Date Prepared | Date Analyzed | PDS/PDSD Batch Number |
|---|---|---|---|---|---|
| **09-07-2181-5** | **Solid** | **ICP/MS 03** | **07/28/09** | **07/29/09** | **090728S01** |

| Parameter | PDS %REC | PDSD %REC | %REC CL | RPD | RPD CL | Qualifiers |
|---|---|---|---|---|---|---|
| Chromium | 97 | 103 | 75-125 | 4 | 0-15 | |
| Copper | 102 | 111 | 75-125 | 5 | 0-22 | |
| Nickel | 101 | 107 | 75-125 | 5 | 0-15 | |
| Zinc | 99 | 120 | 75-125 | 6 | 0-18 | |

RPD - Relative Percent Difference , CL - Control Limit

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**Calscience Environmental Laboratories, Inc.**

## Quality Control - Duplicate

MBC Applied Environmental Sciences
3000 Redhill Avenue
Costa Mesa, CA 92626-4524

Date Received: N/A
Work Order No: 09-07-2037

Project: MGS 09205A

**Matrix: Solid**

| Parameter | Method | QC Sample ID | Date Analyzed | Sample Conc | DUP Conc | RPD | RPD CL | Qualifiers |
|---|---|---|---|---|---|---|---|---|
| Solids, Total | SM 2540 B | B1-(I, II, III) | 07/30/09 | 77.9 | 77.6 | 0 | 0-25 | |

RPD - Relative Percent Difference , CL - Control Limit

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Calscience Environmental Laboratories, Inc.

# Quality Control - LCS/LCS Duplicate

| | | | |
|---|---|---|---|
| MBC Applied Environmental Sciences | | Date Received: | N/A |
| 3000 Redhill Avenue | | Work Order No: | 09-07-2037 |
| Costa Mesa, CA 92626-4524 | | Preparation: | EPA 3050B |
| | | Method: | EPA 6020 |

Project: MGS 09205A

| Quality Control Sample ID | Matrix | Instrument | Date Prepared | Date Analyzed | LCS/LCSD Batch Number |
|---|---|---|---|---|---|
| **096-10-002-1,554** | **Solid** | **ICP/MS 03** | **07/28/09** | **07/29/09** | **090728L01** |

| Parameter | LCS %REC | LCSD %REC | %REC CL | RPD | RPD CL | Qualifiers |
|---|---|---|---|---|---|---|
| Chromium | 98 | 103 | 80-120 | 5 | 0-20 | |
| Copper | 104 | 106 | 80-120 | 2 | 0-20 | |
| Nickel | 102 | 104 | 80-120 | 2 | 0-20 | |
| Zinc | 108 | 112 | 80-120 | 3 | 0-20 | |

RPD - Relative Percent Difference , CL - Control Limit

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Calscience Environmental Laboratories, Inc.

## Glossary of Terms and Qualifiers

Work Order Number: 09-07-2037

| Qualifier | Definition |
|---|---|
| * | See applicable analysis comment. |
| 1 | Surrogate compound recovery was out of control due to a required sample dilution, therefore, the sample data was reported without further clarification. |
| 2 | Surrogate compound recovery was out of control due to matrix interference. The associated method blank surrogate spike compound was in control and, therefore, the sample data was reported without further clarification. |
| 3 | Recovery of the Matrix Spike (MS) or Matrix Spike Duplicate (MSD) compound was out of control due to matrix interference. The associated LCS and/or LCSD was in control and, therefore, the sample data was reported without further clarification. |
| 4 | The MS/MSD RPD was out of control due to matrix interference. The LCS/LCSD RPD was in control and, therefore, the sample data was reported without further clarification. |
| 5 | The PDS/PDSD associated with this batch of samples was out of control due to a matrix interference effect. The associated batch LCS/LCSD was in control and, hence, the associated sample data was reported with no further corrective action required. |
| A | Result is the average of all dilutions, as defined by the method. |
| B | Analyte was present in the associated method blank. |
| C | Analyte presence was not confirmed on primary column. |
| E | Concentration exceeds the calibration range. |
| H | Sample received and/or analyzed past the recommended holding time. |
| J | Analyte was detected at a concentration below the reporting limit and above the laboratory method detection limit. Reported value is estimated. |
| ME | LCS Recovery Percentage is within LCS ME Control Limit range. |
| N | Nontarget Analyte. |
| ND | Parameter not detected at the indicated reporting limit. |
| Q | Spike recovery and RPD control limits do not apply resulting from the parameter concentration in the sample exceeding the spike concentration by a factor of four or greater. |
| U | Undetected at the laboratory method detection limit. |
| X | % Recovery and/or RPD out-of-range. |
| Z | Analyte presence was not confirmed by second column or GC/MS analysis. |
| | Solid - Unless otherwise indicated, solid sample data is reported on a wet weight basis, not corrected for % moisture. |

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# APPENDIX E

## Mussel tissue chemistry by station

**Calscience Environmental Laboratories, Inc.**

# Analytical Report

MBC Applied Environmental Sciences
3000 Redhill Avenue
Costa Mesa, CA 92626-4524

Project: MGS 09205A

| | |
|---|---|
| Date Received: | 08/04/09 |
| Work Order No: | 09-08-0196 |
| Preparation: | EPA 3050B |
| Method: | EPA 6020 |
| Units: | mg/kg |
| | Page 1 of 1 |

| Client Sample Number | Lab Sample Number | Date /Time Collected | Matrix | Instrument | Date Prepared | Date/Time Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **MGS-I** | **09-08-0196-1-A** | **07/22/09 00:00** | **Tissue** | **ICP/MS 03** | **08/10/09** | **08/10/09 20:00** | **090810L01** |

Comment(s): -Results are reported on a dry weight basis.

| Parameter | Result | RL | DF | Qual | Parameter | Result | RL | DF | Qual |
|---|---|---|---|---|---|---|---|---|---|
| Chromium | 1.55 | 0.187 | 0.5 | | Nickel | 0.863 | 0.0935 | 0.5 | |
| Copper | 2.22 | 0.280 | 0.5 | | Zinc | 24.8 | 1.87 | 0.5 | |

| Client Sample Number | Lab Sample Number | Date /Time Collected | Matrix | Instrument | Date Prepared | Date/Time Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **MGS-II** | **09-08-0196-2-A** | **07/22/09 00:00** | **Tissue** | **ICP/MS 03** | **08/10/09** | **08/10/09 20:04** | **090810L01** |

Comment(s): -Results are reported on a dry weight basis.

| Parameter | Result | RL | DF | Qual | Parameter | Result | RL | DF | Qual |
|---|---|---|---|---|---|---|---|---|---|
| Chromium | 1.33 | 0.191 | 0.5 | | Nickel | 0.665 | 0.0956 | 0.5 | |
| Copper | 2.10 | 0.287 | 0.5 | | Zinc | 26.0 | 1.91 | 0.5 | |

| Client Sample Number | Lab Sample Number | Date /Time Collected | Matrix | Instrument | Date Prepared | Date/Time Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **MGS-III** | **09-08-0196-3-A** | **07/22/09 00:00** | **Tissue** | **ICP/MS 03** | **08/10/09** | **08/10/09 20:08** | **090810L01** |

Comment(s): -Results are reported on a dry weight basis.

| Parameter | Result | RL | DF | Qual | Parameter | Result | RL | DF | Qual |
|---|---|---|---|---|---|---|---|---|---|
| Chromium | 1.49 | 0.179 | 0.5 | | Nickel | 0.698 | 0.0896 | 0.5 | |
| Copper | 2.12 | 0.269 | 0.5 | | Zinc | 25.3 | 1.79 | 0.5 | |

| Client Sample Number | Lab Sample Number | Date /Time Collected | Matrix | Instrument | Date Prepared | Date/Time Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **Method Blank** | **099-12-411-12** | **N/A** | **Tissue** | **ICP/MS 03** | **08/10/09** | **08/10/09 18:45** | **090810L01** |

| Parameter | Result | RL | DF | Qual | Parameter | Result | RL | DF | Qual |
|---|---|---|---|---|---|---|---|---|---|
| Chromium | ND | 0.100 | 0.5 | | Nickel | ND | 0.0500 | 0.5 | |
| Copper | ND | 0.150 | 0.5 | | Zinc | ND | 1.00 | 0.5 | |

RL - Reporting Limit , DF - Dilution Factor , Qual - Qualifiers

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Calscience Environmental Laboratories, Inc.

# Analytical Report

MBC Applied Environmental Sciences
3000 Redhill Avenue
Costa Mesa, CA 92626-4524

Date Received: 08/04/09
Work Order No: 09-08-0196

Project: MGS 09205A



| Client Sample Number | Lab Sample Number | Date Collected | Matrix |
|---|---|---|---|
| **MGS-I** | **09-08-0196-1** | **07/22/09** | **Tissue** |

| Parameter | Result | RL | DF | Qual | Units | Date Prepared | Date Analyzed | Method |
|---|---|---|---|---|---|---|---|---|
| Solids, Total | 53.5 | 0.100 | 1 | | % | 08/05/09 | 08/05/09 | SM 2540 B |

| Client Sample Number | Lab Sample Number | Date Collected | Matrix |
|---|---|---|---|
| **MGS-II** | **09-08-0196-2** | **07/22/09** | **Tissue** |

| Parameter | Result | RL | DF | Qual | Units | Date Prepared | Date Analyzed | Method |
|---|---|---|---|---|---|---|---|---|
| Solids, Total | 52.3 | 0.100 | 1 | | % | 08/05/09 | 08/05/09 | SM 2540 B |

| Client Sample Number | Lab Sample Number | Date Collected | Matrix |
|---|---|---|---|
| **MGS-III** | **09-08-0196-3** | **07/22/09** | **Tissue** |

| Parameter | Result | RL | DF | Qual | Units | Date Prepared | Date Analyzed | Method |
|---|---|---|---|---|---|---|---|---|
| Solids, Total | 55.8 | 0.100 | 1 | | % | 08/05/09 | 08/05/09 | SM 2540 B |

| Client Sample Number | Lab Sample Number | Date Collected | Matrix |
|---|---|---|---|
| **Method Blank** | | **N/A** | **Solid** |

| Parameter | Result | RL | DF | Qual | Units | Date Prepared | Date Analyzed | Method |
|---|---|---|---|---|---|---|---|---|
| Solids, Total | ND | 0.100 | 1 | | % | 08/05/09 | 08/05/09 | SM 2540 B |

RL - Reporting Limit , DF - Dilution Factor , Qual - Qualifiers

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Calscience Environmental Laboratories, Inc.

## Quality Control - Spike/Spike Duplicate

| | | |
|---|---|---|
| MBC Applied Environmental Sciences | Date Received: | 08/04/09 |
| 3000 Redhill Avenue | Work Order No: | 09-08-0196 |
| Costa Mesa, CA 92626-4524 | Preparation: | EPA 3050B |
| | Method: | EPA 6020 |

Project MGS 09205A

| Quality Control Sample ID | Matrix | Instrument | Date Prepared | Date Analyzed | MS/MSD Batch Number |
|---|---|---|---|---|---|
| **09-08-0194-1** | **Tissue** | **ICP/MS 03** | **08/10/09** | **08/10/09** | **090810S01** |

| Parameter | MS %REC | MSD %REC | %REC CL | RPD | RPD CL | Qualifiers |
|---|---|---|---|---|---|---|
| Chromium | 98 | 96 | 80-120 | 2 | 0-20 | |
| Copper | 103 | 101 | 80-120 | 2 | 0-20 | |
| Nickel | 98 | 95 | 80-120 | 3 | 0-20 | |
| Zinc | 96 | 96 | 80-120 | 0 | 0-20 | |

RPD - Relative Percent Difference , CL - Control Limit

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Calscience Environmental Laboratories, Inc.

## Quality Control - PDS / PDSD

MBC Applied Environmental Sciences
3000 Redhill Avenue
Costa Mesa, CA 92626-4524

Date Received: 08/04/09
Work Order No: 09-08-0196
Preparation: EPA 3050B
Method: EPA 6020

Project: MGS 09205A

| Quality Control Sample ID | Matrix | Instrument | Date Prepared | Date Analyzed | PDS/PDSD Batch Number |
|---|---|---|---|---|---|
| **09-08-0194-1** | **Tissue** | **ICP/MS 03** | **08/10/09** | **08/10/09** | **090810S01** |

| Parameter | PDS %REC | PDSD %REC | %REC CL | RPD | RPD CL | Qualifiers |
|---|---|---|---|---|---|---|
| Chromium | 95 | 97 | 75-125 | 2 | 0-20 | |
| Copper | 100 | 97 | 75-125 | 2 | 0-20 | |
| Nickel | 98 | 97 | 75-125 | 1 | 0-20 | |
| Zinc | 74 | 73 | 75-125 | 0 | 0-20 | 5 |

RPD - Relative Percent Difference , CL - Control Limit

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Calscience Environmental Laboratories, Inc.

## Quality Control - Duplicate

MBC Applied Environmental Sciences
3000 Redhill Avenue
Costa Mesa, CA 92626-4524

Date Received: N/A
Work Order No: 09-08-0196

Project: MGS 09205A

**Matrix: Tissue**

| Parameter | Method | QC Sample ID | Date Analyzed | Sample Conc | DUP Conc | RPD | RPD CL | Qualifiers |
|---|---|---|---|---|---|---|---|---|
| Solids, Total | SM 2540 B | 09-08-0194-1 | 08/05/09 | 66.5 | 66.4 | 0 | 0-25 | |

RPD - Relative Percent Difference , CL - Control Limit

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**Calscience Environmental Laboratories, Inc.**

## Quality Control - LCS/LCS Duplicate

MBC Applied Environmental Sciences
3000 Redhill Avenue
Costa Mesa, CA 92626-4524

| | |
|---|---|
| Date Received: | N/A |
| Work Order No: | 09-08-0196 |
| Preparation: | EPA 3050B |
| Method: | EPA 6020 |

Project: MGS 09205A

| Quality Control Sample ID | Matrix | Instrument | Date Prepared | Date Analyzed | LCS/LCSD Batch Number |
|---|---|---|---|---|---|
| **099-12-411-12** | **Tissue** | **ICP/MS 03** | **08/10/09** | **08/10/09** | **090810L01** |

| Parameter | LCS %REC | LCSD %REC | %REC CL | RPD | RPD CL | Qualifiers |
|---|---|---|---|---|---|---|
| Chromium | 100 | 98 | 80-120 | 2 | 0-20 | |
| Copper | 104 | 102 | 80-120 | 1 | 0-20 | |
| Nickel | 101 | 100 | 80-120 | 0 | 0-20 | |
| Zinc | 105 | 107 | 80-120 | 2 | 0-20 | |

RPD - Relative Percent Difference , CL - Control Limit

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**Calscience Environmental Laboratories, Inc.**

## Glossary of Terms and Qualifiers

Work Order Number: 09-08-0196

| Qualifier | Definition |
|---|---|
| * | See applicable analysis comment. |
| 1 | Surrogate compound recovery was out of control due to a required sample dilution, therefore, the sample data was reported without further clarification. |
| 2 | Surrogate compound recovery was out of control due to matrix interference. The associated method blank surrogate spike compound was in control and, therefore, the sample data was reported without further clarification. |
| 3 | Recovery of the Matrix Spike (MS) or Matrix Spike Duplicate (MSD) compound was out of control due to matrix interference. The associated LCS and/or LCSD was in control and, therefore, the sample data was reported without further clarification. |
| 4 | The MS/MSD RPD was out of control due to matrix interference. The LCS/LCSD RPD was in control and, therefore, the sample data was reported without further clarification. |
| 5 | The PDS/PDSD associated with this batch of samples was out of control due to a matrix interference effect. The associated batch LCS/LCSD was in control and, hence, the associated sample data was reported with no further corrective action required. |
| A | Result is the average of all dilutions, as defined by the method. |
| B | Analyte was present in the associated method blank. |
| C | Analyte presence was not confirmed on primary column. |
| E | Concentration exceeds the calibration range. |
| H | Sample received and/or analyzed past the recommended holding time. |
| J | Analyte was detected at a concentration below the reporting limit and above the laboratory method detection limit. Reported value is estimated. |
| ME | LCS Recovery Percentage is within LCS ME Control Limit range. |
| N | Nontarget Analyte. |
| ND | Parameter not detected at the indicated reporting limit. |
| Q | Spike recovery and RPD control limits do not apply resulting from the parameter concentration in the sample exceeding the spike concentration by a factor of four or greater. |
| U | Undetected at the laboratory method detection limit. |
| X | % Recovery and/or RPD out-of-range. |
| Z | Analyte presence was not confirmed by second column or GC/MS analysis. |
| | Solid - Unless otherwise indicated, solid sample data is reported on a wet weight basis, not corrected for % moisture. |

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**Calscience Environmental Laboratories, Inc.**

## Analytical Report

MBC Applied Environmental Sciences
3000 Redhill Avenue
Costa Mesa, CA 92626-4524

| | |
|---|---|
| Date Received: | 08/04/09 |
| Work Order No: | 09-08-0198 |
| Preparation: | EPA 3050B |
| Method: | EPA 6020 |
| Units: | mg/kg |

Project: MGS 09205A / OBGS 09206A



| Client Sample Number | Lab Sample Number | Date /Time Collected | Matrix | Instrument | Date Prepared | Date/Time Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **RRI Source-I** | **09-08-0198-1-A** | **03/10/09 00:00** | **Tissue** | **ICP/MS 03** | **08/10/09** | **08/10/09 20:40** | **090810L01** |

Comment(s): -Results are reported on a dry weight basis.

| Parameter | Result | RL | DF | Qual | Parameter | Result | RL | DF | Qual |
|---|---|---|---|---|---|---|---|---|---|
| Chromium | 0.982 | 0.156 | 0.5 | | Nickel | 0.462 | 0.0781 | 0.5 | |
| Copper | 1.17 | 0.234 | 0.5 | | Zinc | 27.7 | 1.56 | 0.5 | |

| Client Sample Number | Lab Sample Number | Date /Time Collected | Matrix | Instrument | Date Prepared | Date/Time Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **RRI Source-II** | **09-08-0198-2-A** | **03/10/09 00:00** | **Tissue** | **ICP/MS 03** | **08/10/09** | **08/10/09 20:44** | **090810L01** |

Comment(s): -Results are reported on a dry weight basis.

| Parameter | Result | RL | DF | Qual | Parameter | Result | RL | DF | Qual |
|---|---|---|---|---|---|---|---|---|---|
| Chromium | 0.885 | 0.165 | 0.5 | | Nickel | 0.478 | 0.0824 | 0.5 | |
| Copper | 1.29 | 0.247 | 0.5 | | Zinc | 26.4 | 1.65 | 0.5 | |

| Client Sample Number | Lab Sample Number | Date /Time Collected | Matrix | Instrument | Date Prepared | Date/Time Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **RRI Source-III** | **09-08-0198-3-A** | **03/10/09 00:00** | **Tissue** | **ICP/MS 03** | **08/10/09** | **08/10/09 20:48** | **090810L01** |

Comment(s): -Results are reported on a dry weight basis.

| Parameter | Result | RL | DF | Qual | Parameter | Result | RL | DF | Qual |
|---|---|---|---|---|---|---|---|---|---|
| Chromium | 0.594 | 0.145 | 0.5 | | Nickel | 0.275 | 0.0725 | 0.5 | |
| Copper | 0.938 | 0.217 | 0.5 | | Zinc | 22.6 | 1.45 | 0.5 | |

| Client Sample Number | Lab Sample Number | Date /Time Collected | Matrix | Instrument | Date Prepared | Date/Time Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **Method Blank** | **099-12-411-12** | **N/A** | **Tissue** | **ICP/MS 03** | **08/10/09** | **08/10/09 18:45** | **090810L01** |

| Parameter | Result | RL | DF | Qual | Parameter | Result | RL | DF | Qual |
|---|---|---|---|---|---|---|---|---|---|
| Chromium | ND | 0.100 | 0.5 | | Nickel | ND | 0.0500 | 0.5 | |
| Copper | ND | 0.150 | 0.5 | | Zinc | ND | 1.00 | 0.5 | |

RL - Reporting Limit , DF - Dilution Factor , Qual - Qualifiers

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Calscience Environmental Laboratories, Inc.

# Analytical Report

MBC Applied Environmental Sciences
3000 Redhill Avenue
Costa Mesa, CA 92626-4524

Date Received: 08/04/09
Work Order No: 09-08-0198

Project: MGS 09205A / OBGS 09206A



| Client Sample Number | Lab Sample Number | Date Collected | Matrix |
|---|---|---|---|
| **RRI Source-I** | **09-08-0198-1** | **03/10/09** | **Tissue** |

| Parameter | Result | RL | DF | Qual | Units | Date Prepared | Date Analyzed | Method |
|---|---|---|---|---|---|---|---|---|
| Solids, Total | 64.0 | 0.100 | 1 | | % | 08/05/09 | 08/05/09 | SM 2540 B |

| | | | |
|---|---|---|---|
| **RRI Source-II** | **09-08-0198-2** | **03/10/09** | **Tissue** |

| Parameter | Result | RL | DF | Qual | Units | Date Prepared | Date Analyzed | Method |
|---|---|---|---|---|---|---|---|---|
| Solids, Total | 60.7 | 0.100 | 1 | | % | 08/05/09 | 08/05/09 | SM 2540 B |

| | | | |
|---|---|---|---|
| **RRI Source-III** | **09-08-0198-3** | **03/10/09** | **Tissue** |

| Parameter | Result | RL | DF | Qual | Units | Date Prepared | Date Analyzed | Method |
|---|---|---|---|---|---|---|---|---|
| Solids, Total | 69.0 | 0.100 | 1 | | % | 08/05/09 | 08/05/09 | SM 2540 B |

| | | | |
|---|---|---|---|
| **Method Blank** | | **N/A** | **Solid** |

| Parameter | Result | RL | DF | Qual | Units | Date Prepared | Date Analyzed | Method |
|---|---|---|---|---|---|---|---|---|
| Solids, Total | ND | 0.100 | 1 | | % | 08/05/09 | 08/05/09 | SM 2540 B |

RL - Reporting Limit , DF - Dilution Factor , Qual - Qualifiers

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Calscience Environmental Laboratories, Inc.

## Quality Control - Spike/Spike Duplicate

| | | |
|---|---|---|
| MBC Applied Environmental Sciences | Date Received: | 08/04/09 |
| 3000 Redhill Avenue | Work Order No: | 09-08-0198 |
| Costa Mesa, CA 92626-4524 | Preparation: | EPA 3050B |
| | Method: | EPA 6020 |

Project MGS 09205A / OBGS 09206A

| Quality Control Sample ID | Matrix | Instrument | Date Prepared | Date Analyzed | MS/MSD Batch Number |
|---|---|---|---|---|---|
| **09-08-0194-1** | **Tissue** | **ICP/MS 03** | **08/10/09** | **08/10/09** | **090810S01** |

| Parameter | MS %REC | MSD %REC | %REC CL | RPD | RPD CL | Qualifiers |
|---|---|---|---|---|---|---|
| Chromium | 98 | 96 | 80-120 | 2 | 0-20 | |
| Copper | 103 | 101 | 80-120 | 2 | 0-20 | |
| Nickel | 98 | 95 | 80-120 | 3 | 0-20 | |
| Zinc | 96 | 96 | 80-120 | 0 | 0-20 | |

RPD - Relative Percent Difference , CL - Control Limit

Calscience Environmental Laboratories, Inc.

## Quality Control - PDS / PDSD

| | | | |
|---|---|---|---|
| MBC Applied Environmental Sciences | | Date Received | 08/04/09 |
| 3000 Redhill Avenue | | Work Order No: | 09-08-0198 |
| Costa Mesa, CA 92626-4524 | | Preparation: | EPA 3050B |
| | | Method: | EPA 6020 |

Project: MGS 09205A / OBGS 09206A

| Quality Control Sample ID | Matrix | Instrument | Date Prepared | Date Analyzed | PDS/PDSD Batch Number |
|---|---|---|---|---|---|
| **09-08-0194-1** | **Tissue** | **ICP/MS 03** | **08/10/09** | **08/10/09** | **090810S01** |

| Parameter | PDS %REC | PDSD %REC | %REC CL | RPD | RPD CL | Qualifiers |
|---|---|---|---|---|---|---|
| Chromium | 95 | 97 | 75-125 | 2 | 0-20 | |
| Copper | 100 | 97 | 75-125 | 2 | 0-20 | |
| Nickel | 98 | 97 | 75-125 | 1 | 0-20 | |
| Zinc | 74 | 73 | 75-125 | 0 | 0-20 | 5 |

RPD - Relative Percent Difference , CL - Control Limit

**Calscience Environmental Laboratories, Inc.**

## Quality Control - Duplicate

| | | |
|---|---|---|
| MBC Applied Environmental Sciences | Date Received: | N/A |
| 3000 Redhill Avenue | Work Order No: | 09-08-0198 |
| Costa Mesa, CA 92626-4524 | | |

Project: MGS 09205A / OBGS 09206A

**Matrix: Tissue**

| Parameter | Method | QC Sample ID | Date Analyzed | Sample Conc | DUP Conc | RPD | RPD CL | Qualifiers |
|---|---|---|---|---|---|---|---|---|
| Solids, Total | SM 2540 B | 09-08-0194-1 | 08/05/09 | 66.5 | 66.4 | 0 | 0-25 | |

RPD - Relative Percent Difference , CL - Control Limit

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Calscience Environmental Laboratories, Inc.

# Quality Control - LCS/LCS Duplicate

| | | | |
|---|---|---|---|
| MBC Applied Environmental Sciences | | Date Received: | N/A |
| 3000 Redhill Avenue | | Work Order No: | 09-08-0198 |
| Costa Mesa, CA 92626-4524 | | Preparation: | EPA 3050B |
| | | Method: | EPA 6020 |

Project: MGS 09205A / OBGS 09206A

| Quality Control Sample ID | Matrix | Instrument | Date Prepared | Date Analyzed | LCS/LCSD Batch Number |
|---|---|---|---|---|---|
| **099-12-411-12** | **Tissue** | **ICP/MS 03** | **08/10/09** | **08/10/09** | **090810L01** |

| Parameter | LCS %REC | LCSD %REC | %REC CL | RPD | RPD CL | Qualifiers |
|---|---|---|---|---|---|---|
| Chromium | 100 | 98 | 80-120 | 2 | 0-20 | |
| Copper | 104 | 102 | 80-120 | 1 | 0-20 | |
| Nickel | 101 | 100 | 80-120 | 0 | 0-20 | |
| Zinc | 105 | 107 | 80-120 | 2 | 0-20 | |

RPD - Relative Percent Difference , CL - Control Limit

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Calscience Environmental Laboratories, Inc.

# Analytical Report

MBC Applied Environmental Sciences
3000 Redhill Avenue
Costa Mesa, CA 92626-4524

| | |
|---|---|
| Date Received: | 08/04/09 |
| Work Order No: | 09-08-0202 |
| Preparation: | EPA 3050B |
| Method: | EPA 6020 |
| Units: | mg/kg |

Project: RBGS 09204A



| Client Sample Number | Lab Sample Number | Date/Time Collected | Matrix | Instrument | Date Prepared | Date/Time Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **RBGS MBP - I** | **09-08-0202-1-A** | **07/15/09 00:00** | **Tissue** | **ICP/MS 03** | **08/10/09** | **08/10/09 23:06** | **090810L02** |

Comment(s): -Results are reported on a dry weight basis.

| Parameter | Result | RL | DF | Qual | Parameter | Result | RL | DF | Qual |
|---|---|---|---|---|---|---|---|---|---|
| Chromium | 1.21 | 0.157 | 0.5 | | Nickel | 0.427 | 0.0787 | 0.5 | |
| Copper | 3.75 | 0.236 | 0.5 | | Zinc | 35.6 | 1.57 | 0.5 | |

| Client Sample Number | Lab Sample Number | Date/Time Collected | Matrix | Instrument | Date Prepared | Date/Time Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **RBGS MBP - II** | **09-08-0202-2-A** | **07/15/09 00:00** | **Tissue** | **ICP/MS 03** | **08/10/09** | **08/10/09 23:10** | **090810L02** |

Comment(s): -Results are reported on a dry weight basis.

| Parameter | Result | RL | DF | Qual | Parameter | Result | RL | DF | Qual |
|---|---|---|---|---|---|---|---|---|---|
| Chromium | 1.12 | 0.161 | 0.5 | | Nickel | 0.347 | 0.0804 | 0.5 | |
| Copper | 3.89 | 0.241 | 0.5 | | Zinc | 32.6 | 1.61 | 0.5 | |

| Client Sample Number | Lab Sample Number | Date/Time Collected | Matrix | Instrument | Date Prepared | Date/Time Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **RBGS MBP - III** | **09-08-0202-3-A** | **07/15/09 00:00** | **Tissue** | **ICP/MS 03** | **08/10/09** | **08/10/09 23:14** | **090810L02** |

Comment(s): -Results are reported on a dry weight basis.

| Parameter | Result | RL | DF | Qual | Parameter | Result | RL | DF | Qual |
|---|---|---|---|---|---|---|---|---|---|
| Chromium | 1.26 | 0.163 | 0.5 | | Nickel | 0.570 | 0.0816 | 0.5 | |
| Copper | 3.63 | 0.245 | 0.5 | | Zinc | 38.3 | 1.63 | 0.5 | |

| Client Sample Number | Lab Sample Number | Date/Time Collected | Matrix | Instrument | Date Prepared | Date/Time Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **Method Blank** | **099-12-411-13** | **N/A** | **Tissue** | **ICP/MS 03** | **08/10/09** | **08/10/09 21:04** | **090810L02** |

| Parameter | Result | RL | DF | Qual | Parameter | Result | RL | DF | Qual |
|---|---|---|---|---|---|---|---|---|---|
| Chromium | ND | 0.100 | 0.5 | | Nickel | ND | 0.0500 | 0.5 | |
| Copper | ND | 0.150 | 0.5 | | Zinc | ND | 1.00 | 0.5 | |

RL - Reporting Limit , DF - Dilution Factor , Qual - Qualifiers

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Appendix E. (Cont.).

**Calscience Environmental Laboratories, Inc.**

## Analytical Report

MBC Applied Environmental Sciences
3000 Redhill Avenue
Costa Mesa, CA 92626-4524

Date Received: 08/04/09
Work Order No: 09-08-0202

Project: RBGS 09204A



| Client Sample Number | Lab Sample Number | Date Collected | Matrix |
|---|---|---|---|
| **RBGS MBP - I** | **09-08-0202-1** | **07/15/09** | **Tissue** |

| Parameter | Result | RL | DF | Qual | Units | Date Prepared | Date Analyzed | Method |
|---|---|---|---|---|---|---|---|---|
| Solids, Total | 63.5 | 0.100 | 1 | | % | 08/05/09 | 08/05/09 | SM 2540 B |

| | | | |
|---|---|---|---|
| **RBGS MBP - II** | **09-08-0202-2** | **07/15/09** | **Tissue** |

| Parameter | Result | RL | DF | Qual | Units | Date Prepared | Date Analyzed | Method |
|---|---|---|---|---|---|---|---|---|
| Solids, Total | 62.2 | 0.100 | 1 | | % | 08/05/09 | 08/05/09 | SM 2540 B |

| | | | |
|---|---|---|---|
| **RBGS MBP- III** | **09-08-0202-3** | **07/15/09** | **Tissue** |

| Parameter | Result | RL | DF | Qual | Units | Date Prepared | Date Analyzed | Method |
|---|---|---|---|---|---|---|---|---|
| Solids, Total | 61.3 | 0.100 | 1 | | % | 08/05/09 | 08/05/09 | SM 2540 B |

| | | | |
|---|---|---|---|
| **Method Blank** | | **N/A** | **Solid** |

| Parameter | Result | RL | DF | Qual | Units | Date Prepared | Date Analyzed | Method |
|---|---|---|---|---|---|---|---|---|
| Solids, Total | ND | 0.100 | 1 | | % | 08/05/09 | 08/05/09 | SM 2540 B |

RL - Reporting Limit , DF - Dilution Factor , Qual - Qualifiers

Appendix E. (Cont.).

**Calscience Environmental Laboratories, Inc.**

## Quality Control - Spike/Spike Duplicate

MBC Applied Environmental Sciences
3000 Redhill Avenue
Costa Mesa, CA 92626-4524

| | |
|---|---|
| Date Received: | 08/04/09 |
| Work Order No: | 09-08-0202 |
| Preparation: | EPA 3050B |
| Method: | EPA 6020 |

Project RBGS 09204A

| Quality Control Sample ID | Matrix | Instrument | Date Prepared | Date Analyzed | MS/MSD Batch Number |
|---|---|---|---|---|---|
| **09-08-0200-1** | **Tissue** | **ICP/MS 03** | **08/10/09** | **08/10/09** | **090810S02** |

| Parameter | MS %REC | MSD %REC | %REC CL | RPD | RPD CL | Qualifiers |
|---|---|---|---|---|---|---|
| Chromium | 102 | 101 | 80-120 | 1 | 0-20 | |
| Copper | 60 | 57 | 80-120 | 2 | 0-20 | 3 |
| Nickel | 103 | 102 | 80-120 | 1 | 0-20 | |
| Zinc | 108 | 104 | 80-120 | 2 | 0-20 | |

RPD - Relative Percent Difference , CL - Control Limit

Appendix E. (Cont.).

Calscience Environmental Laboratories, Inc.

## Quality Control - PDS / PDSD

| | | | |
|---|---|---|---|
| MBC Applied Environmental Sciences | | Date Received | 08/04/09 |
| 3000 Redhill Avenue | | Work Order No: | 09-08-0202 |
| Costa Mesa, CA 92626-4524 | | Preparation: | EPA 3050B |
| | | Method: | EPA 6020 |

Project: RBGS 09204A

| Quality Control Sample ID | Matrix | Instrument | Date Prepared | Date Analyzed | PDS/PDSD Batch Number |
|---|---|---|---|---|---|
| **09-08-0200-1** | **Tissue** | **ICP/MS 03** | **08/10/09** | **08/10/09** | **090810S02** |

| Parameter | PDS %REC | PDSD %REC | %REC CL | RPD | RPD CL | Qualifiers |
|---|---|---|---|---|---|---|
| Chromium | 99 | 99 | 75-125 | 1 | 0-20 | |
| Copper | 101 | 99 | 75-125 | 1 | 0-20 | |
| Nickel | 99 | 98 | 75-125 | 1 | 0-20 | |
| Zinc | 94 | 95 | 75-125 | 0 | 0-20 | |

RPD - Relative Percent Difference , CL - Control Limit

Calscience Environmental Laboratories, Inc.

# Quality Control - Duplicate

MBC Applied Environmental Sciences
3000 Redhill Avenue
Costa Mesa, CA 92626-4524

Date Received: N/A
Work Order No: 09-08-0202

Project: RBGS 09204A

**Matrix: Tissue**

| Parameter | Method | QC Sample ID | Date Analyzed | Sample Conc | DUP Conc | RPD | RPD CL | Qualifiers |
|---|---|---|---|---|---|---|---|---|
| Solids, Total | SM 2540 B | 09-08-0199-1 | 08/05/09 | 63.4 | 66.3 | 4 | 0-25 | |

RPD - Relative Percent Difference , CL - Control Limit

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Calscience Environmental Laboratories, Inc.

## Quality Control - LCS/LCS Duplicate

| | | | |
|---|---|---|---|
| MBC Applied Environmental Sciences | | Date Received: | N/A |
| 3000 Redhill Avenue | | Work Order No: | 09-08-0202 |
| Costa Mesa, CA 92626-4524 | | Preparation: | EPA 3050B |
| | | Method: | EPA 6020 |

Project: RBGS 09204A

| Quality Control Sample ID | Matrix | Instrument | Date Prepared | Date Analyzed | LCS/LCSD Batch Number |
|---|---|---|---|---|---|
| **099-12-411-13** | **Tissue** | **ICP/MS 03** | **08/10/09** | **08/10/09** | **090810L02** |

| Parameter | LCS %REC | LCSD %REC | %REC CL | RPD | RPD CL | Qualifiers |
|---|---|---|---|---|---|---|
| Chromium | 101 | 101 | 80-120 | 0 | 0-20 | |
| Copper | 102 | 105 | 80-120 | 3 | 0-20 | |
| Nickel | 100 | 102 | 80-120 | 3 | 0-20 | |
| Zinc | 104 | 104 | 80-120 | 0 | 0-20 | |

RPD - Relative Percent Difference , CL - Control Limit

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# APPENDIX F

## Infauna data by station

**Appendix F-1. Infaunal master species list. Mandalay Generating Station NPDES, 2009.**

PHYLUM (Phy)
- Subphylum or Class
  - Species

CNIDARIA (CN)
- Anthozoa
  - *Renilla koellikeri*[1]
  - *Zaolutus actius*

PLATYHELMINTHES (PL)
  - *Stylochoplana* sp

NEMERTEA (NE)
- Anopla
  - *Carinoma mutabilis*
  - Lineidae
  - *Tubulanus polymorphus*[2]
- Enopla
  - Nemertea sp B Paquette 2005
  - *Paranemertes californica*[3]
  - *Tetrastemma candidum*
- Uncertain
  - Nemertea

NEMATODA (NT)
  - Nematoda

MOLLUSCA (MO)
- Gastropoda
  - *Caesia perpinguis*[4]
  - *Callianax pycna*
  - *Skenea dalli*[5]
- Bivalvia
  - *Cooperella subdiaphana*
  - *Leukoma staminea*[6]
  - *Macoma* sp
  - *Mactromeris catilliformis*[7]
  - *Mysella* sp C SCAMIT 1988
  - Mytilidae
  - *Periploma discus*
  - *Petricola* sp
  - *Rochefortia coani*[8]
  - *Rochefortia tumida*[9]
  - *Siliqua lucida*
  - *Solen sicarius*
  - *Tellina bodegensis*
  - *Tellina modesta*

ANNELIDA (AN)
- Polychaeta
  - *Amaeana occidentalis*
  - *Ampharete labrops*
  - *Apoprionospio pygmaea*[10]
  - *Aricidea (Acmira) catherinae*[11]
  - *Armandia brevis*[12]
  - *Chone eiffelturris*[13]
  - *Chone mollis*
  - *Dispio uncinata*
  - *Glycera macrobranchia*[14]
  - *Glycinde armigera*
  - *Goniadia littorea*
  - *Hesionella mccullochae*
  - Maldanidae
  - *Malmgreniella macginitiei*
  - *Mediomastus acutus*
  - *Nephtys caecoides*

ANNELIDA (AN) Cont
- Polychaeta (cont)
  - *Nephtys cornuta*
  - *Onuphis* sp A SCAMIT 1992
  - *Owenia collaris*[15]
  - *Pectinaria californiensis*
  - Phyllodocidae
  - *Phyllodoce hartmanae*
  - *Polydora cirrosa*
  - *Prionospio (Prionospio) jubata*
  - *Scoletoma* sp C (Harris 1985)
  - *Scoletoma tetraura* Cmplx[16]
  - *Scoloplos armiger* Cmplx[17]
  - *Spiochaetopterus costarum* Cmplx[18]
  - *Spiophanes bombyx*
  - *Spiophanes duplex*[19]
  - *Sthenelais tertiaglabra*
  - *Typosyllis farallonensis*[20]

ARTHROPODA (AR)
- Ostracoda
  - *Euphilomedes carcharodonta*
  - *Parasterope hulingsi*
- Maxillopoda
  - Harpacticoida
- Malacostraca
  - *Americhelidium shoemakeri*[21]
  - *Anchicolurus occidentalis*
  - *Campylaspis* sp C Myers & Benedict 1974
  - *Caprella mendax*
  - *Cumella californica*[22]
  - *Diastylopsis tenuis*
  - *Edotia sublittoralis*
  - *Eohaustorius sawyeri*
  - *Gammaropsis thompsoni*
  - *Ischyrocerus pelagops*
  - *Jassa slatteryi*[23]
  - *Lamprops carinatus*
  - *Lamprops quadriplicatus*
  - *Mayerella banksia*
  - *Photis brevipes*
  - *Photis macinerneyi*
  - *Rhepoxynius abronius*
  - *Rhepoxynius menziesi*[24]
  - *Rhepoxynius* sp
  - *Rhepoxynius* sp A SCAMIT 1987
  - *Rhepoxynius tridentatus*
  - *Rhepoxynius variatus*
  - *Romaleon* sp[25]
  - *Uromunna ubiquita*[26]

ECHINODERMATA (EC)
- Ophiuroidea
  - Amphiuridae
- Echinoidea
  - *Dendraster excentricus*

PHORONA (PR)
  - *Phoronis* sp

CHORDATA (CO)
  - Enteropneusta[27]

## Appendix F-1. Cont.

| PHYLUM (Phy)<br>Subphylum or Class<br>Species | PHYLUM<br>Subphylum or Class<br>Species |
|---|---|

The following footnotes indicate names used in previous surveys:

1 *Renilla kollikeri*
2 *Tubulanus pellucidus/polymorphus*
3 *Paranemertes* sp A of SCAMIT
4 *Nassarius perpinguis*
5 *Cyclostremella dalli*
6 *Protothaca staminea*
7 *Spisula catilliformis*
8 *Rocheforta* sp A SCAMIT 1988
9 *Mysella tumida*
10 *Apoprionospio pygmaeus*
11 *Acesta catherinae, Acmira catherinae*
12 *Armandia bioculata*
13 *Chone* sp SD 1 Pt. Loma 1997
14 *Glycera convoluta*
15 *Owenia fusiformis*
16 *Lumbrineris "tetraura", L. tetraura*
17 *Scoloplos "armiger", S. armiger*
18 *Spiochaetopterus costarum*
19 *Spiophanes missionensis*
20 *Syllis (Typosyllis) farallonensis*
21 *Synchelidium shoemakeri*
22 *Cumella* sp A MBC
23 *Jassa falcata* (in part)
24 *Paraphoxus epistomus, Rhepoxynius epistomus*
25 *Cancer* sp (in part)
26 *Munna ubiquita*
27 Hemichordata

**Appendix F-2. Infauna results by station. Mandalay Generating Station NPDES, 2009.**

| | | Station | | | | | | Percent |
|---|---|---|---|---|---|---|---|---|
| Phylum | Species | B1 | B2 | B3 | B4 | B5 | Total | Total |
| CN | *Zaolutus actius* | 164 | 228 | 507 | 1 | 25 | 925 | 20.33 |
| AN | *Apoprionospio pygmaea* | 164 | 84 | 66 | 60 | 199 | 573 | 12.60 |
| AN | *Owenia collaris* | 74 | 163 | 276 | 10 | 33 | 556 | 12.22 |
| AN | *Armandia brevis* | 44 | 209 | 137 | 3 | 133 | 526 | 11.56 |
| AN | *Ampharete labrops* | 5 | 87 | 112 | - | 69 | 273 | 6.00 |
| MO | *Tellina modesta* | 40 | 57 | 52 | 30 | 76 | 255 | 5.61 |
| AR | *Photis macinerneyi* | 50 | 147 | 37 | 9 | 10 | 253 | 5.56 |
| AR | *Diastylopsis tenuis* | 12 | 26 | 29 | 8 | 28 | 103 | 2.26 |
| AN | *Onuphis* sp A SCAMIT 1992 | 19 | 29 | 24 | 14 | 12 | 98 | 2.15 |
| AN | *Mediomastus acutus* | 6 | 2 | 1 | 7 | 68 | 84 | 1.85 |
| AR | *Rhepoxynius menziesi* | 2 | 25 | 6 | 25 | 20 | 78 | 1.71 |
| AN | *Pectinaria californiensis* | 2 | 6 | 32 | 2 | 35 | 77 | 1.69 |
| AR | *Euphilomedes carcharodonta* | 46 | 6 | 2 | 21 | - | 75 | 1.65 |
| AN | *Scoloplos armiger* Cmplx | 17 | 13 | 16 | 25 | - | 71 | 1.56 |
| AR | *Uromunna ubiquita* | 8 | 43 | 10 | 1 | 9 | 71 | 1.56 |
| AN | *Chone eiffelturris* | - | 16 | 11 | 7 | 14 | 48 | 1.06 |
| AN | *Spiophanes bombyx* | 11 | 7 | 16 | 4 | 9 | 47 | 1.03 |
| MO | *Siliqua lucida* | 8 | 13 | 11 | 7 | 3 | 42 | 0.92 |
| EC | *Dendraster excentricus* | 6 | 15 | 3 | 8 | 3 | 35 | 0.77 |
| AR | *Romaleon* sp | 1 | - | 27 | - | 5 | 33 | 0.73 |
| AN | *Goniada littorea* | 1 | 1 | 6 | 2 | 20 | 30 | 0.66 |
| AR | *Rhepoxynius* sp A SCAMIT 1987 | - | 3 | 1 | 1 | 14 | 19 | 0.42 |
| NE | Lineidae | - | 5 | 7 | 4 | 3 | 19 | 0.42 |
| AR | *Americhelidium shoemakeri* | 7 | 6 | 2 | 2 | 1 | 18 | 0.40 |
| NE | *Carinoma mutabilis* | 7 | 4 | 1 | 2 | 2 | 16 | 0.35 |
| AN | *Glycera macrobranchia* | 5 | 5 | 2 | 3 | - | 15 | 0.33 |
| AN | *Spiochaetopterus costarum* Cmplx | 2 | 3 | 4 | 3 | 2 | 14 | 0.31 |
| MO | *Macoma* sp | 1 | 1 | 1 | 5 | 5 | 13 | 0.29 |
| MO | *Skenea dalli* | 1 | 10 | 2 | - | - | 13 | 0.29 |
| AN | *Nephtys caecoides* | 5 | 2 | 1 | 3 | - | 11 | 0.24 |
| AR | *Photis brevipes* | - | - | 2 | - | 6 | 8 | 0.18 |
| MO | Mytilidae | - | 6 | 1 | - | - | 7 | 0.15 |
| NE | *Tetrastemma candidum* | 1 | 1 | 2 | 1 | 2 | 7 | 0.15 |
| NT | Nematoda | - | 2 | 2 | - | 3 | 7 | 0.15 |
| AN | *Phyllodoce hartmanae* | - | 3 | 1 | - | 2 | 6 | 0.13 |
| MO | *Mactromeris catilliformis* | - | 1 | 1 | - | 4 | 6 | 0.13 |
| AN | *Prionospio (Prionospio) jubata* | 1 | - | 4 | - | - | 5 | 0.11 |
| AR | *Caprella mendax* | 1 | - | 2 | 2 | - | 5 | 0.11 |
| AR | *Ischyrocerus pelagops* | 1 | 1 | 2 | - | 1 | 5 | 0.11 |
| AR | *Lamprops quadriplicatus* | - | - | 1 | 4 | - | 5 | 0.11 |
| AN | *Spiophanes duplex* | - | - | 4 | - | - | 4 | 0.09 |
| AN | *Typosyllis farallonensis* | 2 | 1 | 1 | - | - | 4 | 0.09 |
| AR | *Anchicolurus occidentalis* | 1 | 1 | - | 2 | - | 4 | 0.09 |
| AR | *Lamprops carinatus* | 1 | 3 | - | - | - | 4 | 0.09 |
| EC | Amphiuridae | - | 4 | - | - | - | 4 | 0.09 |
| MO | *Leukoma staminea* | 1 | - | 2 | - | 1 | 4 | 0.09 |
| MO | *Caesia perpinguis* | - | 2 | 1 | - | - | 3 | 0.07 |
| MO | *Cooperella subdiaphana* | - | - | - | 1 | 2 | 3 | 0.07 |
| MO | Rochefortia coani | - | - | - | - | 3 | 3 | 0.07 |
| MO | *Solen sicarius* | 1 | - | - | 1 | 1 | 3 | 0.07 |
| NE | Nemertea | - | - | 2 | - | 1 | 3 | 0.07 |
| PL | *Stylochoplana* sp | 1 | 1 | - | 1 | - | 3 | 0.07 |
| PR | *Phoronis* sp | - | - | 1 | - | 2 | 3 | 0.07 |
| AN | *Dispio uncinata* | 1 | 1 | - | - | - | 2 | 0.04 |
| AN | *Glycinde armigera* | - | 1 | 1 | - | - | 2 | 0.04 |
| AN | *Malmgreniella macginitiei* | 1 | - | - | - | 1 | 2 | 0.04 |
| AN | Phyllodocidae | 1 | 1 | - | - | - | 2 | 0.04 |
| AN | *Polydora cirrosa* | - | 2 | - | - | - | 2 | 0.04 |
| AN | *Scoletoma tetraura* Cmplx | - | 1 | - | - | 1 | 2 | 0.04 |
| AR | *Campylaspis* sp C Myers&Benedict 1974 | 1 | - | - | 1 | - | 2 | 0.04 |
| AR | *Edotia sublittoralis* | 2 | - | - | - | - | 2 | 0.04 |
| AR | *Rhepoxyniu*s sp | 2 | - | - | - | - | 2 | 0.04 |
| AR | *Rhepoxynius tridentatus* | - | - | 2 | - | - | 2 | 0.04 |
| AR | *Rhepoxynius variatus* | 2 | - | - | - | - | 2 | 0.04 |
| MO | *Tellina bodegensis* | 2 | - | - | - | - | 2 | 0.04 |

**Appendix F-2. (Cont.).**

| Phylum | Species | Station B1 | B2 | B3 | B4 | B5 | Total | Percent Total |
|---|---|---|---|---|---|---|---|---|
| NE | *Paranemertes californica* | 2 | - | - | - | - | 2 | 0.04 |
| NE | *Tubulanus polymorphus* | - | - | - | 2 | - | 2 | 0.04 |
| AN | *Amaeana occidentalis* | 1 | - | - | - | - | 1 | 0.02 |
| AN | *Aricidea (Acmira) catherinae* | - | - | - | 1 | - | 1 | 0.02 |
| AN | *Chone mollis* | - | 1 | - | - | - | 1 | 0.02 |
| AN | *Hesionella mccullochae* | - | 1 | - | - | - | 1 | 0.02 |
| AN | Maldanidae | - | - | 1 | - | - | 1 | 0.02 |
| AN | *Nephtys cornuta* | - | - | - | - | 1 | 1 | 0.02 |
| AN | *Scoletoma* sp C (Harris 1985) | - | 1 | - | - | - | 1 | 0.02 |
| AN | *Sthenelais tertiaglabra* | - | - | - | - | 1 | 1 | 0.02 |
| AR | *Cumella californica* | - | - | - | - | 1 | 1 | 0.02 |
| AR | *Eohaustorius sawyeri* | - | - | - | 1 | - | 1 | 0.02 |
| AR | *Gammaropsis thompsoni* | 1 | - | - | - | - | 1 | 0.02 |
| AR | Harpacticoida | - | - | 1 | - | - | 1 | 0.02 |
| AR | *Jassa slatteryi* | 1 | - | - | - | - | 1 | 0.02 |
| AR | *Mayerella banksia* | - | 1 | - | - | - | 1 | 0.02 |
| AR | *Parasterope hulingsi* | - | - | 1 | - | - | 1 | 0.02 |
| AR | *Rhepoxynius abronius* | - | - | - | 1 | - | 1 | 0.02 |
| CN | *Renilla koellikeri* | - | - | - | - | 1 | 1 | 0.02 |
| CO | Enteropneusta | - | - | - | 1 | - | 1 | 0.02 |
| MO | *Callianax pycna* | 1 | - | - | - | - | 1 | 0.02 |
| MO | *Mysella* sp C SCAMIT 1988 | - | - | - | 1 | - | 1 | 0.02 |
| MO | *Periploma discus* | - | 1 | - | - | - | 1 | 0.02 |
| MO | *Petricola* sp | - | - | - | - | 1 | 1 | 0.02 |
| MO | *Rochefortia tumida* | - | - | - | - | 1 | 1 | 0.02 |
| NE | Nemertea sp B Paquette 2005 | 1 | - | - | - | - | 1 | 0.02 |
| | Number of individuals | 738 | 1253 | 1437 | 287 | 834 | 4549 | |
| | Number of species | 51 | 51 | 51 | 41 | 45 | 91 | |
| | Diversity (H') | 2.60 | 2.65 | 2.30 | 2.96 | 2.69 | 2.83 | |

**Appendix F-3. Infaunal data by station and replicate. Mandalay Generating Station NPDES, 2009.**

**Station B1**

| Phylum | Species | Replicate B1-I | B1-II | B1-III | B1-IV | Total | Percent Composition | Density No./m² |
|---|---|---|---|---|---|---|---|---|
| AN | *Apoprionospio pygmaea* | 47 | 50 | 45 | 22 | 164 | 22.22 | 4100.0 |
| CN | *Zaolutus actius* | 30 | 33 | 47 | 54 | 164 | 22.22 | 4100.0 |
| AN | *Owenia collaris* | 15 | 20 | 18 | 21 | 74 | 10.03 | 1850.0 |
| AR | *Photis macinerneyi* | 2 | 13 | 21 | 14 | 50 | 6.78 | 1250.0 |
| AR | *Euphilomedes carcharodonta* | 11 | 14 | 15 | 6 | 46 | 6.23 | 1150.0 |
| AN | *Armandia brevis* | 17 | 14 | 5 | 8 | 44 | 5.96 | 1100.0 |
| MO | *Tellina modesta* | 12 | 11 | 8 | 9 | 40 | 5.42 | 1000.0 |
| AN | *Onuphis* sp A SCAMIT 1992 | 6 | 3 | 3 | 7 | 19 | 2.57 | 475.0 |
| AN | *Scoloplos armiger* Cmplx | 9 | 4 | - | 4 | 17 | 2.30 | 425.0 |
| AR | *Diastylopsis tenuis* | - | 3 | 6 | 3 | 12 | 1.63 | 300.0 |
| AN | *Spiophanes bombyx* | 2 | 4 | 4 | 1 | 11 | 1.49 | 275.0 |
| AR | *Uromunna ubiquita* | 1 | 3 | 1 | 3 | 8 | 1.08 | 200.0 |
| MO | *Siliqua lucida* | 1 | 4 | 2 | 1 | 8 | 1.08 | 200.0 |
| AR | *Americhelidium shoemakeri* | - | 4 | 3 | - | 7 | 0.95 | 175.0 |
| NE | *Carinoma mutabilis* | 2 | 1 | 2 | 2 | 7 | 0.95 | 175.0 |
| AN | *Mediomastus acutus* | 1 | 3 | - | 2 | 6 | 0.81 | 150.0 |
| EC | *Dendraster excentricus* | - | 3 | 1 | 2 | 6 | 0.81 | 150.0 |
| AN | *Ampharete labrops* | 1 | 3 | - | 1 | 5 | 0.68 | 125.0 |
| AN | *Glycera macrobranchia* | 2 | - | 3 | - | 5 | 0.68 | 125.0 |
| AN | *Nephtys caecoides* | 2 | 2 | - | 1 | 5 | 0.68 | 125.0 |
| AN | *Pectinaria californiensis* | - | - | - | 2 | 2 | 0.27 | 50.0 |
| AN | *Spiochaetopterus costarum* Cmplx | - | - | 1 | 1 | 2 | 0.27 | 50.0 |
| AN | *Typosyllis farallonensis* | - | 2 | - | - | 2 | 0.27 | 50.0 |
| AR | *Edotia sublittoralis* | - | - | 2 | - | 2 | 0.27 | 50.0 |
| AR | *Rhepoxynius menziesi* | 2 | - | - | - | 2 | 0.27 | 50.0 |
| AR | *Rhepoxynius* sp | - | 1 | 1 | - | 2 | 0.27 | 50.0 |
| AR | *Rhepoxynius variatus* | 2 | - | - | - | 2 | 0.27 | 50.0 |
| MO | *Tellina bodegensis* | 1 | 1 | - | - | 2 | 0.27 | 50.0 |
| NE | *Paranemertes californica* | 1 | - | 1 | - | 2 | 0.27 | 50.0 |
| AN | *Amaeana occidentalis* | - | 1 | - | - | 1 | 0.14 | 25.0 |
| AN | *Dispio uncinata* | 1 | - | - | - | 1 | 0.14 | 25.0 |
| AN | *Goniada littorea* | 1 | - | - | - | 1 | 0.14 | 25.0 |
| AN | *Malmgreniella macginitiei* | - | 1 | - | - | 1 | 0.14 | 25.0 |
| AN | Phyllodocidae | - | - | 1 | - | 1 | 0.14 | 25.0 |
| AN | *Prionospio (Prionospio) jubata* | 1 | - | - | - | 1 | 0.14 | 25.0 |
| AR | *Anchicolurus occidentalis* | 1 | - | - | - | 1 | 0.14 | 25.0 |
| AR | *Campylaspis* sp C Myers&Benedict 1974 | - | - | 1 | - | 1 | 0.14 | 25.0 |
| AR | *Caprella mendax* | 1 | - | - | - | 1 | 0.14 | 25.0 |
| AR | *Gammaropsis thompsoni* | 1 | - | - | - | 1 | 0.14 | 25.0 |
| AR | *Ischyrocerus pelagops* | - | - | 1 | - | 1 | 0.14 | 25.0 |
| AR | *Jassa slatteryi* | - | - | - | 1 | 1 | 0.14 | 25.0 |
| AR | *Lamprops carinatus* | - | 1 | - | - | 1 | 0.14 | 25.0 |
| AR | *Romaleon* sp | - | - | - | 1 | 1 | 0.14 | 25.0 |
| MO | *Callianax pycna* | - | 1 | - | - | 1 | 0.14 | 25.0 |
| MO | *Leukoma staminea* | - | - | 1 | - | 1 | 0.14 | 25.0 |
| MO | *Macoma* sp | - | - | - | 1 | 1 | 0.14 | 25.0 |
| MO | *Skenea dalli* | - | - | 1 | - | 1 | 0.14 | 25.0 |
| MO | *Solen sicarius* | - | - | 1 | - | 1 | 0.14 | 25.0 |
| NE | *Nemertea* sp B Paquette 2005 | - | - | 1 | - | 1 | 0.14 | 25.0 |
| NE | *Tetrastemma candidum* | 1 | - | - | - | 1 | 0.14 | 25.0 |
| PL | *Stylochoplana* sp | - | 1 | - | - | 1 | 0.14 | 25.0 |

**Summary**

| Parameter | Replicate B1-I | B1-II | B1-III | B1-IV | Station Total | Replicate Mean | S.D. |
|---|---|---|---|---|---|---|---|
| Number of individuals | 174 | 201 | 196 | 167 | 738 | 184.5 | 16.5 |
| Number of species | 28 | 27 | 27 | 23 | 51 | 26.3 | 2.2 |
| Diversity (H') | 2.47 | 2.57 | 2.40 | 2.35 | 2.60 | 2.45 | 0.10 |

**Appendix F-3. (Cont.).**

**Station B2**

| Phylum | Species | Replicate B2-I | B2-II | B2-III | B2-IV | Total | Percent Composition | Density No./m² |
|---|---|---|---|---|---|---|---|---|
| CN | *Zaolutus actius* | 21 | 72 | 85 | 50 | 228 | 18.20 | 5700.0 |
| AN | *Armandia brevis* | 16 | 114 | 21 | 58 | 209 | 16.68 | 5225.0 |
| AN | *Owenia collaris* | 15 | 61 | 49 | 38 | 163 | 13.01 | 4075.0 |
| AR | *Photis macinerneyi* | 9 | 57 | 36 | 45 | 147 | 11.73 | 3675.0 |
| AN | *Ampharete labrops* | 10 | 32 | 24 | 21 | 87 | 6.94 | 2175.0 |
| AN | *Apoprionospio pygmaea* | 20 | 42 | 4 | 18 | 84 | 6.70 | 2100.0 |
| MO | *Tellina modesta* | 6 | 18 | 21 | 12 | 57 | 4.55 | 1425.0 |
| AR | *Uromunna ubiquita* | 1 | 12 | 14 | 16 | 43 | 3.43 | 1075.0 |
| AN | *Onuphis* sp A SCAMIT 1992 | 5 | 9 | 8 | 7 | 29 | 2.31 | 725.0 |
| AR | *Diastylopsis tenuis* | 1 | 7 | 11 | 7 | 26 | 2.08 | 650.0 |
| AR | *Rhepoxynius menziesi* | 3 | 6 | 10 | 6 | 25 | 2.00 | 625.0 |
| AN | *Chone eiffelturris* | 2 | 4 | 3 | 7 | 16 | 1.28 | 400.0 |
| EC | *Dendraster excentricus* | 4 | 3 | 5 | 3 | 15 | 1.20 | 375.0 |
| AN | *Scoloplos armiger* Cmplx | 4 | 6 | 3 | - | 13 | 1.04 | 325.0 |
| MO | *Siliqua lucida* | 6 | 1 | 2 | 4 | 13 | 1.04 | 325.0 |
| MO | *Skenea dalli* | - | 2 | 5 | 3 | 10 | 0.80 | 250.0 |
| AN | *Spiophanes bombyx* | 1 | 2 | 3 | 1 | 7 | 0.56 | 175.0 |
| AN | *Pectinaria californiensis* | 1 | - | 3 | 2 | 6 | 0.48 | 150.0 |
| AR | *Americhelidium shoemakeri* | 3 | - | 2 | 1 | 6 | 0.48 | 150.0 |
| AR | *Euphilomedes carcharodonta* | 2 | 1 | - | 3 | 6 | 0.48 | 150.0 |
| MO | Mytilidae | 2 | 2 | 2 | - | 6 | 0.48 | 150.0 |
| AN | *Glycera macrobranchia* | 2 | - | - | 3 | 5 | 0.40 | 125.0 |
| NE | Lineidae | - | 4 | - | 1 | 5 | 0.40 | 125.0 |
| EC | Amphiuridae | 2 | 2 | - | - | 4 | 0.32 | 100.0 |
| NE | *Carinoma mutabilis* | 2 | 1 | 1 | - | 4 | 0.32 | 100.0 |
| AN | *Phyllodoce hartmanae* | - | 3 | - | - | 3 | 0.24 | 75.0 |
| AN | *Spiochaetopterus costarum* Cmplx | - | 1 | 1 | 1 | 3 | 0.24 | 75.0 |
| AR | *Lamprops carinatus* | - | - | - | 3 | 3 | 0.24 | 75.0 |
| AR | *Rhepoxynius* sp A SCAMIT 1987 | - | - | 2 | 1 | 3 | 0.24 | 75.0 |
| AN | *Mediomastus acutus* | 1 | 1 | - | - | 2 | 0.16 | 50.0 |
| AN | *Nephtys caecoides* | 1 | 1 | - | - | 2 | 0.16 | 50.0 |
| AN | *Polydora cirrosa* | - | 2 | - | - | 2 | 0.16 | 50.0 |
| MO | *Caesia perpinguis* | 1 | 1 | - | - | 2 | 0.16 | 50.0 |
| NT | Nematoda | - | 1 | 1 | - | 2 | 0.16 | 50.0 |
| AN | *Chone mollis* | 1 | - | - | - | 1 | 0.08 | 25.0 |
| AN | *Dispio uncinata* | - | - | - | 1 | 1 | 0.08 | 25.0 |
| AN | *Glycinde armigera* | 1 | - | - | - | 1 | 0.08 | 25.0 |
| AN | *Goniada littorea* | - | 1 | - | - | 1 | 0.08 | 25.0 |
| AN | *Hesionella mccullochae* | - | - | - | 1 | 1 | 0.08 | 25.0 |
| AN | Phyllodocidae | - | - | - | 1 | 1 | 0.08 | 25.0 |
| AN | *Scoletoma* sp C (Harris 1985) | - | - | 1 | - | 1 | 0.08 | 25.0 |
| AN | *Scoletoma tetraura* Cmplx | - | - | 1 | - | 1 | 0.08 | 25.0 |
| AN | *Typosyllis farallonensis* | 1 | - | - | - | 1 | 0.08 | 25.0 |
| AR | *Anchicolurus occidentalis* | - | 1 | - | - | 1 | 0.08 | 25.0 |
| AR | *Ischyrocerus pelagops* | - | - | 1 | - | 1 | 0.08 | 25.0 |
| AR | *Mayerella banksia* | 1 | - | - | - | 1 | 0.08 | 25.0 |
| MO | *Macoma* sp | - | - | 1 | - | 1 | 0.08 | 25.0 |
| MO | *Mactromeris catilliformis* | - | 1 | - | - | 1 | 0.08 | 25.0 |
| MO | *Periploma discus* | 1 | - | - | - | 1 | 0.08 | 25.0 |
| NE | *Tetrastemma candidum* | - | 1 | - | - | 1 | 0.08 | 25.0 |
| PL | *Stylochoplana* sp | 1 | - | - | - | 1 | 0.08 | 25.0 |

**Summary**

| Parameter | Replicate B2-I | B2-II | B2-III | B2-IV | Station Total | Replicate Mean | S.D. |
|---|---|---|---|---|---|---|---|
| Number of individuals | 147 | 472 | 320 | 314 | 1253 | 313.3 | 132.8 |
| Number of species | 32 | 33 | 28 | 27 | 51 | 30.0 | 2.9 |
| Diversity (H') | 2.90 | 2.43 | 2.50 | 2.55 | 2.65 | 2.60 | 0.21 |

**Appendix F-3. (Cont.).**

**Station B3**

| Phylum | Species | Replicate B3-I | B3-II | B3-III | B3-IV | Total | Percent Composition | Density No./m² |
|---|---|---|---|---|---|---|---|---|
| CN | *Zaolutus actius* | 177 | 140 | 65 | 125 | 507 | 35.28 | 12675.0 |
| AN | *Owenia collaris* | 111 | 60 | 53 | 52 | 276 | 19.21 | 6900.0 |
| AN | *Armandia brevis* | 27 | 29 | 26 | 55 | 137 | 9.53 | 3425.0 |
| AN | *Ampharete labrops* | 65 | 16 | 15 | 16 | 112 | 7.79 | 2800.0 |
| AN | *Apoprionospio pygmaea* | 8 | 13 | 12 | 33 | 66 | 4.59 | 1650.0 |
| MO | *Tellina modesta* | 8 | 16 | 14 | 14 | 52 | 3.62 | 1300.0 |
| AR | *Photis macinerneyi* | 2 | 20 | 4 | 11 | 37 | 2.57 | 925.0 |
| AN | *Pectinaria californiensis* | 2 | 11 | 3 | 16 | 32 | 2.23 | 800.0 |
| AR | *Diastylopsis tenuis* | 2 | 7 | 7 | 13 | 29 | 2.02 | 725.0 |
| AR | *Romaleon* sp | 27 | - | - | - | 27 | 1.88 | 675.0 |
| AN | *Onuphis* sp A SCAMIT 1992 | 10 | 4 | 4 | 6 | 24 | 1.67 | 600.0 |
| AN | *Scoloplos armiger* Cmplx | - | 5 | 3 | 8 | 16 | 1.11 | 400.0 |
| AN | *Spiophanes bombyx* | 1 | 8 | 1 | 6 | 16 | 1.11 | 400.0 |
| AN | *Chone eiffelturris* | 4 | 3 | 1 | 3 | 11 | 0.77 | 275.0 |
| MO | *Siliqua lucida* | 3 | 2 | 1 | 5 | 11 | 0.77 | 275.0 |
| AR | *Uromunna ubiquita* | - | 3 | 3 | 4 | 10 | 0.70 | 250.0 |
| NE | Lineidae | 2 | 1 | 1 | 3 | 7 | 0.49 | 175.0 |
| AN | *Goniada littorea* | 1 | 1 | 2 | 2 | 6 | 0.42 | 150.0 |
| AR | *Rhepoxynius menziesi* | 1 | 1 | - | 4 | 6 | 0.42 | 150.0 |
| AN | *Prionospio (Prionospio) jubata* | 2 | 1 | - | 1 | 4 | 0.28 | 100.0 |
| AN | *Spiochaetopterus costarum* Cmplx | 1 | - | - | 3 | 4 | 0.28 | 100.0 |
| AN | *Spiophanes duplex* | - | 2 | - | 2 | 4 | 0.28 | 100.0 |
| EC | *Dendraster excentricus* | - | - | - | 3 | 3 | 0.21 | 75.0 |
| AN | *Glycera macrobranchia* | 1 | - | 1 | - | 2 | 0.14 | 50.0 |
| AR | *Americhelidium shoemakeri* | 1 | - | - | 1 | 2 | 0.14 | 50.0 |
| AR | *Caprella mendax* | 2 | - | - | - | 2 | 0.14 | 50.0 |
| AR | *Euphilomedes carcharodonta* | 1 | - | - | 1 | 2 | 0.14 | 50.0 |
| AR | *Ischyrocerus pelagops* | 1 | - | 1 | - | 2 | 0.14 | 50.0 |
| AR | *Photis brevipes* | 1 | 1 | - | - | 2 | 0.14 | 50.0 |
| AR | *Rhepoxynius tridentatus* | - | - | 1 | 1 | 2 | 0.14 | 50.0 |
| MO | *Leukoma staminea* | - | 1 | - | 1 | 2 | 0.14 | 50.0 |
| MO | *Skenea dalli* | - | 1 | - | 1 | 2 | 0.14 | 50.0 |
| NE | Nemertea | - | - | - | 2 | 2 | 0.14 | 50.0 |
| NE | *Tetrastemma candidum* | - | 1 | - | 1 | 2 | 0.14 | 50.0 |
| NT | Nematoda | - | 1 | - | 1 | 2 | 0.14 | 50.0 |
| AN | *Glycinde armigera* | 1 | - | - | - | 1 | 0.07 | 25.0 |
| AN | Maldanidae | - | 1 | - | - | 1 | 0.07 | 25.0 |
| AN | *Mediomastus acutus* | - | - | - | 1 | 1 | 0.07 | 25.0 |
| AN | *Nephtys caecoides* | - | - | - | 1 | 1 | 0.07 | 25.0 |
| AN | *Phyllodoce hartmanae* | 1 | - | - | - | 1 | 0.07 | 25.0 |
| AN | *Typosyllis farallonensis* | - | 1 | - | - | 1 | 0.07 | 25.0 |
| AR | Harpacticoida | - | 1 | - | - | 1 | 0.07 | 25.0 |
| AR | *Lamprops quadriplicatus* | - | - | - | 1 | 1 | 0.07 | 25.0 |
| AR | *Parasterope hulingsi* | - | - | - | 1 | 1 | 0.07 | 25.0 |
| AR | *Rhepoxynius* sp A SCAMIT 1987 | - | 1 | - | - | 1 | 0.07 | 25.0 |
| MO | *Caesia perpinguis* | - | - | - | 1 | 1 | 0.07 | 25.0 |
| MO | *Macoma* sp | 1 | - | - | - | 1 | 0.07 | 25.0 |
| MO | *Mactromeris catilliformis* | - | - | - | 1 | 1 | 0.07 | 25.0 |
| MO | Mytilidae | - | - | 1 | - | 1 | 0.07 | 25.0 |
| NE | *Carinoma mutabilis* | - | - | - | 1 | 1 | 0.07 | 25.0 |
| PR | *Phoronis* sp | - | - | - | 1 | 1 | 0.07 | 25.0 |

**Summary**

| Parameter | Replicate B3-I | B3-II | B3-III | B3-IV | Station Total | Replicate Mean | S.D. |
|---|---|---|---|---|---|---|---|
| Number of individuals | 464 | 352 | 219 | 402 | 1437 | 359.3 | 104.1 |
| Number of species | 28 | 29 | 21 | 38 | 51 | 29.0 | 7.0 |
| Diversity (H') | 1.91 | 2.18 | 2.15 | 2.50 | 2.30 | 2.19 | 0.24 |

**Appendix F-3. (Cont.).**

**Station B4**

| Phylum | Species | Replicate B4-I | B4-II | B4-III | B4-IV | Total | Percent Composition | Density No./m² |
|---|---|---|---|---|---|---|---|---|
| AN | *Apoprionospio pygmaea* | 9 | 18 | 16 | 17 | 60 | 20.91 | 1500.0 |
| MO | *Tellina modesta* | 4 | 6 | 10 | 10 | 30 | 10.45 | 750.0 |
| AN | *Scoloplos armiger* Cmplx | 6 | 6 | 4 | 9 | 25 | 8.71 | 625.0 |
| AR | *Rhepoxynius menziesi* | 3 | 9 | 9 | 4 | 25 | 8.71 | 625.0 |
| AR | *Euphilomedes carcharodonta* | 5 | 4 | 8 | 4 | 21 | 7.32 | 525.0 |
| AN | *Onuphis* sp A SCAMIT 1992 | 2 | 2 | 2 | 8 | 14 | 4.88 | 350.0 |
| AN | *Owenia collaris* | 3 | 2 | 4 | 1 | 10 | 3.48 | 250.0 |
| AR | *Photis macinerneyi* | 2 | 3 | 2 | 2 | 9 | 3.14 | 225.0 |
| AR | *Diastylopsis tenuis* | - | 4 | 3 | 1 | 8 | 2.79 | 200.0 |
| EC | *Dendraster excentricus* | 2 | 2 | 4 | - | 8 | 2.79 | 200.0 |
| AN | *Chone eiffelturris* | 1 | 2 | 1 | 3 | 7 | 2.44 | 175.0 |
| AN | *Mediomastus acutus* | 4 | 2 | - | 1 | 7 | 2.44 | 175.0 |
| MO | *Siliqua lucida* | 1 | 1 | 5 | - | 7 | 2.44 | 175.0 |
| MO | *Macoma* sp | 1 | 1 | 1 | 2 | 5 | 1.74 | 125.0 |
| AN | *Spiophanes bombyx* | 1 | 1 | 2 | - | 4 | 1.39 | 100.0 |
| AR | *Lamprops quadriplicatus* | 1 | - | 2 | 1 | 4 | 1.39 | 100.0 |
| NE | Lineidae | 1 | 1 | - | 2 | 4 | 1.39 | 100.0 |
| AN | *Armandia brevis* | 2 | 1 | - | - | 3 | 1.05 | 75.0 |
| AN | *Glycera macrobranchia* | - | 1 | 1 | 1 | 3 | 1.05 | 75.0 |
| AN | *Nephtys caecoides* | 1 | 1 | - | 1 | 3 | 1.05 | 75.0 |
| AN | *Spiochaetopterus costarum* Cmplx | 1 | - | 1 | 1 | 3 | 1.05 | 75.0 |
| AN | *Goniada littorea* | - | 2 | - | - | 2 | 0.70 | 50.0 |
| AN | *Pectinaria californiensis* | - | - | 1 | 1 | 2 | 0.70 | 50.0 |
| AR | *Americhelidium shoemakeri* | - | - | 1 | 1 | 2 | 0.70 | 50.0 |
| AR | *Anchicolurus occidentalis* | - | - | 2 | - | 2 | 0.70 | 50.0 |
| AR | *Caprella mendax* | - | 1 | 1 | - | 2 | 0.70 | 50.0 |
| NE | *Carinoma mutabilis* | 1 | - | - | 1 | 2 | 0.70 | 50.0 |
| NE | *Tubulanus polymorphus* | - | - | 2 | - | 2 | 0.70 | 50.0 |
| AN | *Aricidea (Acmira) catherinae* | - | 1 | - | - | 1 | 0.35 | 25.0 |
| AR | *Campylaspis* sp C Myers&Benedict 1974 | - | 1 | - | - | 1 | 0.35 | 25.0 |
| AR | *Eohaustorius sawyeri* | - | 1 | - | - | 1 | 0.35 | 25.0 |
| AR | *Rhepoxynius abronius* | - | - | 1 | - | 1 | 0.35 | 25.0 |
| AR | *Rhepoxynius* sp A SCAMIT 1987 | - | - | - | 1 | 1 | 0.35 | 25.0 |
| AR | *Uromunna ubiquita* | - | - | - | 1 | 1 | 0.35 | 25.0 |
| CN | *Zaolutus actius* | - | 1 | - | - | 1 | 0.35 | 25.0 |
| CO | Enteropneusta | 1 | - | - | - | 1 | 0.35 | 25.0 |
| MO | *Cooperella subdiaphana* | - | - | 1 | - | 1 | 0.35 | 25.0 |
| MO | *Mysella* sp C SCAMIT 1988 | - | - | 1 | - | 1 | 0.35 | 25.0 |
| MO | *Solen sicarius* | - | 1 | - | - | 1 | 0.35 | 25.0 |
| NE | *Tetrastemma candidum* | - | - | - | 1 | 1 | 0.35 | 25.0 |
| PL | *Stylochoplana* sp | - | - | - | 1 | 1 | 0.35 | 25.0 |

**Summary**

| Parameter | Replicate B4-I | B4-II | B4-III | B4-IV | Station Total | Replicate Mean | S.D. |
|---|---|---|---|---|---|---|---|
| Number of individuals | 52 | 75 | 85 | 75 | 287 | 71.8 | 14.0 |
| Number of species | 21 | 26 | 25 | 24 | 41 | 24.0 | 2.2 |
| Diversity (H') | 2.76 | 2.77 | 2.79 | 2.64 | 2.96 | 2.74 | 0.07 |

**Appendix F-3. (Cont.).**

**Station B5**

| Phylum | Species | Replicate B5-I | B5-II | B5-III | B5-IV | Total | Percent Composition | Density No./m² |
|---|---|---|---|---|---|---|---|---|
| AN | *Apoprionospio pygmaea* | 51 | 53 | 24 | 71 | 199 | 23.86 | 4975.0 |
| AN | *Armandia brevis* | 67 | 20 | 13 | 33 | 133 | 15.95 | 3325.0 |
| MO | *Tellina modesta* | 15 | 18 | 17 | 26 | 76 | 9.11 | 1900.0 |
| AN | *Ampharete labrops* | 41 | 9 | 10 | 9 | 69 | 8.27 | 1725.0 |
| AN | *Mediomastus acutus* | 19 | 10 | 10 | 29 | 68 | 8.15 | 1700.0 |
| AN | *Pectinaria californiensis* | 6 | 9 | 3 | 17 | 35 | 4.20 | 875.0 |
| AN | *Owenia collaris* | 4 | 11 | 11 | 7 | 33 | 3.96 | 825.0 |
| AR | *Diastylopsis tenuis* | 9 | 6 | 8 | 5 | 28 | 3.36 | 700.0 |
| CN | *Zaolutus actius* | 14 | 1 | 2 | 8 | 25 | 3.00 | 625.0 |
| AN | *Goniada littorea* | 4 | 4 | 8 | 4 | 20 | 2.40 | 500.0 |
| AR | *Rhepoxynius menziesi* | 8 | 3 | 7 | 2 | 20 | 2.40 | 500.0 |
| AN | *Chone eiffelturris* | 1 | 3 | 4 | 6 | 14 | 1.68 | 350.0 |
| AR | *Rhepoxynius* sp A SCAMIT 1987 | 6 | 4 | 4 | - | 14 | 1.68 | 350.0 |
| AN | *Onuphis* sp A SCAMIT 1992 | 2 | 5 | 3 | 2 | 12 | 1.44 | 300.0 |
| AR | *Photis macinerneyi* | 2 | - | 2 | 6 | 10 | 1.20 | 250.0 |
| AN | *Spiophanes bombyx* | - | 2 | 4 | 3 | 9 | 1.08 | 225.0 |
| AR | *Uromunna ubiquita* | 6 | - | 1 | 2 | 9 | 1.08 | 225.0 |
| AR | *Photis brevipes* | 5 | 1 | - | - | 6 | 0.72 | 150.0 |
| AR | *Romaleon* sp | 5 | - | - | - | 5 | 0.60 | 125.0 |
| MO | *Macoma* sp | 1 | 3 | - | 1 | 5 | 0.60 | 125.0 |
| MO | *Mactromeris catilliformis* | - | 1 | 2 | 1 | 4 | 0.48 | 100.0 |
| EC | *Dendraster excentricus* | - | 1 | 1 | 1 | 3 | 0.36 | 75.0 |
| MO | *Rochefortia coani* | - | - | 3 | - | 3 | 0.36 | 75.0 |
| MO | *Siliqua lucida* | - | 1 | 1 | 1 | 3 | 0.36 | 75.0 |
| NE | Lineidae | - | - | 2 | 1 | 3 | 0.36 | 75.0 |
| NT | Nematoda | - | 2 | 1 | - | 3 | 0.36 | 75.0 |
| AN | *Phyllodoce hartmanae* | 2 | - | - | - | 2 | 0.24 | 50.0 |
| AN | *Spiochaetopterus costarum* Cmplx | - | - | 1 | 1 | 2 | 0.24 | 50.0 |
| MO | *Cooperella subdiaphana* | - | 2 | - | - | 2 | 0.24 | 50.0 |
| NE | *Carinoma mutabilis* | - | 2 | - | - | 2 | 0.24 | 50.0 |
| NE | *Tetrastemma candidum* | 2 | - | - | - | 2 | 0.24 | 50.0 |
| PR | *Phoronis* sp | - | - | 2 | - | 2 | 0.24 | 50.0 |
| AN | *Malmgreniella macginitiei* | - | - | 1 | - | 1 | 0.12 | 25.0 |
| AN | *Nephtys cornuta* | - | - | 1 | - | 1 | 0.12 | 25.0 |
| AN | *Scoletoma tetraura* Cmplx | - | - | 1 | - | 1 | 0.12 | 25.0 |
| AN | *Sthenelais tertiaglabra* | - | 1 | - | - | 1 | 0.12 | 25.0 |
| AR | *Americhelidium shoemakeri* | - | - | - | 1 | 1 | 0.12 | 25.0 |
| AR | *Cumella californica* | 1 | - | - | - | 1 | 0.12 | 25.0 |
| AR | *Ischyrocerus pelagops* | 1 | - | - | - | 1 | 0.12 | 25.0 |
| CN | *Renilla koellikeri* | 1 | - | - | - | 1 | 0.12 | 25.0 |
| MO | *Leukoma staminea* | - | - | - | 1 | 1 | 0.12 | 25.0 |
| MO | *Petricola* sp | 1 | - | - | - | 1 | 0.12 | 25.0 |
| MO | *Rochefortia tumida* | 1 | - | - | - | 1 | 0.12 | 25.0 |
| MO | *Solen sicarius* | - | 1 | - | - | 1 | 0.12 | 25.0 |
| NE | Nemertea | - | - | - | 1 | 1 | 0.12 | 25.0 |

**Summary**

| Parameter | Replicate B5-I | B5-II | B5-III | B5-IV | Station Total | Replicate Mean | S.D. |
|---|---|---|---|---|---|---|---|
| Number of individuals | 275 | 173 | 147 | 239 | 834 | 208.5 | 58.9 |
| Number of species | 26 | 25 | 28 | 25 | 45 | 26.0 | 1.4 |
| Diversity (H') | 2.46 | 2.51 | 2.88 | 2.38 | 2.69 | 2.56 | 0.22 |

**Appendix F-4. Infaunal wet weight biomass data (g). Mandalay Generating Station NPDES. 2009.**

| Sta-Rep | Annelida | Arthropoda | Mollusca | Echinodermata | Misc. | Total |
|---|---|---|---|---|---|---|
| B1-I | 0.3332 | <0.0001 | 0.0318 | - | <0.0001 | 0.3650 |
| B1-II | 0.3322 | 0.0362 | 0.0488 | 0.0584 | 0.0062 | 0.4818 |
| B1-III | 0.1788 | 0.0020 | 0.0612 | 0.0506 | 0.0320 | 0.3246 |
| B1-IV | 0.3333 | 0.3788 | 0.0085 | 0.0083 | 0.0550 | 0.7839 |
| Total | 1.1775 | 0.4170 | 0.1503 | 0.1173 | 0.0932 | 1.9553 |
| | | | | | | |
| B2-I | 0.2300 | 0.0053 | 0.0011 | <0.0001 | 0.0847 | 0.3211 |
| B2-II | 0.6334 | <0.0001 | 0.2162 | 0.0142 | 0.0721 | 0.9359 |
| B2-III | 0.5679 | 0.0060 | 0.0460 | 0.0358 | 0.0463 | 0.7020 |
| B2-IV | 0.5736 | <0.0001 | 0.0563 | <0.0001 | 0.0077 | 0.6376 |
| Total | 2.0049 | 0.0113 | 0.3196 | 0.0500 | 0.2108 | 2.5966 |
| | | | | | | |
| B3-I | 2.1720 | 0.2736 | 0.0735 | - | 0.0939 | 2.6130 |
| B3-II | 0.9276 | <0.0001 | <0.0001 | - | 0.0854 | 1.0130 |
| B3-III | 0.8198 | <0.0001 | 0.0799 | - | 0.0290 | 0.9287 |
| B3-IV | 0.6127 | 0.0220 | 0.0893 | <0.0001 | 0.0096 | 0.7336 |
| Total | 4.5321 | 0.2956 | 0.2427 | <0.0001 | 0.2179 | 5.2883 |
| | | | | | | |
| B4-I | 0.0273 | <0.0001 | 0.0132 | <0.0001 | <0.0001 | 0.0405 |
| B4-II | 0.4250 | <0.0001 | 0.0207 | 0.0086 | <0.0001 | 0.4543 |
| B4-III | 0.0909 | 0.0599 | <0.0001 | 0.0404 | 0.0054 | 0.1966 |
| B4-IV | 0.0367 | <0.0001 | 0.0460 | - | 0.0554 | 0.1381 |
| Total | 0.5799 | 0.0599 | 0.0799 | 0.0490 | 0.0608 | 0.8295 |
| | | | | | | |
| B5-I | 0.6685 | 0.0534 | 0.0006 | - | 3.6764 [a] | 4.3989 |
| B5-II | 0.1445 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | 0.1445 |
| B5-III | 0.3269 | <0.0001 | 0.0761 | <0.0001 | <0.0001 | 0.4030 |
| B5-IV | 0.0666 | <0.0001 | 0.0143 | <0.0001 | <0.0001 | 0.0809 |
| Total | 1.2065 | 0.0534 | 0.0910 | <0.0001 | 3.6764 | 5.0273 |
| Grand Total | 9.5009 | 0.8372 | 0.8835 | 0.2163 | 4.2591 | 15.6970 |

Notes: - = no animals    a = 1 *Renilla koellikeri*

**Appendix F-5. Yearly abundance of the top 40 infaunal species, 1978 - 2009. Mandalay Generating Station NPDES, 2009.**

| | | Year | | | | | | | | | | | | | | | | | | | | | | | Percent |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Phy | Species | 1978 | 1980 | 1986 | 1988 | 1990 | 1991 | 1992 | 1993 | 1994 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | Total | Total |
| AN | *Apoprionospio pygmaea* | 86 | 213 | 17 | 175 | 52 | 490 | 170 | 128 | 203 | 100 | 658 | 28 | 143 | 569 | 354 | 719 | 86 | 744 | 113 | 86 | 56 | 573 | 5763 | 20.05 |
| MO | *Donax gouldii* | - | - | - | - | - | - | - | - | - | - | 3064 | - | 2 | - | - | 6 | - | 1 | 1 | 3 | 8 | - | 3085 | 10.73 |
| AN | *Mediomastus acutus* | 5 | 1 | - | - | - | - | - | 1 | 58 | 35 | 1026 | 28 | 12 | 103 | 83 | 3 | 40 | 6 | 22 | 38 | 14 | 84 | 1559 | 5.42 |
| EC | *Dendraster excentricus* | 12 | 1 | 43 | 17 | 87 | 14 | 14 | - | 10 | 103 | 52 | 75 | 34 | 41 | 15 | 7 | 4 | 3 | 27 | 788 | 1 | 35 | 1383 | 4.81 |
| AR | *Diastylopsis tenuis* | 123 | 163 | 75 | 33 | 12 | 9 | 5 | 11 | 88 | 45 | 2 | 51 | 56 | 7 | 19 | - | 4 | 424 | 74 | 32 | 2 | 103 | 1338 | 4.65 |
| AR | *Rhepoxynius menziesi* | 17 | 25 | 20 | 61 | 43 | 14 | 18 | 14 | 34 | - | 35 | 270 | 84 | 67 | 71 | 64 | 85 | 36 | 30 | 55 | 34 | 78 | 1155 | 4.02 |
| CN | *Zaolutus actius* | - | 4 | - | - | - | - | - | - | - | 99 | 4 | 7 | 40 | 4 | 17 | - | - | - | - | 39 | - | 925 | 1139 | 3.96 |
| AN | *Owenia collaris* | 5 | 40 | - | 2 | 10 | 88 | 9 | 44 | 2 | 130 | 8 | 31 | 111 | 5 | 29 | 1 | 1 | - | 10 | 31 | - | 556 | 1113 | 3.87 |
| AN | *Scoloplos armiger* Cmplx | 61 | 28 | 20 | 111 | 187 | 149 | 55 | 69 | 43 | 71 | 16 | 10 | 10 | 20 | 12 | 18 | 33 | 4 | - | - | 5 | 71 | 993 | 3.45 |
| AN | *Chone eiffelturris* | - | - | - | - | - | - | - | - | - | - | 14 | 1 | 20 | 7 | 25 | 5 | 290 | 10 | 242 | 49 | 2 | 48 | 713 | 2.48 |
| AN | *Armandia brevis* | - | 7 | - | 5 | - | 1 | - | - | 7 | 3 | 6 | 9 | - | 6 | 3 | - | 11 | 46 | 3 | 50 | - | 526 | 683 | 2.38 |
| AN | *Spiophanes bombyx* | 14 | 51 | 92 | 46 | 17 | 2 | 3 | 154 | 60 | 15 | 13 | 8 | 43 | 4 | 2 | - | 12 | 76 | 6 | 4 | - | 47 | 669 | 2.33 |
| MO | *Tellina modesta* | 2 | 18 | 29 | 2 | 4 | - | - | 1 | 11 | 101 | 2 | 19 | 46 | 20 | 8 | 1 | 23 | 3 | 25 | 57 | 14 | 255 | 641 | 2.23 |
| MO | *Siliqua lucida* | - | 17 | 9 | 112 | - | 4 | - | - | 82 | 62 | 22 | 31 | 6 | 17 | 11 | - | 1 | 12 | 12 | 42 | - | 42 | 482 | 1.68 |
| AR | *Euphilomedes carcharodonta* | - | 1 | 1 | 3 | - | - | - | - | 47 | 333 | - | - | - | - | 2 | - | - | - | - | - | - | 75 | 462 | 1.61 |
| NE | *Carinoma mutabilis* | - | 3 | 16 | 18 | 7 | 18 | 28 | 19 | 25 | 24 | 78 | 17 | 18 | 29 | 28 | 7 | 14 | 11 | 52 | 23 | 1 | 16 | 452 | 1.57 |
| AR | *Photis macinerneyi* | - | - | 13 | 45 | - | - | - | - | 4 | 20 | 2 | 5 | 10 | 6 | 1 | - | - | 58 | 3 | 14 | - | 253 | 434 | 1.51 |
| AN | *Ampharete labrops* | 1 | - | 3 | 5 | - | 4 | - | - | 6 | - | 5 | 3 | 6 | 5 | 24 | - | 2 | 1 | 1 | 8 | - | 273 | 347 | 1.21 |
| AN | *Goniada littorea* | 21 | 26 | 6 | - | 6 | 2 | - | 3 | 6 | 11 | 36 | 74 | 37 | 5 | 9 | - | 4 | 11 | 12 | 4 | - | 30 | 303 | 1.05 |
| AN | *Magelona pitelkai* | 9 | 131 | - | 38 | 13 | 21 | 14 | 24 | 20 | 5 | - | 1 | - | 8 | 6 | 5 | 1 | 3 | - | - | - | - | 299 | 1.04 |
| AN | *Pectinaria californiensis* | - | 1 | 9 | 60 | 3 | - | - | - | 4 | 112 | - | 1 | 6 | - | 2 | - | 1 | - | - | 8 | - | 77 | 284 | 0.99 |
| AR | *Americhelidium shoemakeri* | 4 | - | - | 1 | 7 | - | - | - | 8 | 3 | - | 5 | 23 | 68 | 25 | 13 | 18 | 2 | 5 | 34 | 3 | 18 | 237 | 0.82 |
| AR | *Euphilomedes longiseta* | - | - | - | 2 | 10 | 22 | - | - | - | - | 3 | - | 3 | 5 | 54 | 12 | 12 | 6 | 28 | 31 | 37 | - | 225 | 0.78 |
| AN | *Nephtys caecoides* | 6 | 4 | 8 | 5 | 9 | 24 | 8 | 11 | 14 | 3 | 3 | 6 | 11 | 9 | 19 | 21 | 8 | 2 | 10 | 12 | 1 | 11 | 205 | 0.71 |
| AR | *Rhepoxynius* sp A SCAMIT 1987 | 2 | 5 | 9 | 12 | 26 | 11 | - | - | 23 | 37 | - | 4 | 11 | 12 | 12 | - | 2 | 4 | 3 | - | - | 19 | 192 | 0.67 |
| MO | *Mactromeris catilliformis* | - | - | - | - | - | - | - | - | - | 12 | - | - | - | 14 | 120 | - | 1 | 1 | 12 | 2 | - | 6 | 168 | 0.58 |
| AN | *Mediomastus* spp | - | 9 | 16 | 17 | 12 | 7 | 4 | - | - | - | 91 | 2 | 1 | 2 | - | - | - | - | - | - | - | - | 161 | 0.56 |
| AN | *Onuphis* sp A SCAMIT 1992 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 6 | - | 3 | 24 | 11 | 4 | 10 | 98 | 156 | 0.54 |
| AR | *Mandibulophoxus gilesi* | 14 | - | - | - | - | 36 | 15 | - | 4 | 15 | - | - | 3 | - | - | 4 | 23 | - | - | 11 | 9 | - | 134 | 0.47 |
| NE | Lineidae | - | - | - | 1 | - | - | - | - | - | 9 | 22 | 13 | 5 | 4 | 2 | 1 | 24 | 10 | 14 | 5 | - | 19 | 129 | 0.45 |
| AR | *Uromunna ubiquita* | - | - | - | 1 | - | - | - | - | - | 33 | 2 | 4 | 1 | 3 | 6 | 1 | 3 | 1 | - | 2 | - | 71 | 128 | 0.45 |
| AN | *Magelona sacculata* | 2 | 23 | 47 | 22 | 16 | 4 | - | - | - | - | - | - | - | 2 | 6 | - | - | - | - | - | - | - | 122 | 0.42 |
| AN | *Spiophanes duplex* | 4 | 17 | - | 11 | - | - | - | 4 | 3 | 1 | 1 | - | 5 | 1 | - | - | - | 70 | - | - | - | 4 | 121 | 0.42 |
| MO | *Solen sicarius* | 2 | - | 9 | 16 | 3 | 5 | 2 | 5 | 3 | 20 | 20 | 3 | 6 | - | - | 1 | - | - | 16 | 7 | - | 3 | 121 | 0.42 |
| AN | *Onuphis eremita* | - | - | - | - | 11 | 9 | - | 45 | 1 | 1 | 17 | - | 1 | - | 1 | 19 | - | - | - | 8 | 2 | - | 115 | 0.40 |
| AN | *Mediomastus ambiseta* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 13 | - | 61 | 5 | 20 | 6 | - | - | 105 | 0.37 |
| AR | *Anchicolurus occidentalis* | - | - | - | 2 | - | 3 | - | 1 | 2 | 4 | - | 19 | 4 | 1 | 1 | 1 | 4 | 35 | 15 | 2 | 7 | 4 | 105 | 0.37 |
| AN | *Glycera macrobranchia* | 1 | 1 | - | 1 | 13 | 3 | 4 | 3 | 3 | 6 | 4 | 1 | 1 | 4 | 8 | 2 | 6 | 6 | 6 | 7 | 2 | 15 | 97 | 0.34 |
| AN | *Chone albocincta* | - | - | - | - | 5 | 14 | - | 5 | 9 | 62 | - | - | - | - | 1 | - | - | - | - | - | - | - | 96 | 0.33 |
| AR | *Isocheles pilosus* | 12 | 1 | - | 75 | 1 | - | - | - | - | 1 | - | - | 2 | 1 | - | - | - | - | - | - | - | - | 93 | 0.32 |
| | Number of individuals | 504 | 1008 | 612 | 1041 | 699 | 1021 | 399 | 599 | 946 | 1737 | 5311 | 896 | 915 | 1161 | 1123 | 952 | 885 | 1726 | 843 | 1595 | 228 | 4549 | 28750 | |
| | Number of species | 52 | 75 | 68 | 72 | 70 | 53 | 35 | 38 | 81 | 91 | 59 | 82 | 79 | 75 | 75 | 38 | 75 | 60 | 57 | 69 | 34 | 91 | 333 | |
| | Number of stations / reps | 5/4 | 5/4 | 5/4 | 5/4 | 5/4 | 5/4 | 5/4 | 5/4 | 5/4 | 5/4 | 3/4 | 5/4 | 5/4 | 5/4 | 5/4 | 4/2 | 5/4 | 5/4 | 5/4 | 5/4 | 4/2 | 5/4 | | |
| | Diversity (H') | 2.81 | 2.99 | 3.38 | 3.13 | 3.03 | 2.15 | 2.28 | 2.46 | 3.21 | 3.27 | 1.46 | 3.01 | 3.25 | 2.36 | 2.88 | 1.25 | 2.82 | 2.09 | 2.84 | 2.43 | 2.58 | 2.83 | 3.50 | |

NOTE: From 1978 to 1988 infaunal samples were collected in summer and winter. In this appendix, only summer samples are considered.

**Appendix F-6. Index of Relative Importance for the top 25 infaunal organisms observed during infaunal sampling and contigency table of Spearman rank correlation coefficients by year, 1990 - 2009. Mandalay Generating Station NPDES, 2009.**

| Species | 1990 | 1993 | 1994 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Apoprionospio pygmaea* | 2 | 4 | 1 | 3 | 3 | 6 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 2 | 1 | 1 |
| *Rhepoxynius menziesi* | 2 | 3 | 6 | - | 3 | 1 | 4 | 3 | 2 | 2 | 2 | 6 | 5 | 4 | 2 | 9 |
| *Dendraster excentricus* | 2 | 1 | 14 | 4 | 3 | 2 | 8 | 5 | 11 | 7 | 13 | 14 | 6 | 1 | 11 | 17 |
| *Mediomastus acutus* | - | - | 4 | 13 | 1 | 8 | 13 | 4 | 7 | 11 | 5 | 11 | 8 | 9 | 4 | 12 |
| *Diastylopsis tenuis* | 7 | 6 | 3 | 11 | 18 | 4 | 3 | 12 | 8 | - | 15 | 2 | 1 | 12 | 10 | 7 |
| *Scoloplos armiger* Cmplx | 1 | 2 | 8 | 7 | 11 | 10 | 15 | 8 | 13 | 4 | 4 | 13 | - | - | 6 | 16 |
| *Carinoma mutabilis* | 14 | 6 | 7 | 12 | 2 | 11 | 12 | 5 | 4 | 7 | 7 | 7 | 3 | 10 | 11 | 19 |
| *Chone eiffelturris* | - | - | - | - | 10 | 20 | 8 | 13 | 9 | 12 | 2 | 10 | 1 | 4 | 9 | 12 |
| *Tellina modesta* | 15 | - | 12 | 9 | 18 | 9 | 4 | 7 | 16 | 13 | 5 | 14 | 9 | 3 | 3 | 3 |
| *Siliqua lucida* | - | - | 2 | 5 | 8 | 6 | 17 | 9 | 12 | - | 18 | 9 | 11 | 6 | - | 9 |
| *Euphilomedes longiseta* | 5 | - | - | - | 15 | - | 21 | 16 | 5 | 6 | 9 | 12 | 6 | 8 | 4 | - |
| *Owenia collaris* | 7 | - | 21 | 2 | 12 | 5 | 2 | 20 | 3 | 13 | 18 | - | 12 | 15 | - | 2 |
| *Spiophanes bombyx* | 5 | 8 | 4 | 14 | 8 | 12 | 7 | 21 | 21 | - | 10 | 3 | 14 | 18 | - | 11 |
| *Euphilomedes carcharodonta* | - | - | 8 | 1 | - | - | - | - | 21 | - | - | - | - | - | - | 15 |
| *Americhelidium shoemakeri* | 12 | - | 15 | 18 | - | 15 | 10 | 2 | 6 | 5 | 8 | 18 | 17 | 10 | 8 | 20 |
| *Armandia brevis* | - | - | 16 | 19 | 13 | 13 | - | 14 | 20 | - | 11 | 5 | 15 | 7 | - | 4 |
| *Goniada littorea* | 13 | - | 18 | 16 | 7 | 3 | 6 | 16 | 18 | - | 14 | 8 | 10 | 18 | - | 18 |
| *Zaolutus actius* | - | - | - | 8 | 15 | 13 | 11 | 22 | 17 | - | - | - | - | 12 | - | 4 |
| *Nephtys caecoides* | 9 | - | 10 | 19 | 17 | 16 | 14 | 11 | 10 | 3 | 11 | 18 | 12 | 16 | 11 | 22 |
| *Magelona pitelkai* | 10 | 5 | 11 | 17 | - | 20 | - | 10 | 18 | 10 | 18 | 17 | - | - | - | - |
| *Donax gouldii* | - | - | - | - | 6 | - | 22 | - | - | 9 | - | 20 | 19 | 21 | 7 | - |
| *Photis macinerneyi* | - | - | 19 | 15 | 18 | 17 | 16 | 19 | 24 | - | - | 4 | 15 | 12 | - | 6 |
| *Rhepoxynius* sp A SCAMIT 1987 | 10 | - | 12 | 9 | - | 18 | 17 | 15 | 15 | - | 16 | 16 | 18 | - | - | 21 |
| *Pectinaria californiensis* | 16 | 8 | 20 | 5 | - | 20 | 19 | - | 21 | - | 18 | - | - | 20 | - | 12 |
| *Ampharete labrops* | - | - | 17 | - | 14 | 19 | 20 | 16 | 13 | - | 16 | 20 | 19 | 17 | - | 8 |
| 1990 | - | 0.39 | 0.38 | 0.35 | -0.21 | 0.14 | -0.11 | -0.10 | -0.01 | 0.16 | **0.45** | 0.07 | -0.09 | 0.09 | 0.14 | 0.26 |
| 1993 | - | - | -0.06 | 0.05 | -0.27 | 0.07 | -0.21 | -0.24 | 0.01 | -0.09 | 0.18 | -0.30 | **-0.48** | -0.02 | 0.14 | 0.02 |
| 1994 | - | - | - | 0.35 | -0.08 | 0.31 | -0.11 | 0.11 | **0.43** | -0.13 | **0.46** | 0.00 | 0.29 | 0.14 | -0.35 | 0.25 |
| 1997 | - | - | - | - | 0.02 | 0.39 | -0.24 | 0.19 | **0.41** | -0.17 | 0.20 | 0.07 | 0.16 | 0.10 | -0.04 | 0.31 |
| 1998 | - | - | - | - | - | -0.04 | 0.08 | **0.59** | 0.05 | -0.06 | -0.11 | -0.05 | 0.16 | 0.28 | 0.08 | -0.35 |
| 1999 | - | - | - | - | - | - | 0.14 | 0.25 | 0.43 | -0.11 | 0.26 | 0.16 | 0.05 | 0.05 | -0.20 | 0.20 |
| 2000 | - | - | - | - | - | - | - | 0.03 | -0.10 | -0.09 | 0.02 | **0.42** | 0.33 | 0.36 | 0.12 | 0.15 |
| 2001 | - | - | - | - | - | - | - | - | 0.31 | -0.24 | 0.22 | -0.12 | 0.25 | 0.25 | -0.38 | -0.16 |
| 2002 | - | - | - | - | - | - | - | - | - | **-0.55** | 0.14 | -0.23 | -0.10 | -0.01 | **-0.61** | 0.13 |
| 2003 | - | - | - | - | - | - | - | - | - | - | -0.11 | 0.37 | -0.08 | -0.21 | **0.53** | -0.18 |
| 2004 | - | - | - | - | - | - | - | - | - | - | - | 0.13 | 0.14 | 0.13 | -0.24 | 0.11 |
| 2005 | - | - | - | - | - | - | - | - | - | - | - | - | **0.46** | -0.10 | 0.39 | 0.16 |
| 2006 | - | - | - | - | - | - | - | - | - | - | - | - | - | 0.38 | -0.11 | 0.03 |
| 2007 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | -0.07 | -0.05 |
| 2008 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0.29 |
| 2009 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

**Bold** = Correlation is significant at the 0.05 level (2-tailed)

# APPENDIX G

## Demersal fish and macroinvertebrate trawl data by station

**Appendix G-1. Species list of fish and macroinvertebrate species taken by otter trawl. Mandalay Generating Station NPDES, 2009.**

| Phylum | Class | Family | Species | Common name |
|---|---|---|---|---|
| Arthropoda | | | | |
| | Malacostraca | | | |
| | | Albuneidae | | |
| | | | *Blepharipoda occidentalis* | spiny mole crab |
| | | Cancridae | | |
| | | | *Metacarcinus anthonyi* | yellow crab |
| | | | *Metacarcinus gracilis* | graceful crab |
| | | | *Romaleon antennarius* | Pacific rock crab |
| | | Crangonidae | | |
| | | | *Crangon alaskensis* | Alaska bay shrimp |
| | | | *Crangon nigromaculata* | blackspotted bay shrimp |
| | | | *Lissocrangon stylirostris* | smooth bay shrimp |
| | | Epialtidae | | |
| | | | *Pugettia producta* | northern kelp crab |
| | | Hippolytidae | | |
| | | | *Heptacarpus stimpsoni* | Stimpson coastal shrimp |
| | | Leucosiidae | | |
| | | | *Randallia ornata* | globose sand crab |
| | | Majidae | | |
| | | | *Loxorhynchus grandis* | sheep crab |
| | | Palinuridae | | |
| | | | *Panulirus interruptus* | California spiny lobster |
| | | Penaeidae | | |
| | | | *Farfantepenaeus californiensis* | yellowleg shrimp |
| | | Portunidae | | |
| | | | *Portunus xantusii* | Xantus swimming crab |
| Cnidaria | | | | |
| | Anthozoa | | | |
| | | Renillidae | | |
| | | | *Renilla koellikeri* | sea pansy |
| | Hydrozoa | | | |
| | | Polyorchidae | | |
| | | | *Polyorchis penicillatus* | red jellyfish |
| Echinodermata | | | | |
| | Echinoidea | | | |
| | | Dendrasteridae | | |
| | | | *Dendraster excentricus* | Pacific sand dollar |
| Chordata | | | | |
| | Chondrichthyes | | | |
| | | Myliobatidae | | |
| | | | *Myliobatis californica* | bat ray |
| | | Platyrhinidae | | |
| | | | *Platyrhinoidis triseriata* | thornback |
| | | Rhinobatidae | | |
| | | | *Rhinobatos productus* | shovelnose guitarfish |
| | | Squalidae | | |
| | | | *Squalus acanthias* | spiny dogfish |
| Chordata | | | | |
| | Actinopterygii | | | |
| | | Agonidae | | |
| | | | *Stellerina xyosterna* | pricklebreast poacher |
| | | Clupeidae | | |
| | | | *Sardinops sagax* | Pacific sardine |
| | | Cottidae | | |
| | | | *Leptocottus armatus* | Pacific staghorn sculpin |
| | | Embiotocidae | | |
| | | | *Amphistichus argenteus* | barred surfperch |
| | | | *Cymatogaster aggregata* | shiner perch |
| | | | *Hyperprosopon argenteum* | walleye surfperch |
| | | | *Phanerodon furcatus* | white seaperch |
| | | Engraulidae | | |
| | | | *Anchoa compressa* | deepbody anchovy |
| | | | *Anchoa delicatissima* | slough anchovy |
| | | | *Engraulis mordax* | northern anchovy |
| | | Gasterosteidae | | |
| | | | *Aulorhynchus flavidus* | tubesnout |
| | | Hexagrammidae | | |
| | | | *Oxylebius pictus* | painted greenling |
| | | Ophididae | | |
| | | | *Ophidion scrippsae* | basketweave cusk-eel |
| | | Paralichthyidae | | |
| | | | *Xystreurys liolepis* | fantail sole |
| | | | *Paralichthys californicus* | California halibut |
| | | | *Citharichthys stigmaeus* | speckled sanddab |
| | | Pleuronectidae | | |
| | | | *Parophrys vetulus* | English sole |
| | | | *Pleuronichthys guttulatus* | diamond turbot |
| | | Sciaenidae | | |
| | | | *Genyonemus lineatus* | white croaker |
| | | | *Menticirrhus undulatus* | California corbina |
| | | | *Seriphus politus* | queenfish |
| | | Scorpaenidae | | |
| | | | *Sebastes dalli* | calico rockfish |
| | | | *Sebastes miniatus* | vermilion rockfish |
| | | Syngnathidae | | |
| | | | *Syngnathus californiensis* | kelp pipefish |
| | | | *Syngnathus exilis* | barcheek pipefish |
| | | Synodontidae | | |
| | | | *Synodus lucioceps* | California lizardfish |

**Appendix G-2. Abundance of fish species in trawl replicates, winter and summer. Mandalay Generating Station NPDES, 2009.**

| | Winter | | | | | | | | | Summer | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T1 | | T2 | | T3 | | T4 | | | T1 | | T2 | | T3 | | T4 | | | Annual | Percent |
| Species | I | II | I | II | I | II | I | II | Total | I | II | I | II | I | II | I | II | Total | Total | Total |
| *Genyonemus lineatus* | 125 | 176 | 3 | 5 | 20 | 8 | 2 | - | 339 | 155 | 718 | - | - | - | - | - | - | 873 | 1,212 | 45 |
| *Citharichthys stigmaeus* | 38 | 75 | 10 | 29 | 8 | 14 | 15 | 12 | 201 | 10 | 7 | 104 | 54 | 117 | 145 | 58 | 82 | 577 | 778 | 29 |
| *Amphistichus argenteus* | 4 | 3 | 5 | 5 | 1 | 4 | 8 | 7 | 37 | 1 | - | 4 | 13 | 50 | 59 | 12 | 7 | 146 | 183 | 7 |
| *Engraulis mordax* | 12 | 4 | 13 | 4 | 2 | 2 | 12 | 1 | 50 | 7 | 41 | 1 | 7 | 1 | - | 9 | - | 66 | 116 | 4 |
| *Stellerina xyosterna* | - | 1 | 4 | 3 | - | 1 | 1 | - | 10 | 36 | 21 | 5 | - | 1 | - | - | - | 63 | 73 | 3 |
| *Cymatogaster aggregata* | - | - | - | 1 | - | - | - | - | 1 | 17 | 21 | 5 | 10 | 2 | - | - | - | 55 | 56 | 2 |
| *Syngnathus exilis* | 9 | 10 | 2 | 1 | 1 | 3 | 3 | 2 | 31 | 4 | - | 7 | 2 | 4 | 2 | 2 | 3 | 24 | 55 | 2 |
| *Squalus acanthias* | - | - | - | - | 6 | 2 | 23 | 7 | 38 | - | - | - | - | - | - | - | - | - | 38 | 1 |
| *Syngnathus californiensis* | 8 | 13 | - | - | 2 | - | 2 | 1 | 26 | 1 | 7 | - | - | 1 | - | 1 | 1 | 11 | 37 | 1 |
| *Hyperprosopon argenteum* | - | - | - | - | - | - | - | - | - | 5 | 6 | 3 | 12 | - | - | - | - | 26 | 26 | 1 |
| *Seriphus politus* | - | 1 | - | - | - | - | - | - | 1 | 16 | 6 | - | - | - | - | - | - | 22 | 23 | 1 |
| *Parophrys vetulus* | 1 | - | - | - | 1 | - | 2 | - | 4 | - | - | - | - | 1 | - | 7 | 10 | 18 | 22 | 1 |
| *Platyrhinoidis triseriata* | - | - | - | - | 1 | 4 | 4 | 4 | 13 | - | - | - | 1 | - | 1 | - | - | 2 | 15 | 1 |
| *Synodus lucioceps* | - | - | - | - | - | - | - | - | - | - | - | - | - | 5 | - | 5 | 3 | 13 | 13 | <1 |
| *Leptocottus armatus* | - | - | - | - | - | - | - | - | - | 1 | 3 | 1 | - | - | 1 | - | 3 | 9 | 9 | <1 |
| *Menticirrhus undulatus* | 3 | 3 | 1 | - | - | 2 | - | - | 9 | - | - | - | - | - | - | - | - | - | 9 | <1 |
| *Phanerodon furcatus* | - | - | - | - | - | - | - | - | - | 1 | 5 | 2 | - | 1 | - | - | - | 9 | 9 | <1 |
| *Myliobatis californica* | - | - | - | - | - | - | - | - | - | - | - | - | 4 | 1 | - | - | - | 5 | 5 | <1 |
| *Anchoa delicatissima* | 1 | - | - | - | 1 | - | - | - | 2 | - | - | - | - | - | - | - | - | - | 2 | <1 |
| *Sebastes dalli* | 1 | - | - | 1 | - | - | - | - | 2 | - | - | - | - | - | - | - | - | - | 2 | <1 |
| *Sebastes miniatus* | - | - | - | - | - | - | - | 2 | 2 | - | - | - | - | - | - | - | - | - | 2 | <1 |
| *Anchoa compressa* | - | 1 | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | 1 | <1 |
| *Aulorhynchus flavidus* | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | 1 | 1 | <1 |
| *Ophidion scrippsae* | - | - | - | - | 1 | - | - | - | 1 | - | - | - | - | - | - | - | - | - | 1 | <1 |
| *Oxylebius pictus* | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | 1 | 1 | <1 |
| *Paralichthys californicus* | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | 1 | 1 | <1 |
| *Pleuronichthys guttulatus* | - | - | - | - | 1 | - | - | - | 1 | - | - | - | - | - | - | - | - | - | 1 | <1 |
| *Rhinobatos productus* | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | 1 | 1 | <1 |
| *Sardinops sagax* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | 1 | <1 |
| *Xystreurys liolepis* | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | 1 | 1 | <1 |
| Total abundance | 202 | 287 | 38 | 49 | 45 | 40 | 72 | 36 | 769 | 255 | 837 | 133 | 104 | 184 | 208 | 94 | 110 | 1,925 | 2,694 | |
| Species | 10 | 10 | 7 | 8 | 12 | 9 | 10 | 8 | 19 | 13 | 12 | 10 | 9 | 11 | 5 | 7 | 8 | 22 | 30 | |
| Diversity (H') | 1.26 | 1.12 | 1.67 | 1.39 | 1.81 | 1.89 | 1.89 | 1.77 | 1.72 | 1.41 | 0.68 | 0.96 | 1.55 | 1.04 | 0.70 | 1.27 | 0.99 | 1.61 | 1.70 | |
| Area Trawled ($m^2$) | 3,078.1 | 3,035.3 | 3,145.8 | 3,101.4 | 3,031.7 | 3,081.9 | 3,151.3 | 3,073.0 | | 3,284.8 | 3,211.1 | 2,979.6 | 3,065.3 | 3,053.7 | 3,042.9 | 2,861.6 | 2,952.9 | | | |
| Abundance less than 30 mm SL. | | | | | | | | | | | | | | | | | | | | |
| *Genyonemus lineatus* | 85 | 55 | 1 | 6 | 35 | 17 | 6 | 1 | 206 | - | - | - | - | - | - | - | - | - | 206 | |
| Total Abundance < 30 mm SL | 85 | 55 | 1 | 6 | 35 | 17 | 6 | 1 | 206 | - | - | - | - | - | - | - | - | - | 206 | |

**Appendix G-3. Biomass (kg) of fish species in trawl replicates. Mandalay Generating Station NPDES, 2009.**

| | Winter | | | | | | | | | Summer | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T1 | | T2 | | T3 | | T4 | | | T1 | | T2 | | T3 | | T4 | | | Annual | Percent |
| Species | I | II | I | II | I | II | I | II | Total | I | II | I | II | I | II | I | II | Total | Total | Total |
| *Squalus acanthias* | - | - | - | - | 1.30 | 0.36 | 4.70 | 1.70 | 8.06 | - | - | - | - | - | - | - | - | - | 8.06 | 23 |
| *Myliobatis californica* | - | - | - | - | - | - | - | - | - | - | - | - | 5.20 | 2.10 | - | - | - | 7.30 | 7.30 | 21 |
| *Citharichthys stigmaeus* | 0.16 | 0.20 | 0.06 | 0.09 | 0.14 | 0.07 | 0.06 | 0.03 | 0.80 | 0.03 | 0.05 | 0.71 | 0.46 | 0.60 | 0.81 | 0.40 | 0.52 | 3.58 | 4.38 | 13 |
| *Genyonemus lineatus* | 0.18 | 0.18 | 0.00 | 0.00 | 0.02 | 0.01 | 0.00 | - | 0.39 | 0.72 | 1.83 | - | - | - | - | - | - | 2.55 | 2.94 | 8 |
| *Amphistichus argenteus* | 0.12 | 0.10 | 0.14 | 0.11 | 0.03 | 0.10 | 0.21 | 0.17 | 0.98 | 0.01 | - | 0.08 | 0.19 | 0.70 | 0.75 | 0.11 | 0.10 | 1.94 | 2.92 | 8 |
| *Platyrhinoidis triseriata* | - | - | - | - | 0.02 | 0.63 | 0.58 | 0.52 | 1.75 | - | - | - | 0.49 | - | 0.24 | - | - | 0.73 | 2.48 | 7 |
| *Menticirrhus undulatus* | 0.66 | 0.79 | 0.09 | - | - | 0.35 | - | - | 1.89 | - | - | - | - | - | - | - | - | - | 1.89 | 5 |
| *Engraulis mordax* | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 | 0.01 | 0.02 | 0.00 | 0.04 | 0.10 | 0.62 | 0.02 | 0.13 | 0.01 | - | 0.12 | - | 1.00 | 1.04 | 3 |
| *Seriphus politus* | - | 0.02 | - | - | - | - | - | - | 0.02 | 0.37 | 0.15 | - | - | - | - | - | - | 0.52 | 0.54 | 2 |
| *Paralichthys californicus* | - | - | - | - | - | - | - | - | - | 0.51 | - | - | - | - | - | - | - | 0.51 | 0.51 | 1 |
| *Cymatogaster aggregata* | - | - | - | 0.05 | - | - | - | - | 0.05 | 0.11 | 0.04 | 0.04 | 0.11 | 0.01 | - | - | - | 0.31 | 0.36 | 1 |
| *Rhinobatos productus* | - | - | - | - | - | - | - | - | - | - | 0.35 | - | - | - | - | - | - | 0.35 | 0.35 | 1 |
| *Pleuronichthys guttulatus* | - | - | - | - | 0.33 | - | - | - | 0.33 | - | - | - | - | - | - | - | - | - | 0.33 | 1 |
| *Stellerina xyosterna* | - | 0.01 | 0.05 | 0.03 | - | 0.01 | 0.01 | - | 0.11 | 0.09 | 0.05 | 0.02 | - | 0.01 | - | - | - | 0.17 | 0.28 | 1 |
| *Leptocottus armatus* | - | - | - | - | - | - | - | - | - | 0.03 | 0.08 | 0.04 | - | - | 0.03 | - | 0.08 | 0.26 | 0.26 | 1 |
| *Hyperprosopon argenteum* | - | - | - | - | - | - | - | - | - | 0.04 | 0.06 | 0.02 | 0.09 | - | - | - | - | 0.21 | 0.21 | 1 |
| *Synodus lucioceps* | - | - | - | - | - | - | - | - | - | - | - | - | - | 0.08 | - | 0.06 | 0.04 | 0.19 | 0.19 | 1 |
| *Xystreurys liolepis* | - | - | - | - | - | - | - | - | - | - | - | - | 0.16 | - | - | - | - | 0.16 | 0.16 | <1 |
| *Parophrys vetulus* | 0.00 | - | - | - | 0.00 | - | 0.00 | - | 0.00 | - | - | - | - | 0.03 | - | 0.02 | 0.09 | 0.15 | 0.15 | <1 |
| *Syngnathus exilis* | 0.02 | 0.02 | 0.01 | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 | 0.07 | 0.01 | - | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.01 | 0.05 | 0.12 | <1 |
| *Syngnathus californiensis* | 0.02 | 0.03 | - | - | 0.01 | - | 0.01 | 0.00 | 0.07 | 0.00 | 0.01 | - | - | 0.00 | - | 0.00 | 0.00 | 0.02 | 0.09 | <1 |
| *Sardinops sagax* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0.03 | 0.03 | 0.03 | <1 |
| *Phanerodon furcatus* | - | - | - | - | - | - | - | - | - | 0.00 | 0.00 | 0.00 | - | 0.00 | - | - | - | 0.01 | 0.01 | <1 |
| *Anchoa delicatissima* | 0.00 | - | - | - | 0.00 | - | - | - | 0.01 | - | - | - | - | - | - | - | - | - | 0.01 | <1 |
| *Aulorhynchus flavidus* | - | - | - | - | - | - | - | - | - | - | 0.01 | - | - | - | - | - | - | 0.01 | 0.01 | <1 |
| *Ophidion scrippsae* | - | - | - | - | 0.00 | - | - | - | 0.00 | - | - | - | - | - | - | - | - | - | 0.00 | <1 |
| *Anchoa compressa* | - | 0.00 | - | - | - | - | - | - | 0.00 | - | - | - | - | - | - | - | - | - | 0.00 | <1 |
| *Oxylebius pictus* | - | - | - | - | - | - | - | - | - | - | - | 0.00 | - | - | - | - | - | 0.00 | 0.00 | <1 |
| *Sebastes dalli* | 0.00 | - | - | 0.00 | - | - | - | - | 0.00 | - | - | - | - | - | - | - | - | - | 0.00 | <1 |
| *Sebastes miniatus* | - | - | - | - | - | - | - | 0.00 | 0.00 | - | - | - | - | - | - | - | - | - | 0.00 | <1 |
| Total Biomass (kg) | 1.17 | 1.36 | 0.34 | 0.28 | 1.85 | 1.53 | 5.59 | 2.43 | 14.57 | 2.03 | 3.26 | 0.95 | 6.84 | 3.55 | 1.83 | 0.72 | 0.88 | 20.05 | 34.62 | |

Biomass (kg) less than 30 mm SL.

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Genyonemus lineatus* | 0.04 | 0.02 | 0.00 | 0.00 | 0.02 | 0.01 | 0.00 | 0.00 | 0.09 | - | - | - | - | - | - | - | - | - | 0.09 |
| Total Biomass (kg) | 0.04 | 0.02 | 0.00 | 0.00 | 0.02 | 0.01 | 0.00 | 0.00 | 0.09 | - | - | - | - | - | - | - | - | - | 0.09 |

Note: 0.00 = < 0.005, "-" = absent, anomalies due to rounding

**Appendix G-4. Length of fish species in trawl replicates. Manalay Generating Station NPDES, winter 2009.**

| MGS T1-I | Length (cm) | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 14 | 15 | 18 | 19 | 20 | 21 | 22 | 24 | 25 | 26 |
| *Amphistichus argenteus* | - | - | - | - | - | - | - | 1 | 3 | - | - | - | - | - | - | - | - | - | - | - |
| *Anchoa delicatissima* | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Citharichthys stigmaeus* | - | 9 | 7 | 7 | 4 | 5 | 2 | 3 | - | 1 | - | - | - | - | - | - | - | - | - | - |
| *Engraulis mordax* | - | 1 | 5 | 5 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Genyonemus lineatus* | - | 50 | 58 | 12 | 3 | - | - | 1 | 1 | - | - | - | - | - | - | - | - | - | - | - |
| *Menticirrhus undulatus* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | 1 | 1 |
| *Parophrys vetulus* | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Sebastes dalli* | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Syngnathus californiensis* | - | - | - | - | - | - | - | - | - | - | - | 1 | - | 1 | - | 2 | 3 | 1 | - | - |
| *Syngnathus exilis* | - | - | - | - | - | - | - | - | - | - | 1 | 1 | 1 | 1 | 2 | 2 | 1 | - | - | - |

| MGS T1-II | Length (cm) | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 11 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 28 |
| *Amphistichus argenteus* | - | - | - | - | - | - | - | 1 | 2 | - | - | - | - | - | - | - | - | - |
| *Anchoa compressa* | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - |
| *Citharichthys stigmaeus* | 1 | 19 | 21 | 13 | 5 | 7 | 7 | 2 | - | - | - | - | - | - | - | - | - | - |
| *Engraulis mordax* | - | 1 | 1 | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Genyonemus lineatus* | - | 84 | 80 | 11 | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - |
| *Menticirrhus undulatus* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | 1 | 1 |
| *Seriphus politus* | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - |
| *Stellerina xyosterna* | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - |
| *Syngnathus californiensis* | - | - | - | - | - | - | - | - | - | - | 1 | 1 | 4 | 3 | 2 | 1 | 1 | - |
| *Syngnathus exilis* | - | - | - | - | - | - | - | - | - | 1 | 2 | 2 | 2 | 2 | 1 | - | - | - |

| MGS T2-I | Length (cm) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Species | 3 | 4 | 5 | 7 | 8 | 9 | 10 | 11 | 15 | 18 |
| *Amphistichus argenteus* | - | - | - | - | - | 3 | 1 | 1 | - | - |
| *Citharichthys stigmaeus* | 2 | 1 | 3 | 1 | 1 | 1 | - | 1 | - | - |
| *Engraulis mordax* | - | 8 | 5 | - | - | - | - | - | - | - |
| *Genyonemus lineatus* | 2 | 1 | - | - | - | - | - | - | - | - |
| *Menticirrhus undulatus* | - | - | - | - | - | - | - | - | - | 1 |
| *Stellerina xyosterna* | - | - | - | - | - | - | 2 | 2 | - | - |
| *Syngnathus exilis* | - | - | - | - | - | - | - | 1 | 1 | - |

| MGS T2-II | Length (cm) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 21 |
| *Amphistichus argenteus* | - | - | - | - | - | - | - | 5 | - | - | - |
| *Citharichthys stigmaeus* | 2 | 1 | 14 | 5 | 2 | 3 | 2 | - | - | - | - |
| *Cymatogaster aggregata* | - | - | - | - | - | - | - | - | - | 1 | - |
| *Engraulis mordax* | - | - | 4 | - | - | - | - | - | - | - | - |
| *Genyonemus lineatus* | 1 | 4 | - | - | - | - | - | - | - | - | - |
| *Sebastes dalli* | 1 | - | - | - | - | - | - | - | - | - | - |
| *Stellerina xyosterna* | - | - | - | - | - | - | 1 | 1 | 1 | - | - |
| *Syngnathus exilis* | - | - | - | - | - | - | - | - | - | - | 1 |

| MGS T3-I | Length (cm) | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 15 | 19 | 24 | 34 | 37 | 39 | 43 | 45 |
| *Amphistichus argenteus* | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - |
| *Anchoa delicatissima* | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - |
| *Citharichthys stigmaeus* | - | 2 | 1 | - | 1 | 1 | 1 | 2 | - | - | - | - | - | - | - | - | - |
| *Engraulis mordax* | - | - | - | 1 | 1 | - | - | - | - | - | - | - | - | - | - | - | - |
| *Genyonemus lineatus* | - | 15 | 5 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Ophidion scrippsae* | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - |
| *Parophrys vetulus* | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Platyrhinoidis triseriata* | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - |
| *Pleuronichthys guttulatus* | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - |
| *Squalus acanthias* | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | 1 | 2 | 1 |
| *Syngnathus californiensis* | - | - | - | - | - | - | - | - | - | - | 1 | 1 | - | - | - | - | - |
| *Syngnathus exilis* | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - |

**Appendix G-4. (Cont.)**

MGS T3-II

| Species | Length (cm) 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 15 | 16 | 17 | 20 | 25 | 37 | 46 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Amphistichus argenteus* | - | - | - | - | - | - | - | 4 | - | - | - | - | - | - | - | - |
| *Citharichthys stigmaeus* | - | 4 | 3 | 1 | 3 | 1 | 2 | - | - | - | - | - | - | - | - | - |
| *Engraulis mordax* | - | - | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Genyonemus lineatus* | 2 | 6 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Menticirrhus undulatus* | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | - | - |
| *Platyrhinoidis triseriata* | - | - | - | - | - | - | - | - | - | 1 | 1 | 1 | - | - | - | 1 |
| *Squalus acanthias* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 | - |
| *Stellerina xyosterna* | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - |
| *Syngnathus exilis* | - | - | - | - | - | - | - | - | - | 1 | - | 1 | 1 | - | - | - |

MGS T4-I

| Species | Length (cm) 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 13 | 15 | 17 | 18 | 20 | 21 | 22 | 27 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 43 | 45 | 46 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Amphistichus argenteus* | - | - | - | - | - | - | - | 4 | 3 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Citharichthys stigmaeus* | - | - | 1 | 5 | 2 | 1 | 4 | 1 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Engraulis mordax* | - | - | - | 10 | 1 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Genyonemus lineatus* | - | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Parophrys vetulus* | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Platyrhinoidis triseriata* | - | - | - | - | - | - | - | - | - | - | 1 | 1 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - |
| *Squalus acanthias* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 2 | 4 | 4 | 2 | 4 | 1 | 2 | 2 | 1 |
| *Stellerina xyosterna* | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Syngnathus californiensis* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | 1 | - | - | - | - | - | - | - | - | - | - |
| *Syngnathus exilis* | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | - | 1 | - | - | - | - | - | - | - | - | - | - | - |

MGS T4-II

| Species | Length (cm) 3 | 4 | 5 | 6 | 8 | 9 | 10 | 14 | 16 | 17 | 20 | 21 | 22 | 35 | 37 | 39 | 40 | 42 | 45 | 46 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Amphistichus argenteus* | - | - | - | - | - | 2 | 5 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Citharichthys stigmaeus* | - | 2 | 6 | 3 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Engraulis mordax* | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Platyrhinoidis triseriata* | - | - | - | - | - | - | - | 1 | 1 | 1 | - | - | - | - | - | - | - | - | 1 | - |
| *Sebastes miniatus* | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Squalus acanthias* | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | 1 | 1 | 2 | - | 1 |
| *Syngnathus californiensis* | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - |
| *Syngnathus exilis* | - | - | - | - | - | - | - | - | - | - | 1 | 1 | - | - | - | - | - | - | - | - |

Fish diseases, abnormalities, and paratism

| Species | Sta-Rep | Note |
|---|---|---|
| None | - | - - - - - - - - - - - - - - - - - - - - - - - - - - - - - |

**Appendix G-5. Length of fish species in trawl replicates. Mandalay Generating Station NPDES, summer 2009.**

MGS T1-I

| | Length (cm) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 20 | 22 | 30 |
| *Amphistichus argenteus* | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - |
| *Citharichthys stigmaeus* | 1 | - | 2 | 2 | 5 | - | - | - | - | - | - | - | - | - | - |
| *Cymatogaster aggregata* | - | 6 | 8 | - | - | - | 2 | - | - | 1 | - | - | - | - | - |
| *Engraulis mordax* | - | - | - | - | - | 1 | - | - | 2 | 4 | - | - | - | - | - |
| *Genyonemus lineatus* | - | 1 | 16 | 115 | 23 | - | - | - | - | - | - | - | - | - | - |
| *Hyperprosopon argenteum* | - | - | - | 1 | 4 | - | - | - | - | - | - | - | - | - | - |
| *Leptocottus armatus* | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - |
| *Paralichthys californicus* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 |
| *Phanerodon furcatus* | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - |
| *Seriphus politus* | - | - | - | - | - | - | 1 | 6 | 4 | 3 | 1 | 1 | - | - | - |
| *Stellerina xyosterna* | - | 4 | 13 | 4 | 10 | 5 | - | - | - | - | - | - | - | - | - |
| *Syngnathus californiensis* | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - |
| *Syngnathus exilis* | - | - | - | - | - | - | - | - | - | - | - | - | 3 | 1 | - |

MGS T1-II

| | Length (cm) | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 15 | 17 | 18 | 19 | 21 | 22 | 45 |
| *Aulorhynchus flavidus* | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - |
| *Citharichthys stigmaeus* | - | - | - | 2 | 3 | 1 | 1 | - | - | - | - | - | - | - | - | - | - | - |
| *Cymatogaster aggregata* | 1 | 14 | 5 | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - |
| *Engraulis mordax* | - | - | - | - | 1 | - | - | 3 | 17 | 17 | 3 | - | - | - | - | - | - | - |
| *Genyonemus lineatus* | 1 | 9 | 63 | 116 | 11 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Hyperprosopon argenteum* | - | - | - | 2 | 4 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Leptocottus armatus* | - | - | - | - | - | - | 1 | 1 | - | - | 1 | - | - | - | - | - | - | - |
| *Phanerodon furcatus* | - | 5 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Rhinobatos productus* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 |
| *Seriphus politus* | - | - | - | - | - | - | - | - | 4 | 2 | - | - | - | - | - | - | - | - |
| *Stellerina xyosterna* | - | 5 | 6 | 3 | 4 | 3 | - | - | - | - | - | - | - | - | - | - | - | - |
| *Syngnathus californiensis* | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | 2 | 1 | 1 | 1 | - |

MGS T2-I

| | Length (cm) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 17 | 19 | 20 | 23 | 26 |
| *Amphistichus argenteus* | - | - | - | - | 1 | - | 2 | 1 | - | - | - | - | - | - | - | - |
| *Citharichthys stigmaeus* | 1 | 5 | 21 | 30 | 19 | 13 | 10 | 2 | 1 | 2 | - | - | - | - | - | - |
| *Cymatogaster aggregata* | - | 2 | 2 | - | - | - | - | 1 | - | - | - | - | - | - | - | - |
| *Engraulis mordax* | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - |
| *Hyperprosopon argenteum* | - | - | - | - | 3 | - | - | - | - | - | - | - | - | - | - | - |
| *Leptocottus armatus* | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - |
| *Oxylebius pictus* | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Phanerodon furcatus* | - | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Stellerina xyosterna* | - | 1 | - | - | - | 3 | 1 | - | - | - | - | - | - | - | - | - |
| *Syngnathus exilis* | - | - | - | - | - | - | - | - | - | - | - | 1 | 3 | 1 | 1 | 1 |

MGS T2-II

| | Length (cm) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 19 | 22 | 25 | 34 | 40 | 41 | 42 | 47 |
| *Amphistichus argenteus* | - | - | - | 2 | 9 | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Citharichthys stigmaeus* | 4 | 10 | 15 | 9 | 7 | 6 | 2 | 1 | - | - | - | - | - | - | - | - | - | - | - |
| *Cymatogaster aggregata* | 2 | 3 | - | - | - | 1 | 3 | 1 | - | - | - | - | - | - | - | - | - | - | - |
| *Engraulis mordax* | - | - | - | - | - | - | 1 | 3 | 1 | 1 | 1 | - | - | - | - | - | - | - | - |
| *Hyperprosopon argenteum* | - | - | 3 | 8 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Myliobatis californica* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | - | 1 | 1 |
| *Platyrhinoidis triseriata* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - |
| *Syngnathus exilis* | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | - | - | - | - | - |
| *Xystreurys liolepis* | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - |

**Appendix G-5. (Cont.)**

MGS T3-I

| Species | Length (cm) 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 17 | 19 | 49 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Amphistichus argenteus* | - | - | - | 1 | 16 | 29 | 4 | - | - | - | - | - | - | - |
| *Citharichthys stigmaeus* | 1 | 5 | 25 | 52 | 19 | 5 | 6 | 2 | 2 | - | - | - | - | - |
| *Cymatogaster aggregata* | - | 1 | - | 1 | - | - | - | - | - | - | - | - | - | - |
| *Engraulis mordax* | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - |
| *Myliobatis californica* | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 |
| *Parophrys vetulus* | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - |
| *Phanerodon furcatus* | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - |
| *Stellerina xyosterna* | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - |
| *Syngnathus californiensis* | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - |
| *Syngnathus exilis* | - | - | - | - | - | - | - | - | - | - | 1 | 1 | 2 | - |
| *Synodus lucioceps* | - | - | - | - | - | - | 2 | 1 | - | 2 | - | - | - | - |

MGS T3-II

| Species | Length (cm) 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 21 | 34 |
|---|---|---|---|---|---|---|---|---|---|---|
| *Amphistichus argenteus* | - | - | - | 23 | 31 | 5 | - | - | - | - |
| *Citharichthys stigmaeus* | 4 | 39 | 56 | 18 | 8 | 11 | 6 | 3 | - | - |
| *Leptocottus armatus* | - | - | - | - | - | - | - | 1 | - | - |
| *Platyrhinoidis triseriata* | - | - | - | - | - | - | - | - | - | 1 |
| *Syngnathus exilis* | - | - | - | - | - | - | - | - | 2 | - |

MGS T4-I

| Species | Length (cm) 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 18 | 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Amphistichus argenteus* | - | - | 1 | 2 | 9 | - | - | - | - | - | - | - | - |
| *Citharichthys stigmaeus* | 2 | 8 | 24 | 10 | 4 | 5 | 4 | 1 | - | - | - | - | - |
| *Engraulis mordax* | - | 1 | 2 | 1 | - | - | - | - | 3 | 1 | 1 | - | - |
| *Parophrys vetulus* | 1 | 4 | 1 | - | - | 1 | - | - | - | - | - | - | - |
| *Syngnathus californiensis* | - | - | - | - | - | - | - | - | - | - | 1 | - | - |
| *Syngnathus exilis* | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 |
| *Synodus lucioceps* | - | - | - | - | - | - | - | 2 | 2 | 1 | - | - | - |

MGS T4-II

| Species | Length (cm) 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 18 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Amphistichus argenteus* | - | - | - | 2 | 5 | - | - | - | - | - | - | - | - |
| *Citharichthys stigmaeus* | 5 | 15 | 29 | 12 | 9 | 7 | 4 | 1 | - | - | - | - | - |
| *Leptocottus armatus* | - | - | - | - | - | 1 | - | 2 | - | - | - | - | - |
| *Parophrys vetulus* | - | 7 | 1 | - | - | - | 1 | - | - | 1 | - | - | - |
| *Sardinops sagax* | - | - | - | - | - | - | - | - | - | - | 1 | - | - |
| *Syngnathus californiensis* | - | - | - | - | - | - | - | - | - | - | - | - | 1 |
| *Syngnathus exilis* | - | - | - | - | - | - | - | - | - | - | - | 2 | 1 |
| *Synodus lucioceps* | - | - | - | - | - | - | 1 | - | 1 | 1 | - | - | - |

Fish diseases, abnormalities, and paratism

| Species | Sta-Rep | Note |
|---|---|---|
| None | - - - - - - | - - - - - - - - - - - - - |

**Appendix G-6. Abundance of macroinvertebrate species in trawl replicates, winter and summer. Mandalay Generating Station NPDES, 2009.**

| | Winter | | | | | | | | | Summer | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T1 | | T2 | | T3 | | T4 | | | T1 | | T2 | | T3 | | T4 | | | Annual | Percent |
| Species | I | II | I | II | I | II | I | II | Total | I | II | I | II | I | II | I | II | Total | Total | Total |
| *Dendraster excentricus* | 18 | 13 | 52 | 107 | 29 | 21 | 19 | 12 | 271 | 2,910 | 1,419 | - | - | - | - | - | - | 4,329 | 4,600 | 45 |
| *Crangon nigromaculata* | 436 | 473 | 218 | 964 | 197 | 142 | 291 | 122 | 2,843 | 350 | 683 | 106 | 42 | 8 | 8 | 3 | 15 | 1,215 | 4,058 | 40 |
| *Metacarcinus gracilis* | 49 | 71 | 14 | 51 | 5 | 6 | 4 | 9 | 209 | 92 | 70 | 208 | 175 | 233 | 300 | 28 | 31 | 1,137 | 1,346 | 13 |
| *Crangon alaskensis* | 4 | 4 | 3 | 27 | 4 | 2 | 2 | 3 | 49 | 12 | 3 | - | - | - | - | - | - | 15 | 64 | 1 |
| *Renilla koellikeri* | - | - | 2 | 3 | 8 | 11 | - | 1 | 25 | - | - | - | - | 2 | 3 | - | - | 5 | 30 | <1 |
| *Lissocrangon stylirostris* | 1 | 1 | 1 | 6 | 1 | 1 | 1 | 2 | 14 | - | - | - | - | - | - | - | - | - | 14 | <1 |
| *Metacarcinus anthonyi* | 5 | 6 | - | 1 | 1 | - | - | - | 13 | - | - | - | - | - | - | - | - | - | 13 | <1 |
| *Panulirus interruptus* | - | - | - | - | - | 1 | 1 | - | 2 | 1 | 2 | - | - | - | - | 1 | - | 4 | 6 | <1 |
| *Randallia ornata* | - | - | - | 1 | - | 1 | 1 | 1 | 4 | - | - | - | - | - | - | - | - | - | 4 | <1 |
| *Portunus xantusii* | 1 | - | 1 | 1 | - | - | - | - | 3 | - | - | - | - | - | - | - | - | - | 3 | <1 |
| *Blepharipoda occidentalis* | - | 1 | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | 1 | <1 |
| *Farfantepenaeus californiensis* | - | - | - | - | 1 | - | - | - | 1 | - | - | - | - | - | - | - | - | - | 1 | <1 |
| *Heptacarpus stimpsoni* | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | 1 | 1 | <1 |
| *Loxorhynchus grandis* | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | 1 | 1 | <1 |
| *Polyorchis penicillatus* | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | 1 | 1 | <1 |
| *Pugettia producta* | 1 | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | 1 | <1 |
| *Romaleon antennarius* | 1 | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | 1 | <1 |
| Total Abundance | 516 | 569 | 291 | 1,161 | 246 | 185 | 319 | 150 | 3,437 | 3,366 | 2,178 | 314 | 218 | 243 | 311 | 32 | 46 | 6,708 | 10,145 | |
| Species | 9 | 7 | 7 | 9 | 8 | 8 | 7 | 7 | 14 | 6 | 6 | 2 | 3 | 3 | 3 | 3 | 2 | 9 | 17 | |
| Diversity (H') | 0.61 | 0.60 | 0.79 | 0.66 | 0.75 | 0.86 | 0.39 | 0.74 | 0.70 | 0.48 | 0.77 | 0.64 | 0.52 | 0.19 | 0.17 | 0.45 | 0.63 | 0.92 | 1.08 | |
| Evenness (J') | 0.00 | 0.31 | 0.41 | 0.30 | 0.36 | 0.41 | 0.20 | 0.38 | 0.26 | 0.27 | 0.43 | 0.92 | 0.47 | 0.17 | 0.16 | 0.41 | 0.91 | 0.42 | 0.38 | |
| Area Trawled ($m^2$) | 3,078.1 | 3,035.3 | 3,145.8 | 3,101.4 | 3,031.7 | 3,081.9 | 3,151.3 | 3,073.0 | | 3,284.8 | 3,211.1 | 2,979.6 | 3,065.3 | 3,053.7 | 3,042.9 | 2,861.6 | 2,952.9 | | | |
| Fish Parasites Not Included Above | | | | | | | | | | | | | | | | | | | | |
| none | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |

**Appendix G-7. Biomass (kg) of macroinvertebrates species in trawl replicates, winter and summer. Mandalay Generating Station NPDES, 2009.**

| | Winter | | | | | | | | | Summer | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T1 | | T2 | | T3 | | T4 | | | T1 | | T2 | | T3 | | T4 | | | Annual | Percent |
| Species | I | II | I | II | I | II | I | II | Total | I | II | I | II | I | II | I | II | Total | Total | Total |
| *Metacarcinus gracilis* | 0.17 | 0.18 | 0.10 | 0.20 | 0.06 | 0.23 | 0.02 | 0.29 | 1.25 | 1.10 | 0.84 | 2.50 | 2.10 | 2.80 | 3.60 | 0.45 | 0.46 | 13.85 | 15.10 | 44 |
| *Crangon nigromaculata* | 1.20 | 1.30 | 0.62 | 2.65 | 0.63 | 0.39 | 0.80 | 0.34 | 7.93 | 0.42 | 0.82 | 0.18 | 0.06 | 0.02 | 0.02 | 0.01 | 0.02 | 1.55 | 9.48 | 28 |
| *Dendraster excentricus* | 0.05 | 0.04 | 0.24 | 0.26 | 0.06 | 0.03 | 0.05 | 0.04 | 0.76 | 4.51 | 2.20 | - | - | - | - | - | - | 6.71 | 7.47 | 22 |
| *Panulirus interruptus* | - | - | - | - | - | 0.16 | 0.14 | - | 0.30 | 0.19 | 0.74 | - | - | - | - | 0.26 | - | 1.19 | 1.49 | 4 |
| *Loxorhynchus grandis* | - | - | - | - | - | - | - | - | - | - | - | - | 0.30 | - | - | - | - | 0.30 | 0.30 | 1 |
| *Crangon alaskensis* | 0.01 | 0.01 | 0.01 | 0.03 | 0.01 | 0.01 | 0.00 | 0.01 | 0.07 | 0.01 | 0.00 | - | - | - | - | - | - | 0.01 | 0.08 | <1 |
| *Renilla koellikeri* | - | - | 0.00 | 0.00 | 0.01 | 0.01 | - | 0.00 | 0.02 | - | - | - | - | 0.01 | 0.02 | - | - | 0.03 | 0.05 | <1 |
| *Farfantepenaeus californiensis* | - | - | - | - | 0.03 | - | - | - | 0.03 | - | - | - | - | - | - | - | - | - | 0.03 | <1 |
| *Randallia ornata* | - | - | - | 0.01 | - | 0.01 | 0.00 | 0.00 | 0.02 | - | - | - | - | - | - | - | - | - | 0.02 | <1 |
| *Metacarcinus anthonyi* | 0.01 | 0.01 | - | 0.00 | 0.00 | - | - | - | 0.02 | - | - | - | - | - | - | - | - | - | 0.02 | <1 |
| *Lissocrangon stylirostris* | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | - | - | - | - | - | - | - | - | - | 0.02 | <1 |
| *Portunus xantusii* | 0.00 | - | 0.00 | 0.00 | - | - | - | - | 0.01 | - | - | - | - | - | - | - | - | - | 0.01 | <1 |
| *Romaleon antennarius* | 0.01 | - | - | - | - | - | - | - | 0.01 | - | - | - | - | - | - | - | - | - | 0.01 | <1 |
| *Pugettia producta* | 0.01 | - | - | - | - | - | - | - | 0.01 | - | - | - | - | - | - | - | - | - | 0.01 | <1 |
| *Blepharipoda occidentalis* | - | 0.00 | - | - | - | - | - | - | 0.00 | - | - | - | - | - | - | - | - | - | 0.00 | <1 |
| *Heptacarpus stimpsoni* | - | - | - | - | - | - | - | - | - | 0.00 | - | - | - | - | - | - | - | 0.00 | 0.00 | <1 |
| *Polyorchis penicillatus* | - | - | - | - | - | - | - | - | - | - | 0.00 | - | - | - | - | - | - | 0.00 | 0.00 | <1 |
| Total Biomass (kg) | 1.45 | 1.53 | 0.97 | 3.17 | 0.80 | 0.84 | 1.01 | 0.68 | 10.44 | 6.23 | 4.60 | 2.68 | 2.46 | 2.83 | 3.63 | 0.72 | 0.48 | 23.63 | 34.07 | |
| Fish parasites not included above | | | | | | | | | | | | | | | | | | | | |
| none | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |

Note: 0.00 = < 0.005, "-" = absent, anomalies due to rounding

**Appendix G-8. Abundance of the top 20 fish species in trawl replicates, 1978 - 2009. Mandalay Generating Station NPDES, 2009.**

| Species | 1978 | 1980 | 1986 | 1988 | 1990 | 1991 | 1992 | 1993 | 1994 | 1997 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | Total | Percent Total | F.O. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Genyonemus lineatus* | 6713 | 8446 | 1464 | 1150 | 1592 | 2291 | 2756 | 3043 | 7237 | 20 | 363 | 5363 | 1033 | 9342 | - | 16 | 4632 | 3656 | 1255 | - | 1212 | 61584 | 49.0 | 19 |
| *Seriphus politus* | 966 | 4889 | 830 | 195 | 957 | 1341 | 6049 | 3009 | 5483 | - | 76 | 1352 | 4630 | 3971 | 8 | 138 | 1106 | 34 | 3 | 407 | 23 | 35467 | 28.2 | 20 |
| *Engraulis mordax* | 1476 | 494 | 2 | 52 | 88 | 359 | 1469 | 159 | 115 | - | 640 | 256 | 383 | 1216 | 9 | 3322 | 202 | 231 | 251 | 10 | 116 | 10850 | 8.6 | 20 |
| *Citharichthys stigmaeus* | 36 | 8 | 40 | 64 | 76 | 217 | 4 | 75 | 16 | 7 | 143 | 219 | 38 | 224 | 51 | 476 | 325 | 1148 | 1481 | 132 | 778 | 5558 | 4.4 | 21 |
| *Cymatogaster aggregata* | 107 | 24 | - | 4 | 33 | 63 | 4 | 58 | 88 | 17 | 190 | 42 | 11 | 529 | 18 | 118 | 135 | 330 | 1277 | 332 | 56 | 3436 | 2.7 | 20 |
| *Amphistichus argenteus* | 210 | 172 | 46 | 223 | 38 | 95 | 29 | 115 | 41 | 18 | 1 | 33 | 9 | 42 | - | 45 | 67 | 4 | 29 | 10 | 183 | 1410 | 1.1 | 20 |
| *Syngnathus californiensis* | - | - | - | - | - | - | - | - | - | - | 80 | 149 | 104 | 179 | 3 | 118 | 346 | 245 | 70 | 36 | 37 | 1367 | 1.1 | 11 |
| *Hyperprosopon argenteum* | 335 | 340 | 8 | 18 | - | 50 | 5 | 26 | 28 | 1 | 1 | 16 | 37 | 28 | 1 | 9 | 53 | 67 | - | 14 | 26 | 1063 | 0.8 | 19 |
| *Phanerodon furcatus* | 245 | 321 | 2 | 17 | 18 | 26 | 5 | 5 | 80 | 12 | 25 | - | 1 | 225 | - | - | 23 | 39 | - | - | 9 | 1053 | 0.8 | 16 |
| *Stellerina xyosterna* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 15 | - | 25 | 329 | 35 | 73 | 477 | 0.4 | 5 |
| *Platyrhinoidis triseriata* | 27 | 21 | 12 | 16 | 6 | 56 | 4 | 167 | 2 | 3 | 13 | 14 | 6 | 52 | - | 2 | 24 | 15 | 18 | 1 | 15 | 474 | 0.4 | 20 |
| *Paralichthys californicus* | 25 | 54 | 66 | 58 | 21 | 27 | 1 | 8 | 11 | - | 2 | 5 | 1 | 4 | - | - | 1 | 6 | 5 | 2 | 1 | 298 | 0.2 | 18 |
| *Menticirrhus undulatus* | 15 | 3 | 79 | - | - | 3 | 2 | 33 | 19 | - | 2 | 73 | 24 | 9 | - | 8 | 6 | 3 | 1 | - | 9 | 289 | 0.2 | 16 |
| *Syngnathus exilis* | 3 | - | - | 77 | 5 | - | - | - | 58 | - | - | - | - | - | - | - | - | - | 36 | 16 | 55 | 250 | 0.2 | 7 |
| *Synodus lucioceps* | 17 | 5 | - | - | 8 | - | 1 | 2 | 4 | - | 1 | 1 | 26 | 115 | - | 1 | 9 | - | 10 | 1 | 13 | 214 | 0.2 | 15 |
| *Parophrys vetulus* | 22 | 8 | 5 | 49 | 7 | - | - | 1 | 4 | 1 | 7 | - | - | 15 | - | 1 | 13 | 10 | 1 | - | 22 | 166 | 0.1 | 15 |
| *Umbrina roncador* | 2 | - | 11 | 1 | - | 1 | - | 79 | 50 | - | - | - | 3 | - | - | - | - | - | - | - | - | 147 | 0.1 | 7 |
| *Squalus acanthias* | 6 | 37 | 3 | - | - | 5 | - | - | - | - | - | - | 1 | - | - | - | 41 | 12 | 3 | - | 38 | 146 | 0.1 | 9 |
| *Xystreurys liolepis* | - | 10 | 17 | 10 | 1 | 3 | 1 | 1 | 5 | 1 | 39 | 27 | 1 | 16 | - | - | 1 | - | 1 | 1 | 1 | 136 | 0.1 | 17 |
| *Ophidion scrippsae* | 1 | 3 | 9 | - | 8 | 45 | - | 28 | 4 | - | 1 | 5 | - | - | - | - | 18 | - | - | - | 1 | 123 | 0.1 | 11 |
| Number of individuals | 10299 | 14986 | 2648 | 2009 | 2896 | 4674 | 10399 | 6892 | 13296 | 89 | 1597 | 7616 | 6324 | 16056 | 91 | 4304 | 7062 | 5866 | 4852 | 1010 | 2692 | 125658 | | |
| Number of species | 41 | 35 | 29 | 24 | 23 | 30 | 21 | 28 | 33 | 10 | 25 | 22 | 24 | 27 | 7 | 22 | 33 | 25 | 31 | 17 | 30 | 72 | | |
| Total Biomass (kg) | 501.0 | 1165.4 | 113.2 | 76.6 | 133.8 | 88.1 | 112.2 | 78.8 | 178.3 | 2.5 | 42.8 | 159.1 | 87.1 | 289.3 | 1.3 | 107.5 | 73.9 | 59.1 | 101.6 | 21.4 | | 3392.8 | | |
| Stations / Replicates | 14/1 | 12/1 | 3/2 | 3/2 | 4/2 | 4/2 | 4/2 | 4/2 | 4/2 | 4/2 | 4/2 | 4/2 | 4/2 | 4/2 | 4/1 | 4/2 | 4/2 | 4/2 | 4/2 | 4/2 | 2.00 | | | |
| Seasons | W / S | W / S | W / S | W / S | W / S | W / S | W / S | W / S | W / S | S | W / S | W / S | W / S | W / S | S | W / S | W / S | W / S | W / S | S | W / S | | | |
| Number of Trawls | 28 | 24 | 12 | 12 | 16 | 16 | 16 | 16 | 16 | 8 | 16 | 16 | 16 | 16 | 4 | 16 | 16 | 16 | 16 | 8 | 16 | | | |

Note: F.O. = Frequency of Occurrence; W = winter, S = summer

**Appendix G-9. Abundance of the top 20 macroinvertebrate species in trawl replicates, 1978 - 2009. Mandalay Generating Station NPDES, 2009.**

| Species | **1978** | **1980** | **1986** | **1988** | **1990** | **1991** | **1992** | **1993** | **1994** | **1997** | **1999** | **2000** | **2001** | **2002** | **2003** | **2004** | **2005** | **2006** | **2007** | **2008** | **2009** | Total | Percent Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Dendraster excentricus* | 10 | 0 | 3853 | 165 | 536 | 681 | 5 | 3 | 1322 | 11 | 17860 | 12878 | 11761 | 2832 | 132 | 47 | 529 | 6002 | 158 | 0 | 4600 | 63385 | 60.5 |
| *Crangon nigromaculata* | 55 | 8 | 237 | 116 | 246 | 402 | 18 | 70 | 353 | 5 | 2232 | 3340 | 732 | 1011 | 706 | 3046 | 7485 | 7370 | 5546 | 779 | 4058 | 37815 | 36.1 |
| *Metacarcinus gracilis* | 3 | 3 | 3 | 1 | 141 | 7 | 0 | 4 | 5 | 0 | 12 | 19 | 103 | 59 | 16 | 93 | 76 | 737 | 164 | 11 | 1346 | 2803 | 2.7 |
| *Pyromaia tuberculata* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 46 | 2 | 3 | 1 | 1 | 1 | 6 | 53 | 14 | 0 | 0 | 129 | 0.1 |
| *Astropecten verrilli* | 95 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 98 | 0.1 |
| *Metacarcinus anthonyi* | - | - | 9 | 6 | 2 | 1 | - | - | 2 | - | - | 1 | 1 | - | - | 3 | - | 7 | 4 | 2 | 13 | 51 | 0.0 |
| *Farfantepenaeus californicus* | - | 38 | 1 | - | - | - | - | - | - | - | - | 7 | - | - | - | - | - | - | 3 | - | 1 | 50 | 0.0 |
| *Panulirus interruptus* | 3 | 2 | 2 | - | 2 | 1 | 2 | 2 | 1 | - | 1 | 11 | 3 | 4 | - | - | - | 2 | 5 | 1 | 6 | 48 | 0.0 |
| *Pleurobranchia bachei* | - | - | - | - | - | 45 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 45 | 0.0 |
| *Portunus xantusii* | 12 | - | - | - | - | 5 | - | 4 | 5 | - | 6 | 1 | 1 | - | - | 3 | 3 | 1 | 1 | - | 3 | 45 | 0.0 |
| *Polyorchis pencillatus* | - | - | 1 | 1 | - | - | - | - | - | - | 23 | 5 | - | 3 | - | - | - | 6 | 1 | - | 1 | 41 | 0.0 |
| *Heptacarpus stimpsoni* | - | - | - | - | 4 | - | - | - | 12 | - | - | - | - | - | - | - | - | 8 | 15 | - | 1 | 40 | 0.0 |
| *Renilla kollikeri* | - | - | - | - | - | - | - | - | - | - | 6 | - | 1 | 1 | - | - | - | - | - | 1 | 30 | 39 | 0.0 |
| *Heptacarpus* sp A of MBC | - | - | - | - | 4 | - | - | - | 26 | - | - | - | - | - | - | - | - | - | - | - | - | 30 | 0.0 |
| *Loxorhynchus grandis* | 1 | 2 | - | - | 2 | 4 | - | 2 | - | 2 | - | - | - | 2 | - | - | 1 | 4 | 6 | 2 | 1 | 29 | 0.0 |
| *Caudina arenicola* | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | - | - | 2 | - | 13 | 1 | - | - | 18 | 0.0 |
| *Randallia ornata* | 10 | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | 1 | - | - | 4 | 16 | 0.0 |
| *Nassarius perpinguis* | - | - | 1 | - | - | - | - | - | - | - | - | - | 1 | 4 | - | 1 | - | 7 | 1 | - | - | 15 | 0.0 |
| *Opisthopus transversus* | 5 | 4 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | 1 | 1 | - | 14 | 0.0 |
| *Romaleon antennarius* | 3 | - | - | - | - | 1 | - | 4 | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | 10 | 0.0 |
| Number of Individuals | 215 | 57 | 4115 | 292 | 949 | 1156 | 25 | 92 | 1730 | 18 | 20191 | 16266 | 12612 | 3923 | 855 | 3199 | 8101 | 14215 | 5924 | 799 | 10069 | 104803 | |
| Number of species | 17 | 6 | 15 | 8 | 14 | 15 | 3 | 10 | 12 | 3 | 12 | 11 | 12 | 12 | 4 | 11 | 7 | 16 | 17 | 9 | 17 | 55 | |
| Total Biomass (kg) | N/A | N/A | N/A | 2.14 | 10.39 | 12.91 | 0.06 | 3.44 | 3.09 | 0.08 | 28.92 | 40.64 | 63.05 | 29.00 | 2.42 | 6.93 | 31.67 | 38.11 | 15.30 | 2.66 | 34.07 | 324.88 | |
| Stations / Replicates | 14/1 | 12/1 | 3/2 | 3/2 | 4/2 | 4/2 | 4/2 | 4/2 | 4/2 | 4/2 | 4/2 | 4/2 | 4/2 | 4/2 | 4/1 | 4/2 | 4/2 | 4/2 | 4/2 | 4/2 | 4/2 | | |
| Seasons | W / S | W / S | W / S | W / S | W / S | W / S | W / S | W / S | W / S | S | W / S | W / S | W / S | W / S | S | W / S | W / S | W / S | W / S | S | W / S | | |
| Number of Trawls | 28 | 24 | 12 | 12 | 16 | 16 | 16 | 16 | 16 | 8 | 16 | 16 | 16 | 16 | 4 | 16 | 16 | 16 | 16 | 8 | 16 | | |
| Parasitic species (not included above): | | | | | | | | | | | | | | | | | | | | | | | |
| *Elthusa vulgaris* | 9 | - | 1 | 2 | - | 19 | 31 | 11 | 34 | - | 2 | 2 | - | 31 | 15 | 4 | 4 | 95 | 43 | - | - | 303 | |
| *Elthusa* sp | - | - | - | - | 6 | - | - | - | - | - | - | 3 | 5 | - | - | 52 | 52 | - | - | - | - | 118 | |
| *Elthusa californica* | - | - | - | - | - | - | - | - | - | - | - | - | 4 | - | - | - | - | - | - | - | - | 4 | |
| *Nerocila* sp | - | - | - | - | - | - | - | - | - | - | - | 2 | 1 | - | - | - | - | - | - | - | - | 3 | |
| Copepoda | - | - | - | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 | |
| Bopyridae, unid. | - | - | - | | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | - | - | - | - | 2 | |

Notes: N/A = not available; W = winter, S = summer

# APPENDIX H

## Fish and macroinvertebrate heat treatment and normal operation data

**Appendix H-1. Species list of impinged fish and macroinvertebrate species. Mandalay Generating Station NPDES, 2009.**

| Phylum / Class / Family / Taxa | Common name |
|---|---|
| Arthropoda | |
| Malacostraca | |
| Grapsidae | |
| *Pachygrapsus crassipes* | striped shore crab |
| | |
| Mollusca | |
| Cephalopoda | |
| Octopodidae | |
| *Octopus bimaculatus/bimaculoides* | California two-spot octopus |
| Gastropoda | |
| Aglajidae | |
| *Navanax inermis* | California aglaja |
| Aplysiidae | |
| *Aplysia californica* | California seahare |
| | |
| Chordata | |
| Actinopterygii | |
| Atherinopsidae | |
| *Atherinopsis californiensis* | jacksmelt |
| *Atherinops affinis* | topsmelt |
| Clinidae | |
| *Gibbonsia montereyensis* | crevice kelpfish |
| Clupeidae | |
| *Sardinops sagax* | Pacific sardine |
| Cottidae | |
| *Leptocottus armatus* | Pacific staghorn sculpin |
| Embiotocidae | |
| *Cymatogaster aggregata* | shiner perch |
| Engraulidae | |
| *Engraulis mordax* | northern anchovy |
| Gobiidae | |
| *Gillichthys mirabilis* | longjaw mudsucker |
| Labrisomidae | |
| *Paraclinus integripinnis* | reef finspot |
| Pleuronectidae | |
| *Pleuronichthys guttulatus* | diamond turbot |
| Sciaenidae | |
| *Seriphus politus* | queenfish |
| Scombridae | |
| *Scomber japonicus* | Pacific chub mackerel |
| Sphyraenidae | |
| *Sphyraena argentea* | Pacific barracuda |
| Syngnathidae | |
| *Syngnathus leptorhynchus* | bay pipefish |

**Appendix H-2. Abundance of fish impinged during normal operations by survey date at Mandalay Generating Station. Mandalay Generating Station NPDES, 2009.**

| Species | 10/3/2008 | 12/2/2008 | 2/4/2009 | 4/10/2009 | 6/28/2009 | 8/12/2009 | Total Abundance |
|---|---|---|---|---|---|---|---|
| *Cymatogaster aggregata* | 18 | 108 | - | - | - | 1 | 127 |
| *Leptocottus armatus* | 35 | 58 | - | - | 5 | - | 98 |
| *Atherinops affinis* | - | 10 | - | 1 | - | - | 11 |
| *Syngnathus leptorhynchus* | 1 | 9 | - | - | - | - | 10 |
| *Engraulis mordax* | 4 | 3 | - | 1 | - | 1 | 9 |
| *Gibbonsia montereyensis* | - | 3 | - | - | - | - | 3 |
| *Atherinopsis californiensis* | 2 | - | - | - | - | - | 2 |
| *Sardinops sagax* | - | - | 1 | - | - | 1 | 2 |
| *Gillichthys mirabilis* | - | 1 | - | - | - | - | 1 |
| *Paraclinus integripinnis* | - | - | - | - | - | 1 | 1 |
| *Pleuronichthys guttulatus* | - | - | - | 1 | - | - | 1 |
| *Scomber japonicus* | 1 | - | - | - | - | - | 1 |
| *Seriphus politus* | - | - | - | - | - | 1 | 1 |
| *Sphyraena argentea* | - | 1 | - | - | - | - | 1 |
| Total Abundance | 61 | 193 | 1 | 3 | 5 | 5 | 268 |
| Number of Taxa | 6 | 8 | 1 | 3 | 1 | 5 | 14 |

**Appendix H-3. Biomass (kg) of fish impinged during normal operations by survey date at Mandalay Generating Station. Mandalay Generating Station NPDES, 2009.**

| Species | 10/3/2008 | 12/2/2008 | 2/4/2009 | 4/10/2009 | 6/28/2009 | 8/12/2009 | Total Biomass (kg) |
|---|---|---|---|---|---|---|---|
| *Leptocottus armatus* | 0.592 | 1.520 | - | - | 0.052 | - | 2.164 |
| *Cymatogaster aggregata* | 0.114 | 0.554 | - | - | - | 0.003 | 0.671 |
| *Atherinopsis californiensis* | 0.269 | - | - | - | - | - | 0.269 |
| *Sardinops sagax* | - | - | 0.057 | - | - | 0.092 | 0.149 |
| *Atherinops affinis* | - | 0.073 | - | 0.012 | - | - | 0.085 |
| *Scomber japonicus* | 0.035 | - | - | - | - | - | 0.035 |
| *Gibbonsia montereyensis* | - | 0.032 | - | - | - | - | 0.032 |
| *Engraulis mordax* | 0.006 | 0.017 | - | 0.002 | - | 0.005 | 0.030 |
| *Gillichthys mirabilis* | - | 0.028 | - | - | - | - | 0.028 |
| *Syngnathus leptorhynchus* | 0.001 | 0.012 | - | - | - | - | 0.013 |
| *Paraclinus integripinnis* | - | - | - | - | - | 0.013 | 0.013 |
| *Sphyraena argentea* | - | 0.012 | - | - | - | - | 0.012 |
| *Pleuronichthys guttulatus* | - | - | - | 0.003 | - | - | 0.003 |
| *Seriphus politus* | - | - | - | - | - | 0.001 | 0.001 |
| Total Biomass (kg) | 1.017 | 2.248 | 0.057 | 0.017 | 0.052 | 0.114 | 3.505 |
| Number of Taxa | 6 | 8 | 1 | 3 | 1 | 5 | 14 |

**Appendix H-4. Estimated abundance of fish impinged during normal operations at Mandalay Generating Station. Manalay Generating Station NPDES, 2009.**

| Species | 2008 Oct - Nov | 2008-2009 Dec - Jan | 2009 Feb - Mar | Apr - May | Jun - Jul | Aug - Sep | Total Abundance |
|---|---|---|---|---|---|---|---|
| *Cymatogaster aggregata* | 1,366 | 3,338 | - | - | - | 77 | 4,781 |
| *Leptocottus armatus* | 2,657 | 1,793 | - | - | 211 | - | 4,661 |
| *Engraulis mordax* | 304 | 93 | - | 94 | - | 77 | 568 |
| *Atherinops affinis* | - | 309 | - | 94 | - | - | 403 |
| *Syngnathus leptorhynchus* | 76 | 278 | - | - | - | - | 354 |
| *Atherinopsis californiensis* | 152 | - | - | - | - | - | 152 |
| *Sardinops sagax* | - | - | 50 | - | - | 77 | 127 |
| *Pleuronichthys guttulatus* | - | - | - | 94 | - | - | 94 |
| *Gibbonsia montereyensis* | - | 93 | - | - | - | - | 93 |
| *Paraclinus integripinnis* | - | - | - | - | - | 77 | 77 |
| *Seriphus politus* | - | - | - | - | - | 77 | 77 |
| *Scomber japonicus* | 76 | - | - | - | - | - | 76 |
| *Gillichthys mirabilis* | - | 31 | - | - | - | - | 31 |
| *Sphyraena argentea* | - | 31 | - | - | - | - | 31 |
| Total Abundance | 4,631 | 5,966 | 50 | 282 | 211 | 385 | 11,525 |
| Number of Taxa | 6 | 8 | 1 | 3 | 1 | 5 | 14 |
| Analysis Flow (mg) | 11,767 | 7,832 | 6,277 | 7,596 | 4,869 | 6,438 | |

**Appendix H-5. Estimated biomass (kg) of fish impinged during normal operations at Mandalay Generating Station. Mandalay Generating Station NPDES, 2009.**

| Species | 2008 Oct - Nov | 2008-2009 Dec - Jan | 2009 Feb - Mar | Apr - May | Jun - Jul | Aug - Sep | Total Biomass (kg) |
|---|---|---|---|---|---|---|---|
| *Leptocottus armatus* | 44.94 | 46.98 | - | - | 2.20 | - | 94.12 |
| *Cymatogaster aggregata* | 8.65 | 17.12 | - | - | - | 0.23 | 26.00 |
| *Atherinopsis californiensis* | 20.42 | - | - | - | - | - | 20.42 |
| *Sardinops sagax* | - | - | 2.82 | - | - | 7.06 | 9.88 |
| *Atherinops affinis* | - | 2.26 | - | 1.13 | - | - | 3.39 |
| *Scomber japonicus* | 2.66 | - | - | - | - | - | 2.66 |
| *Engraulis mordax* | 0.46 | 0.53 | - | 0.19 | - | 0.38 | 1.56 |
| *Paraclinus integripinnis* | - | - | - | - | - | 1.00 | 1.00 |
| *Gibbonsia montereyensis* | - | 0.99 | - | - | - | - | 0.99 |
| *Gillichthys mirabilis* | - | 0.87 | - | - | - | - | 0.87 |
| *Syngnathus leptorhynchus* | 0.08 | 0.37 | - | - | - | - | 0.45 |
| *Sphyraena argentea* | - | 0.37 | - | - | - | - | 0.37 |
| *Pleuronichthys guttulatus* | - | - | - | 0.28 | - | - | 0.28 |
| *Seriphus politus* | - | - | - | - | - | 0.08 | 0.08 |
| Total Biomass (kg) | 77.21 | 69.49 | 2.82 | 1.60 | 2.20 | 8.75 | 162.07 |
| Number of Taxa | 6 | 8 | 1 | 3 | 1 | 5 | 14 |
| Analysis Flow (mg) | 11,767 | 7,832 | 6,277 | 7,596 | 4,869 | 6,438 | |

**Appendix H-6. Length frequency of impinged fish measured during normal operation surveys at Mandalay Generating Station. Mandalay Generating Station NPDES, 2009.**

| | Size Class (cm) | | | | | | | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 20 | 28 | Measured |
| *Atherinops affinis* | - | - | 2 | 2 | - | 3 | 1 | 3 | - | - | - | - | - | - | - | - | - | 11 |
| *Atherinopsis californiensis* | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | 1 | 2 |
| *Cymatogaster aggregata* | 3 | 31 | 63 | 21 | - | 1 | - | - | - | - | - | - | - | - | - | - | - | 119 |
| *Engraulis mordax* | 2 | 1 | 3 | - | - | 2 | - | - | 1 | - | - | - | - | - | - | - | - | 9 |
| *Gibbonsia montereyensis* | - | - | - | - | - | 3 | - | - | - | - | - | - | - | - | - | - | - | 3 |
| *Gillichthys mirabilis* | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | 1 |
| *Leptocottus armatus* | - | - | - | 1 | 6 | 19 | 26 | 23 | 13 | 5 | 3 | 2 | - | - | - | - | - | 98 |
| *Paraclinus integripinnis* | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | 1 |
| *Pleuronichthys guttulatus* | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 |
| *Sardinops sagax* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | - | 2 |
| *Scomber japonicus* | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | 1 |
| *Seriphus politus* | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 |
| *Sphyraena argentea* | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | 1 |
| *Syngnathus leptorhynchus* | - | - | - | - | - | - | - | 1 | 2 | - | 2 | 1 | 3 | 1 | - | - | - | 10 |

**Appendix H-7. Abundance of macroinvertebrates impinged during normal operations by survey date at Mandalay Generating Station. Mandalay Generating Station NPDES, 2009.**

| Species | 10/3/2008 | 12/2/2008 | 2/4/2009 | 4/10/2009 | 6/28/2009 | 8/12/2009 | Total Abundance |
|---|---|---|---|---|---|---|---|
| *Octopus bimaculatus/bimaculoides* | - | 4 | 1 | - | 1 | - | 6 |
| *Navanax inermis* | - | - | - | 2 | - | - | 2 |
| *Aplysia californica* | - | - | - | 1 | - | - | 1 |
| *Pachygrapsus crassipes* | 1 | - | - | - | - | - | 1 |
| Total Abundance | 1 | 4 | 1 | 3 | 1 | - | 10 |
| Number of Species | 1 | 1 | 1 | 2 | 1 | - | 4 |

**Appendix H-8. Biomass (kg) of macroinvertebrates impinged during normal operations by survey date at Mandalay Generating Station. Mandalay Generating Station NPDES, 2009.**

| Species | 10/3/2008 | 12/2/2008 | 2/4/2009 | 4/10/2009 | 6/28/2009 | 8/12/2009 | Total Biomass(kg) |
|---|---|---|---|---|---|---|---|
| *Aplysia californica* | - | - | - | 1.024 | - | - | 1.024 |
| *Octopus bimaculatus/bimaculoides* | - | 0.387 | 0.056 | - | 0.025 | - | 0.468 |
| *Navanax inermis* | - | - | - | 0.077 | - | - | 0.077 |
| *Pachygrapsus crassipes* | 0.002 | - | - | - | - | - | 0.002 |
| Total Biomass (kg) | 0.002 | 0.387 | 0.056 | 1.101 | 0.025 | - | 1.571 |
| Number of Species | 1 | 1 | 1 | 2 | 1 | - | 4 |

**Appendix H-9. Estimated monthly abundance of macroinvertebrates impinged during normal operations at Mandalay Generating Station. Mandalay Generating Station NPDES, 2009.**

| | 2008 | 2008-2009 | | 2009 | | | Total |
|---|---|---|---|---|---|---|---|
| Species | Oct - Nov | Dec - Jan | Feb - Mar | Apr - May | Jun - Jul | Aug - Sep | Abundance |
| *Octopus bimaculatus/bimaculoides* | - | 124 | 50 | - | 42 | - | 216 |
| *Navanax inermis* | - | - | - | 188 | - | - | 188 |
| *Aplysia californica* | - | - | - | 94 | - | - | 94 |
| *Pachygrapsus crassipes* | 76 | - | - | - | - | - | 76 |
| Total Abundance | 76 | 124 | 50 | 282 | 42 | - | 574 |
| Number of Species | 1 | 1 | 1 | 2 | 1 | - | 4 |
| Analysis Flow (mg) | 11767 | 7832 | 6277 | 7596 | 4869 | 6438 | |

**Appendix H-10. Estimated monthly biomass (kg) of macroinvertebrates impinged during normal operations at Mandalay Generating Station. Mandalay Generating Station NPDES, 2009.**

| | 2008 | 2008-2009 | | 2009 | | | Total |
|---|---|---|---|---|---|---|---|
| Species | Oct - Nov | Dec - Jan | Feb - Mar | Apr - May | Jun - Jul | Aug - Sep | Biomass(kg) |
| *Aplysia californica* | - | - | - | 96.140 | - | - | 96.140 |
| *Octopus bimaculatus/bimaculoides* | - | 11.960 | 2.770 | - | 1.060 | - | 15.790 |
| *Navanax inermis* | - | - | - | 7.230 | - | - | 7.230 |
| *Pachygrapsus crassipes* | 0.150 | - | - | - | - | - | 0.150 |
| Total Biomass(kg) | 0.002 | 0.387 | 0.056 | 1.101 | 0.025 | - | 119.310 |
| Number of Species | 1 | 1 | 1 | 2 | 1 | - | 4 |
| Analysis Flow (mg) | 11767 | 7832 | 6277 | 7596 | 4869 | 6438 | |

**Appendix H-11. Total one percent or more abundance of fish impinged during heat treatments and estimated normal operations, 2001 - 2009. Mandalay Generating Station NPDES, 2009.**

| | Year | | | | | | | | | | Percent | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Taxa | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | Total | Total | Mean |
| *Leuresthes tenuis* | - | 114883 | 6502 | 4273 | 39910 | - | - | - | - | 165568 | 45.44 | 18396.4 |
| *Cymatogaster aggregata* | 27 | 14305 | 563 | 14709 | 8883 | 48209 | 2295 | 3955 | 4781 | 97727 | 26.82 | 10858.6 |
| *Engraulis mordax* | 3 | 101 | 1 | 1607 | 3137 | 45950 | 263 | 132 | 568 | 51762 | 14.21 | 5751.3 |
| *Atherinops affinis* | - | 6232 | - | - | - | 6830 | 463 | 4263 | 403 | 18191 | 4.99 | 2021.2 |
| *Leptocottus armatus* | 81 | 605 | 98 | 402 | 113 | 542 | 404 | 837 | 4661 | 7743 | 2.12 | 860.3 |
| *Lepidogobius lepidus* | - | - | - | - | 79 | 3665 | 4 | - | - | 3748 | 1.03 | 416.4 |
| *Hyperprosopon ellipticum* | - | - | - | - | - | 3664 | - | - | - | 3664 | 1.01 | 407.1 |
| Number of individuals | 186 | 136,749 | 7,424 | 23,053 | 53,598 | 115,829 | 5,270 | 10,754 | 11,525 | 364,388 | | 40,488 |
| Number of taxa | 6 | 20 | 11 | 13 | 20 | 28 | 26 | 19 | 14 | 51 | | 17.4 |

Note: 0.00 = <0.005.

**Appendix H-12. Total abundance of the top five macroinvertebrates impinged during heat treatments and estimated normal operations, 2001 - 2007. Mandalay Generating Station NPDES, 2009.**

| | Year | | | | | | | | | | Percent | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | Total | Total | Mean |
| *Protothaca staminea* | - | - | 4 | - | - | 27020 | - | - | - | 27024 | 92 | 3002.7 |
| *Pachygrapsus crassipes* | 27 | - | 1 | 4 | 156 | 76 | 451 | 60 | 76 | 851 | 3 | 94.6 |
| *Octopus bimaculatus/bimaculoides* | 1 | 41 | 12 | - | - | 106 | 10 | 88 | 216 | 474 | 2 | 52.7 |
| *Navanax inermis* | - | - | - | 48 | - | 153 | - | 6 | 188 | 395 | 1 | 43.9 |
| *Hemigrapsu nudus* | - | - | - | 129 | - | - | - | 60 | - | 189 | 1 | 21.0 |
| Number of individuals | 154 | 46 | 20 | 190 | 163 | 27,475 | 488 | 309 | 574 | 29,419 | | 3,269 |
| Number of species | 5 | 3 | 4 | 8 | 3 | 7 | 4 | 7 | 4 | 16 | | 5 |