# NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM
# 2007 RECEIVING WATER MONITORING REPORT
# RELIANT ENERGY MANDALAY GENERATING STATION
# VENTURA COUNTY, CALIFORNIA

## 2007 Survey

**Prepared for:**

**Reliant Energy**

**Prepared by:**

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

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**March 2008**

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# EXECUTIVE SUMMARY

The 2007 National Pollutant Discharge Elimination System (NPDES) marine monitoring program for the Reliant 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 2007 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 2007 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 2007, slightly warmer surface temperatures at the surf zone discharge during both tides and in the upper 1 m offshore of the discharge at the 20-ft isobath on flood tide and on the 30-ft isobath on ebb tide suggested the influence of a warm water thermal discharge from the generating station. In summer, temperatures at the discharge and downcoast surf zone and in surface waters at nearby offshore stations indicated the presence of a warm water surface lens, with influence from the plume decreasing with distance from the discharge. However, even at stations influenced by the thermal field, surface temperatures were typical of the area during previous surveys and lower than temperatures found in the vicinity in 2006. All DO values found during both winter and summer sampling were typical of the area, and though slightly depressed in the surf zone at the discharge compared to other stations in summer, were well above the level of biological concern. In winter, pH values were slightly less variable among stations and between tides than found in summer. A mild depression in pH values at the discharge channel in summer was likely a result of slightly lower salinity water in the discharge channel. 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. In the surf zone, salinity was similar at the upcoast and downcoast stations during both seasons on both tides, though salinity at the discharge was consistently lower than at the remaining surf zone stations. The lower values at the discharge as well as some reduction noted at nearby offshore and surf zone stations suggests 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. Still, salinity values reported in 2007 were typical of the nearshore waters of southern California and within values found previously in the area (MBC 2002-2006a).

In 2007, water quality parameters were relatively consistent among stations and between tides during both winter and summer. During both seasons, warmer and slightly less salty surface water was observed near the discharge, 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 cooling water discharge from the Mandalay Generating Station in 2007, the influence was localized and did not appear to have an adverse effect on receiving waters in the study area.

## SEDIMENT CHARACTERISTICS

### Sediment Grain Size

In 2007, sediments were analyzed from five stations offshore the Mandalay Generating Station. Sediments were most similar at the two stations downcoast of the discharge channel and at the nearest upcoast station (Stations B2 through B4) where sediments were composed of about 95% sand with lesser amounts of fine material (silt and clay), with mean grain size in the fine sand category. Sediments offshore of the discharge (Station B1) were coarsest, comprised of almost 98% sand with a mean grain size in the medium sand category. Sediments at the station farthest upcoast of the discharge (Station B5) were finest, with mean grain size in the fine sand to very fine sand category, and a greater contribution by fine material (11%). Coarse sediments at the station offshore of the discharge channel appeared be influenced by turbulence associated with the cooling water discharge, a pattern noted during some previous surveys, while finer sediments have been consistently found at Station B5, likely a result of local inputs from the nearby Santa Clara River. The degree of influence of the discharge on local sediments varies from year to year, suggesting a localized and transitory effect near the discharge. Other than the coarser sediments found in the discharge area, sediment characteristics offshore of the Mandalay Generating Station discharge in 2007 were similar to those found previously in the area and appear to be affected primarily by natural causes.

**Sediment Chemistry**

In 2007, sediments at five stations off the Mandalay Generating Station were analyzed for the presence and concentration of chromium, copper, nickel, and zinc. Metal concentrations were generally similar among stations, with higher copper, nickel and zinc found at the station farthest upcoast from the generating station discharge. Although higher than levels found in 2006, which were among the lowest reported in the area, metal concentrations in 2007 were similar to results found commonly in previous surveys. Highest metal concentrations of copper, nickel and zinc were found upcoast of the discharge where the largest percentage of fine material was recorded, while lowest metal levels occurred offshore of the discharge and at the station farthest downcoast where sediments were coarsest. Sediment metal concentrations have remained relatively uniform in the area since 1990 and have been consistently lower than mean metal concentrations found in sediments at shallow (15–100 ft) 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 2007 did not appear to be influenced by the operation of the Mandalay Generating Station.

**MUSSEL BIOACCUMULATION**

In 2007, mussels were not initially found in the vicinity of the Mandalay Generating Station discharge channel. For that reason, donor mussels were purchased from a commercial supplier in Carlsbad, California and transplanted to a mooring offshore of the Mandalay discharge where the mussels were allowed to acclimate. This mooring was not relocated during the return visit, but a small number of resident mussels just below the target size were found. Tissues from these mussels were composited for analysis, the method utilized in previous surveys, but it was decided that not enough mussel tissue was available for testing of more than one replicate sample. Results were compared with those from mussels collected at the Manhattan Beach Pier in Santa Monica Bay, which served as a reference site.

Concentrations of chromium in mussel tissues from offshore of the Mandalay Generating Station discharge channel in 2007 declined notably from 2006 levels. Copper concentrations in mussel tissues also declined somewhat from 2006 levels. Concentrations of both metals were also lower than levels reported at a pier reference site sampled in 2007. Nickel and zinc concentrations, however, increased from 2006 levels offshore of the discharge, with both nickel and zinc values among the highest found, but within the range reported in previous studies in the area. As in 2006, both nickel and zinc levels in tissues from the discharge area exceeded those at the reference site. While elevated chromium and copper levels were found at the reference site in 2007, concentrations of all metals reported in tissues from offshore of the discharge canal were below levels considered elevated for resident bay mussels by the SMWP. The similarity of tissue metal levels among sites and previous studies suggests that the operation of the Mandalay Generating Station is not elevating metal concentrations above background levels.

## BENTHIC INFAUNA

The infaunal community in 2007 was comprised primarily of small Pacific sand dollars *(Dendraster excentricus*), annelid worms, arthropods, and mollusks. Abundance averaged 319 individuals per station (7,975 individuals/$m^2$), which was about twice that in 2006 and was above the mean of summer surveys conducted in the study area since 1978. Abundance at the station immediately downcoast of the generating station discharge was the highest ever recorded for that location. A total of 69 species was taken, with a mean of 32 species per station and mean species diversity (H') of 2.28. Mean species richness was slightly above that in 2006 and also above the long-term mean, while species diversity was slightly lower than both in 2006 and the long-term mean, probably because of high abundance. 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. Farthest upcoast, the BRI value suggested some disturbance affecting the community. Values for 2007 were slightly above those in 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 generally lower where sediments were coarser, near the generating station and farthest downcoast. However, values were only about average where sediments were finest, farthest upcoast, although species diversity was highest at that location. Abundance and species richness were lowest near the generating station, while species diversity was slightly above the area mean and the BRI value was slightly below the mean.

Infaunal community composition differed somewhat among stations. Small Pacific sand dollars were particularly abundant both immediately upcoast and immediately downcoast of the generating station, resulting in rather low species diversity values. Other community constituents were also similar between those two locations. Most of those species were also abundant farthest upcoast, although sand dollars were far less abundant there. The community near the generating station was most similar to that farthest downcoast, the only location where medium and large Pacific sand dollars were found. Besides sand dollars, other abundant species in the study area included the annelids *Apoprionospio pygmaea*, *Armandia brevis*, and *Chone* sp SD1, the clams *Tellina modesta* and *Siliqua lucida*, and the amphipod *Rhepoxynius menziesi*. *Apoprionospio pygmaea* has usually been the most abundant species in the area. Several species dominant in previous surveys were present in 2007 but were less abundant than in the past. Overall, however, the communities found in 2007 were similar to those encountered previously in the study area and are typical of the nearshore shallow subtidal environment in the Southern California Bight. Infaunal community parameters and composition appeared to be somewhat related to sediment characteristics, but no adverse effects from the generating station discharge were found.

## DEMERSAL FISH AND MACROINVERTEBRATES

In 2007, 4,852 individuals representing 31 fish species weighing 101.6 kg were collected during the monitoring year. Fish communities were similar to previous studies in the area, although the occurrence of schooling species such as white croaker (*Genyonemus lineatus)*, queenfish (*Seriphus politus*) and northern anchovy (*Engraulis mordax*) was lower than typical. The community was dominated during both seasons by speckled sanddab (*Citharichthys stigmaeus*), a non-schooling species that has consistently increased in abundance in yearly surveys since 2003. Summer fish abundance in 2007 was nearly five times that reported in the winter survey. In winter, abundance at the near downcoast station was three times that taken at either near upcoast station or at the station farthest downcoast. Fish abundances and species composition were most similar at the latter two stations in winter. Lowest totals were found at the station farthest upcoast. Overall, trawl-caught abundances in winter were lower upcoast of the generating station discharge than downcoast. During summer, highest abundance was recorded farthest upcoast of the discharge, with similar numbers found at the near downcoast station. Fish assemblages and abundances were also relatively similar between the near upcoast and far downcoast stations, where abundances were about one-third those at the other two stations. No pattern of fish distribution in relation to the discharge was noted in summer. While fish abundance in 2007 was lower than numbers reported in 2006 and less than the long-term mean, abundances were well within the range of previous inter-annual variation.

A total of 5,924 individuals of 17 macroinvertebrate species weighing 15.3 kg were collected during the 2007 monitoring year. Macroinvertebrate abundance in 2007 was higher than the long-term mean abundance, but less than one-half of the total abundance taken in 2006. Blackspotted bay shrimp (*Crangon nigromaculata*) overwhelmingly dominated the annual abundance in 2007, with graceful crab (*Cancer gracilis*) and Pacific sand dollar a distant second and third. During winter, as with fish, trawl-caught abundances were lower upcoast of the generating station discharge than downcoast, with abundance highest at the near downcoast station. Summer macroinvertebrate abundance was more than four times that in the winter, with numbers at the near downcoast station again highest. Assemblages and abundances among stations were most similar at the two stations upcoast of the discharge. Lowest summer macroinvertebrate abundance was reported farthest downcoast of the discharge.

Fish and macroinvertebrate species composition were similar to those in past surveys in the study area. This similarity of species composed primarily of frequently occurring and long-term dominant species indicates a relatively stable assemblage typical of the nearshore, soft-bottom community remains in the area. In both winter and summer, abundance of fish and invertebrates was highest or among the highest at the stations nearest the discharge and lowest at the downcoast station. While spatial differences were apparent, variability in fish and macroinvertebrate communities in the area appeared to be related to natural and seasonal differences in local fish and macroinvertebrates populations. There is 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 one heat treatment and ten normal operation surveys during the 2007 monitoring year. Based on these surveys, an estimated total of 5,270 individuals representing 26 fish taxa and weighing more than 131 kg were impinged at the generating station. In addition, an estimated 488 individuals representing four macroinvertebrate species and weighing more than 10 kg were impinged during the study year, the second highest total since data was reported in 2001.

Overall, fish species impinged in 2007 were similar to those collected in previous surveys, but were generally less abundant than recorded in recent annual surveys. This decline in fish abundance despite increases in cooling water flow volumes suggests variability in the local populations, and is consistent with previous years when fish impingement abundances appeared to fluctuate independently of station operations. Macroinvertebrate composition in 2007 was similar to previous years, though with generally higher abundances. The similarity of species composed primarily of frequently occurring and long-term dominant species indicates a relatively stable assemblage typical of southern California embayments. Variability in fish and macroinvertebrate communities in the area appeared to be related to natural differences in local populations with no distinct distributional pattern of fish or macroinvertebrates evident in relation to the intake. 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 2007 NPDES monitoring program indicated that operation of the Mandalay Generating Station had no detectable adverse effects on the beneficial uses of the receiving waters.

# INTRODUCTION

This report presents and discusses the results of the 2007 receiving water monitoring studies conducted for the Mandalay Generating Station which is owned and operated by Reliant Energy. The 2007 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 2007 surveys were compared among stations and with past physical oceanographic 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, sediments, and mussel tissue, 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 oil- or 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).

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, usually less than about 30 hours per year.

One of four circulator pumps was operating during the winter survey on 31 March 2007, discharging 63.35 mgd. The intake temperature was 17.8°C and the discharge temperature was 21.1°C, a difference of 3.3°C. During the summer survey, 28 August 2007, four circulator pumps were operating, discharging 214.04 mgd. The intake temperature was 20.6°C and the discharge temperature 35.0°C, for a temperature increase of 14.4°C for the water flowing across the condensers. During 2007, the Mandalay Generating Station steam plants operated at 10.23% of their total operating capacity (Siekiel-Zdzienicki 2007, 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.

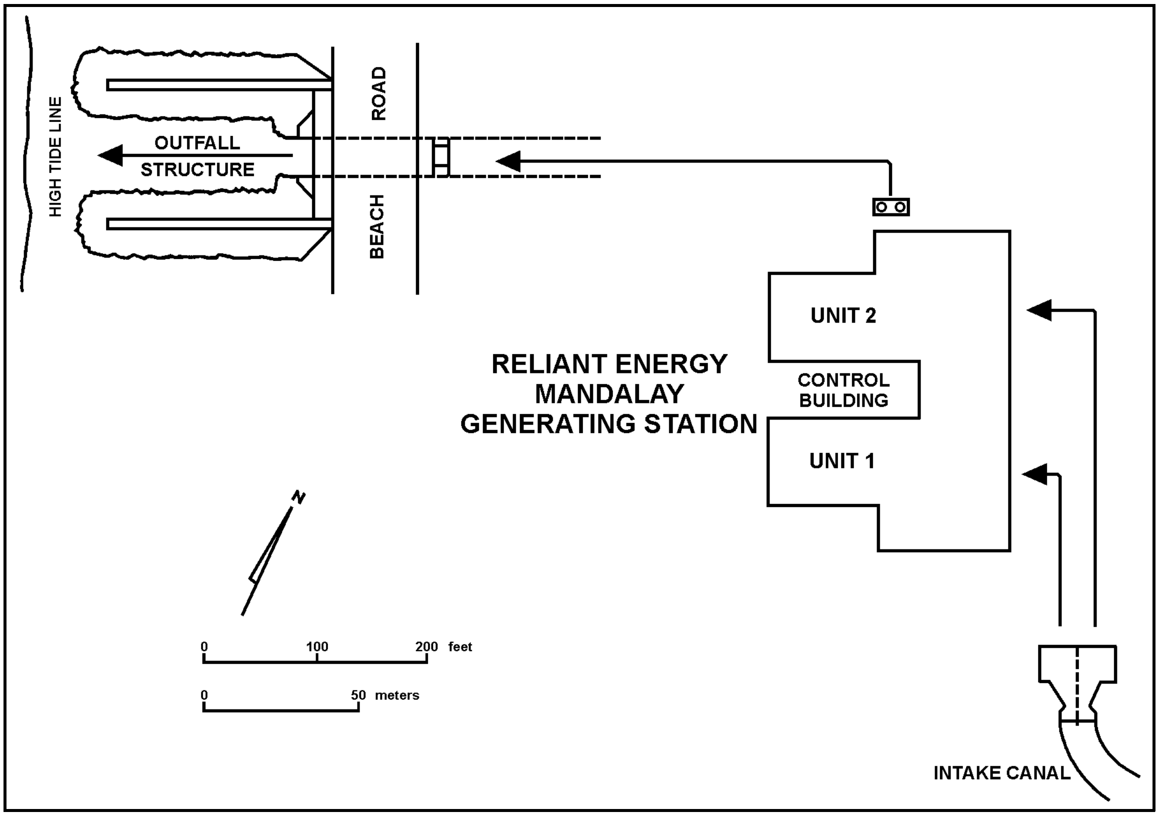



**Figure 1. Diagram of the Mandalay Generating Station cooling water system. Mandalay Generating Station NPDES, 2007.**

## 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 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).

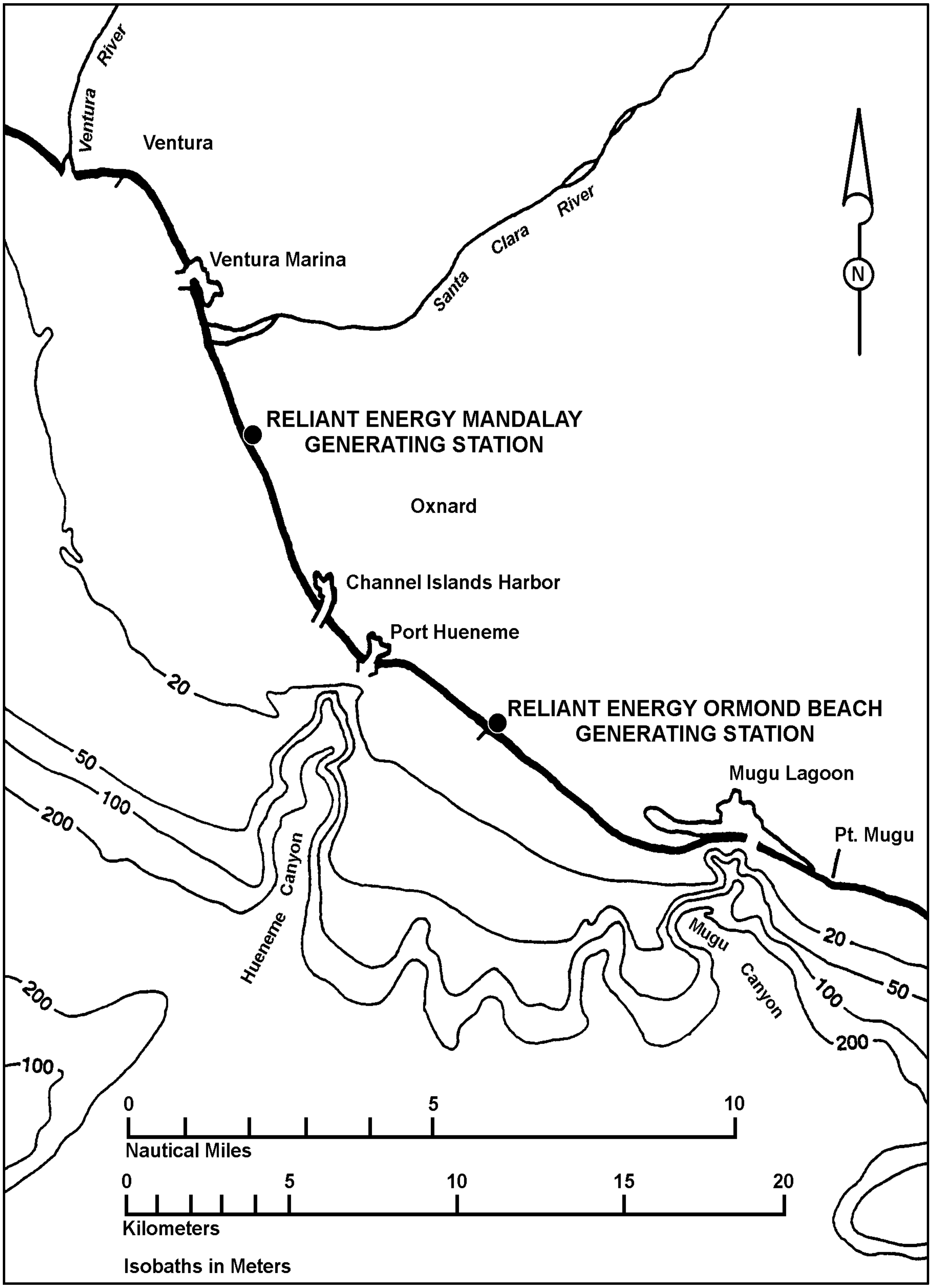



**Figure 2. Location of the study area. Mandalay Generating Station NPDES, 2007.**

**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 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 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 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

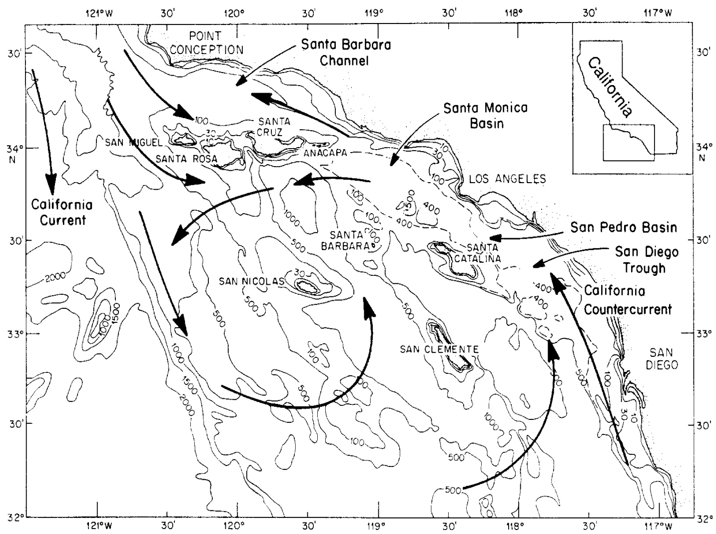



**Figure 3. Surface circulation in the Southern California Bight (from Hickey 1992). Mandalay Generating Station NPDES, 2007.**

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, 1994-2001a, 2002-2006a; 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 2007 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 4. The 2007 monitoring program included 17 water quality (RW) stations, four trawl (T) stations, and five sediment and benthic infauna (B) stations.

## FIELD OBSERVATIONS

The NPDES water quality monitoring surveys were conducted on 31 March and 28 August, trawl surveys were conducted on 30 March and 11 September, and benthic sampling was conducted on 29 August 2007. Latitude and longitude coordinates for all receiving water (RW), trawl (T), and benthic (B) stations are listed in Table 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 slightly to moderately turbid at all offshore stations and heavily turbid at surf-zone Stations RW4 and RW5. Floating plastic trash was noted at Station T4 and drift kelp (*Macrocystis pyrifera*) was noted at Stations RW9, RW11, RW12, RW14, RW17, and T1. Western gulls (*Larus occidentalis*) were seen at all trawl stations and most of the offshore receiving water stations and surf-zone Station RW5. A Western Grebe (*Aechmophorus occidentalis*) was seen at Station RW1 and western sandpipers (*Calidris mauri*) were observed at surf-zone Stations RW1, RW3, and RW5. California sea lions (*Zalophus californianus*) were seen at Stations T2 and T3. California brown pelicans (*Pelecanus occidentalis californicus*) were

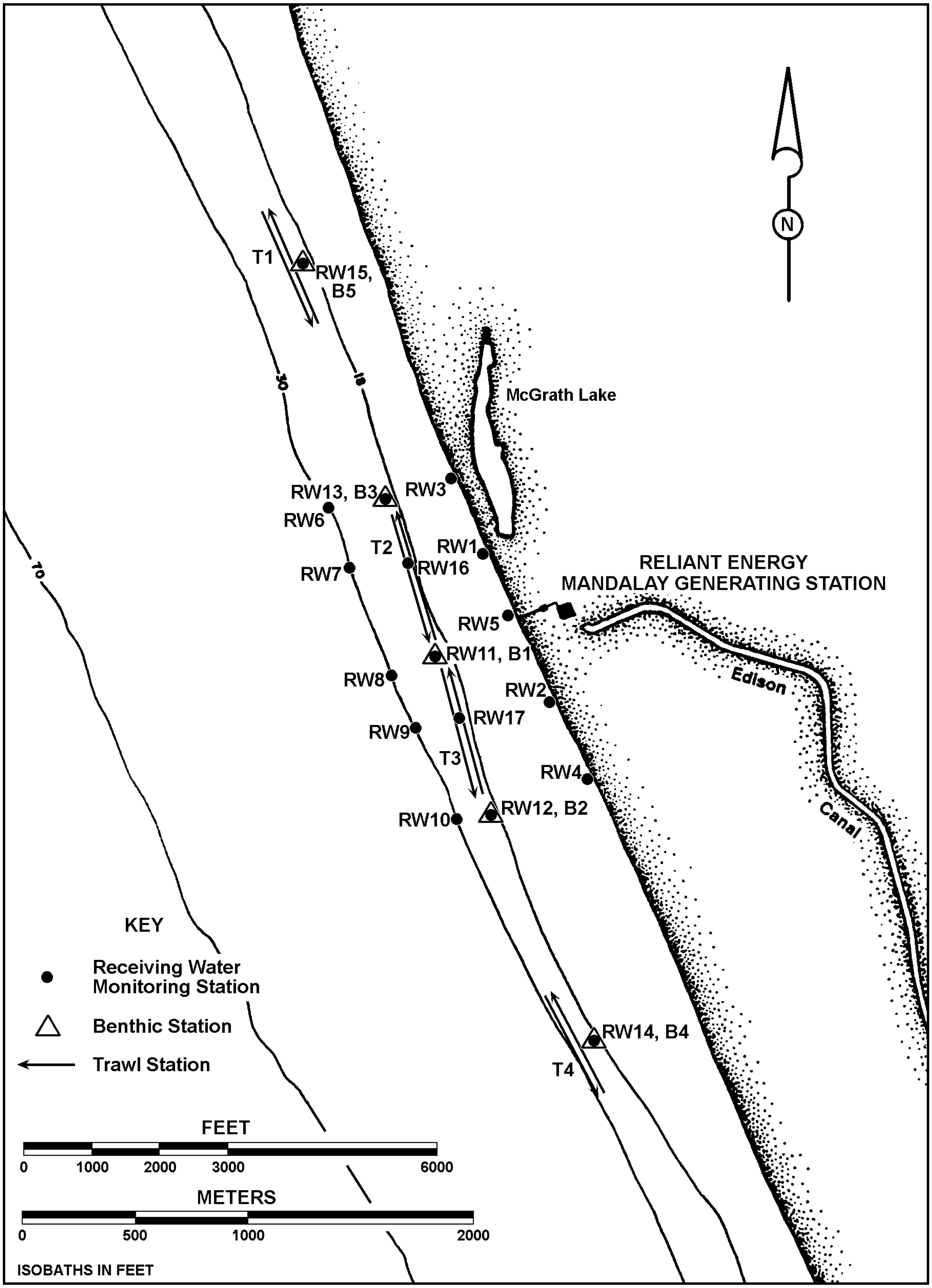



**Figure 4. Location of the monitoring stations. Mandalay Generating Station NPDES, 2007.**

seen throughout the trawl sampling area and at Stations RW4, RW7, and RW11. No California least terns (*Sternula antillarum browni*) were observed during the winter surveys.

During the summer surveys, no oil sheens, grease or apparent red tide were observed in the study area. The water appeared slightly to moderately turbid at all stations during water quality monitoring (28 August), benthic sampling (29 August), and trawl sampling (11 September). Drift kelp was noted at most offshore stations, while drift wood was noted at all surf-zone stations and offshore Station B4. Western gulls were seen throughout all survey areas and Heermann's gulls (*Larus heermanni*) were seen at Stations RW1, RW4, RW13, and T2 through T4. Caspian terns (*Hydroprogne caspia*) were observed throughout the demersal fish trawl area and at Stations RW3 and B1, cormorants (*Phalacrocorax* sp) were seen at Stations RW5, RW11, RW13, RW14, RW16, and T1, and a shearwater (*Puffinus* sp) was observed at Station T2. Sanderlings (*Calidris alba*) and willets (*Tringa semipalmatus*) were seen throughout the surf-zone receiving water stations. Harbor seals (*Phoca vitulina*) were seen at Stations RW9 and RW1 and California sea lions were seen at Stations RW8, RW9, RW11, RW17, T2, and T3. California brown pelicans were observed throughout the trawl sampling area and at Stations RW1, RW3, RW7, and RW12. No California least terns were observed during any of the summer surveys.

**Table 1. Latitude/longitude coordinates of sampling stations. Mandalay Generating Station NPDES, 2007.**

| 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 include the number of individuals, which for trawls is expressed as both number per trawl and per standard sample area, and for infauna, number per grab and density per $m^2$; 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

$$BRI_s = \frac{\sum_{i=1}^{n} \sqrt[3]{a_{si}}\ p_i}{\sum_{i=1}^{n} \sqrt[3]{a_{si}}}$$

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 4 of the Southern California Association of Marine Invertebrate Taxonomists (SCAMIT) list of invertebrate species (SCAMIT 2001).

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)].

**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. Historical raw data are presented in the appendices for possible supplementary study.

## 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 at 17 receiving water (RW) stations located within the surrounding waters of the Mandalay Generating Station discharge channel (Figure 5). Stations RW1 through RW5 are positioned along the beach within the surf-zone. 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 concentration, hydrogen ion concentration, and salinity were recorded during ebbing and flooding tides, during winter and summer surveys.

Winter water quality was monitored at Stations RW1 through RW17 on 31 March 2007 during flood and ebb tides. At surf-zone Stations RW1 through RW5, flood tide was monitored between 0600 and 0700 hours (hr) and ebb tide was monitored between 1130 and 1235 hr. At offshore Stations RW6 through RW17, flood tide was monitored between 0610 and 0705 hr and ebb tide was monitored between 1210 and 1305 hr (Figure 6). On the day of monitoring, the tide rose from a low of +0.9 ft Mean Lower Low Water (MLLW) at 0309 hr to a high of +4.8 ft MLLW at 0859 hr, then fell to a low of +0.1 ft MLLW at 1523 hr. Skies at surf-zone stations were clear with winds from the northwest at 2 to 4 kn. Seas were west at 1 to 2 ft. At offshore stations, skies were clear in the morning with winds from the northwest at 2 to 3 kn. By the afternoon, skies were overcast and foggy with winds from the northwest at 5 to 7 kn. Seas were west at 2 to 3 ft.

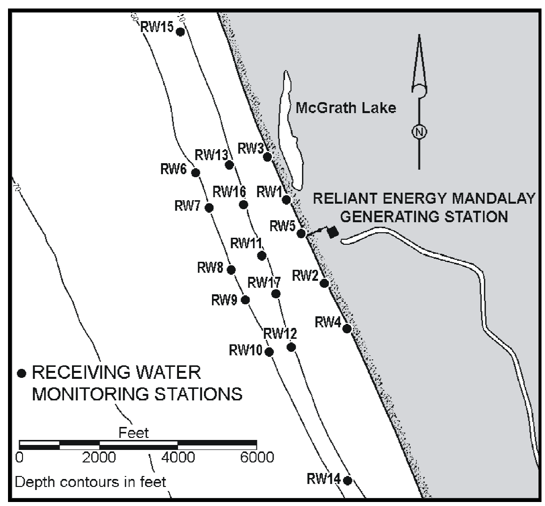


**Figure 5. Location of the water column sampling stations. Mandalay Generating Station NPDES, 2007.**

Summer water quality was monitored at Stations RW1 through RW17 on 28 August 2007 during flood and ebb tides. At surf-zone Stations RW1 through RW5, flood tide was monitored between 0645 and 0755 hr and ebb tide was monitored between 1155 and 1255 hr. At offshore Stations RW6 through RW17, flood tide was monitored between 0620 and 0720 hr and ebb tide was monitored between 1125 and 1225 hr (Figure 6). On the day of monitoring, the tide rose from a low of -0.6 ft MLLW at 0415 hr to a high of +5.0 ft MLLW at 1025 hr, then fell to a low of +1.2 ft MLLW at 1604 hr. Skies at surf-zone stations were partly to mostly cloudy with winds from the northwest at 3 to 5 kn in the morning and increasing to 10 kn by the afternoon. Seas were west at 2 to 3 ft. At offshore stations, skies were clear in the morning and overcast by the afternoon. Winds changed from west at 5 to 7 kn to northwest at 3 to 5 kn during the flood tide monitoring. By ebb tide monitoring, winds were from the west at 10 to 12 kn. Seas were west at 2 to 3 ft.

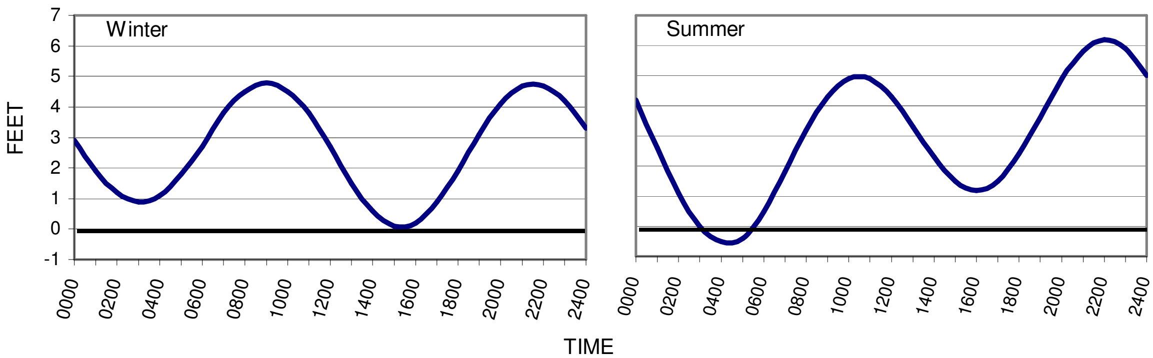



**Figure 6. Tidal rhythms during water column monitoring, winter and summer surveys. Mandalay Generating Station NPDES, 2007.**

Water quality monitoring at surf-zone stations was conducted by collecting surface water samples from the surf-zone. Water samples were analyzed in the field using a YSI 556 Multi-Probe System (YSI) water quality analyzer. During the winter ebb tide surf-zone monitoring, the conductivity/salinity probe of the YSI water quality analyzer malfunctioned. Since salinity monitoring is not included in permitting requirements, only two surf-zone salinity readings were reported for the afternoon ebb tide sampling. Monitoring at offshore stations was conducted using a Sea-Bird Water Quality Monitoring System (SBE 9/17). Data were processed using the Sea-Bird proprietary software (SeaSoft). The resulting data 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 5. 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 one circulating pump was operating with a flow of 63.4 mgd and a discharge temperature of 21.1°C (Siekiel-Zdzienicki 2007, pers. comm.). On the day of the summer sampling all four circulating pumps were in operation with a flow of 214 mgd and a discharge temperature of 35.0°C. Seasonal water quality data for flood and ebb tides are presented in Figures 7 through 10 and summarized in Table 2. Raw data are presented in Appendix B.

### Water Temperature

During winter monitoring, offshore surface water temperatures during the morning flood tide averaged 12.94°C and ranged from 12.55°C at Station RW15, 5,910 ft upcoast of the discharge on the 20-ft isobath, to 13.24°C at Station RW11, offshore of discharge channel on the 20-ft isobath (Table 2 and Figure 7). Surface water temperatures during ebb tide averaged 13.84°C and ranged from 13.58°C at Station RW9, 1,180 ft downcoast of the discharge on the 30-ft isobath to 14.10°C at Station RW8, offshore of discharge channel on the 30-ft isobath. At all stations, surface temperatures during the later ebb tide monitoring were slightly higher than during the early morning flood tide monitoring. On average, temperatures at all stations were 0.9°C higher during the later tide, with the greatest increase between tides (1.34°C) found at Station RW15 (Appendix B-1). Temperature decreased from surface to bottom at all stations during both tides, with mild thermal gradients observed in the upper 2 to 3 m of the water column at most stations on both tides. Average bottom water temperature was 12.17°C during flood tide and 12.86°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 RW11 on flood tide and at Station RW14, 5,910 ft downcoast of the discharge on the 20-ft isobath on ebb tide.

**Table 2. Summary of water quality parameters during flood and ebb tides at offshore stations. Mandalay Generating Station NPDES, 2007.**

| | Temp. (°C) | | D.O. (mg/l) | | pH | | Salinity (psu) | | Temp. (°C) | | D.O. (mg/l) | | pH | | Salinity (psu) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Winter** | | | | | | | | | | | | | | | | |
| | Surface | | | | | | | | Bottom | | | | | | | |
| | flood | ebb | flood | ebb | flood | ebb | flood | ebb | flood | ebb | flood | ebb | flood | ebb | flood | ebb |
| Mean | 12.94 | 13.84 | 7.92 | 8.12 | 7.79 | 7.92 | 33.73 | 33.74 | 12.17 | 12.86 | 7.37 | 7.87 | 7.77 | 7.88 | 33.81 | 33.83 |
| Minimum | 12.55 | 13.58 | 7.69 | 8.04 | 7.77 | 7.90 | 33.67 | 33.65 | 12.00 | 12.19 | 7.22 | 7.46 | 7.75 | 7.86 | 33.79 | 33.77 |
| Maximum | 13.24 | 14.10 | 8.18 | 8.23 | 7.81 | 7.92 | 33.81 | 33.78 | 12.38 | 13.53 | 7.55 | 8.19 | 7.77 | 7.91 | 33.83 | 33.92 |
| **Summer** | | | | | | | | | | | | | | | | |
| | Surface | | | | | | | | Bottom | | | | | | | |
| | flood | ebb | flood | ebb | flood | ebb | flood | ebb | flood | ebb | flood | ebb | flood | ebb | flood | ebb |
| Mean | 15.46 | 15.95 | 7.40 | 7.72 | 7.90 | 8.00 | 33.64 | 33.62 | 14.44 | 13.92 | 7.16 | 6.95 | 7.87 | 7.93 | 33.67 | 33.67 |
| Minimum | 15.00 | 15.34 | 7.18 | 7.57 | 7.88 | 7.96 | 33.61 | 33.54 | 14.15 | 13.62 | 6.80 | 6.70 | 7.83 | 7.91 | 33.66 | 33.65 |
| Maximum | 16.71 | 16.85 | 7.68 | 7.87 | 7.94 | 8.04 | 33.68 | 33.67 | 14.84 | 14.63 | 7.54 | 7.54 | 7.93 | 7.98 | 33.68 | 33.72 |

At surf-zone stations in winter, surface water temperatures during flood tide averaged 12.89°C and ranged from 12.36°C at Station RW4, 2,360 ft downcoast of the discharge channel to 14.03°C at Station RW5, at the discharge channel (Table 3 and Figure 7). Surface water temperatures during ebb tide averaged 14.49°C and ranged from 14.21°C at Station RW3, 2,360 ft upcoast of the discharge channel, and Station RW4, to 15.32°C at Station RW5. Water temperatures varied at all stations by about 1.6°C between tides, with temperatures at Station RW5 higher than temperatures found at Stations RW1 through RW4 by about 1.4°C on flood tide and 1.0°C on ebb tide. Otherwise, temperatures were similar at surf-zone stations away from the discharge, varying by less than 0.4°C among stations on either tide.

During summer monitoring, offshore surface water temperature during flood tide averaged 15.46°C and ranged from 15.00°C at Station RW16, 1,180 upcoast of the discharge on the 20-ft isobath to 16.71°C at Station RW14 (Table 2 and Figure 8). Surface water temperatures during ebb tide averaged 15.95°C and ranged from 15.34°C at Station RW13, 2,360 ft upcoast of the discharge on the 20-ft isobath, to 16.85°C at Station RW12, 2,360 ft downcoast of the discharge on the 20-ft isobath. Surface temperatures during the later ebb tide monitoring averaged 0.5°C higher than during the earlier flood tide except at Stations RW13 and RW14 where temperatures were 0.2°C and 1.2°C higher during flood tide than during ebb tide (Appendix B-2). At Stations RW6 through RW9 along the 30-ft isobath, and upcoast Stations RW13 and RW15 on the 20-ft isobath, surface temperatures during the later ebb tide monitoring were similar to temperatures found during the early morning flood tide. At the remaining stations, the nearest upcoast, the station offshore of the discharge and the two nearest downcoast stations on the 20-ft isobath, and the station furthest downcoast on the 30-ft isobath, surface temperatures were an average of 1.2°C higher on ebb tide, with the highest differential between tides (1.47°C) found at Station RW12. Temperature decreased from surface to bottom at all stations during both tides except at Station RW11 on flood, where temperatures were slightly higher at 1-m depth than at the surface. Most stations showed mild thermal gradients in the upper 2 m on flood tide and upper 4 m on ebb tide, below which temperature reductions with depth were more moderate. Near-bottom water temperatures were

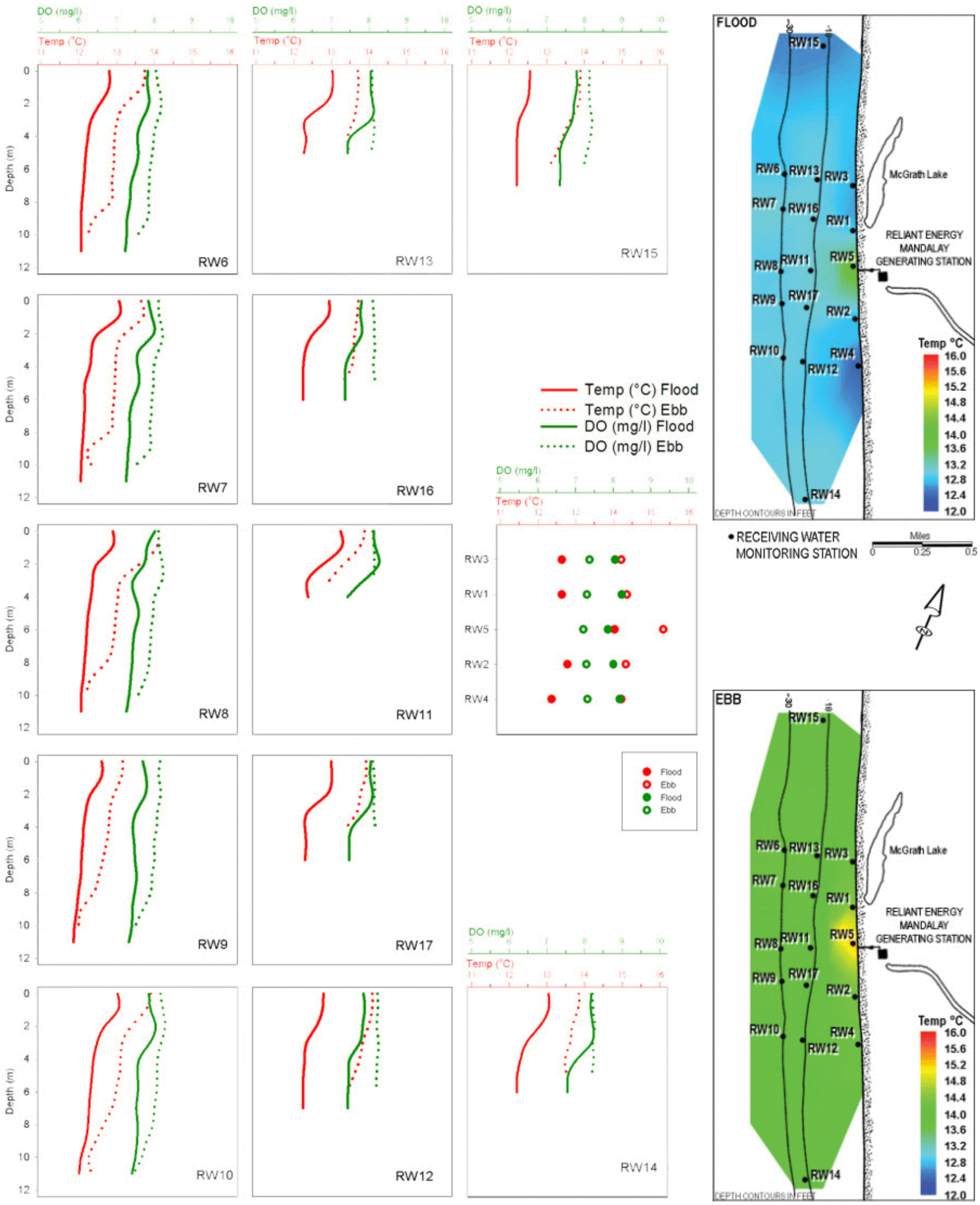



**Figure 7. False color surface temperature contour plots, surf-zone water quality, and temperature and dissolved oxygen vertical profiles during flood and ebb tides, winter survey. Mandalay Generating Station NPDES, 2007.**

generally colder on ebb tide, resulting in stronger, and slightly deeper, thermal gradients at most stations than found on flood tide. Thermoclines exceeding 1°C temperature change within 1-m depth were found at Station RW14 on flood tide and at Stations RW10, RW12, RW16, and RW17 on ebb tide. Average bottom water temperatures were 14.44°C during flood tide and 13.92°C during ebb tide. Coolest bottom water temperatures were recorded at Station RW10 on ebb tide, with generally similar temperatures found near bottom at all stations along the 30-ft isobath on ebb tide. Warmest bottom temperatures were recorded at Station RW15 on both tides.

**Table 3. Summary of water quality parameters during flood and ebb tides at surf-zone stations. Mandalay Generating Station NPDES, 2007.**

| | 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 | 12.89 | 14.49 | 8.06 | 7.30 | 7.79 | 7.96 | 32.84 | 32.81 | 17.70 | 19.92 | 6.88 | 6.64 | 7.68 | 7.82 | 33.64 | 34.60 |
| Minimum | 12.36 | 14.21 | 7.86 | 7.20 | 7.72 | 7.95 | 32.44 | 32.19 | 15.68 | 16.35 | 6.07 | 5.28 | 7.51 | 7.74 | 30.30 | 34.47 |
| Maximum | 14.03 | 15.32 | 8.23 | 7.37 | 7.83 | 7.97 | 32.97 | 33.06 | 22.63 | 29.04 | 7.31 | 7.36 | 7.77 | 7.87 | 34.61 | 34.66 |

At surf-zone stations in summer, surface water temperatures during flood tide averaged 17.70°C and ranged from 15.68°C at Station RW3 to 22.63°C at Station RW5 (Table 3 and Figure 8). Surface water temperatures during ebb tide averaged 19.92°C and ranged from 16.35°C at Station RW3 to 29.04°C at Station RW5. Temperatures recorded at Station RW5 were 5.8°C higher than the average temperature at the other surf-zone stations on flood tide, and 9.1°C warmer on ebb tide.

## Dissolved Oxygen

During winter monitoring, offshore surface dissolved oxygen (DO) concentration during flood tide averaged 7.92 mg/l and ranged from 7.69 mg/l at Station RW9 to 8.18 mg/l at Station RW14 (Table 2 and Figure 7). Surface DO concentrations during ebb tide averaged 8.12 mg/l and ranged from 8.04 mg/l at Station RW6, 2,360 ft upcoast of the discharge on the 30-ft isobath, to 8.23 mg/l at Station RW12. Subsurface DO concentration maxima were recorded within the upper two to four meters of the water column at all stations on both tides except at Station RW8 on flood tide. Surface DO values averaged 0.2 mg/l higher on ebb tide than during flood tide and in general DO concentrations were higher throughout the water column during the later tide (Appendix B-1). Dissolved oxygen concentrations declined only slightly with depth to the bottom below the subsurface maxima, with surface and bottom DO concentrations relatively similar among stations on both tides. Maximum surface-to-bottom DO differential of 0.8 mg/l was found at Station RW7, 1,180 ft upcoast of the discharge on the 30-ft isobath, on flood tide. Average bottom DO values were 7.37 mg/l during flood tide and 7.87 mg/l during ebb tide. The lowest bottom DO values, 7.22 mg/l on flood tide and 7.46 mg/l on ebb tide, occurred at Stations RW6 and RW10, 2,260 ft downcoast of the discharge on the 30-ft isobath, respectively. Highest near-bottom DO concentrations, 7.55 mg/l on flood tide and 8.19 mg/l on ebb tide, were found at Station RW14.

At surf-zone stations in winter, surface DO concentrations during flood tide averaged 8.06 mg/l and ranged from 7.86 mg/l at Station RW5 to 8.23 mg/l at Station RW1 (Table 3 and Figure 7). Surface DO concentrations during ebb tide averaged 7.30 mg/l and ranged from 7.20 mg/l at Station RW5 to 7.37 mg/l at Station RW3.

During summer monitoring, offshore surface DO concentration during flood tide averaged 7.40 mg/l and ranged from 7.18 mg/l at Station RW11 to 7.68 mg/l at Station RW15 (Table 2 and

Figure 8). Surface DO concentrations during ebb tide averaged 7.72 mg/l and ranged from 7.57 mg/l at Station RW12 to 7.87mg/l at Station RW10. Surface dissolved oxygen concentrations were

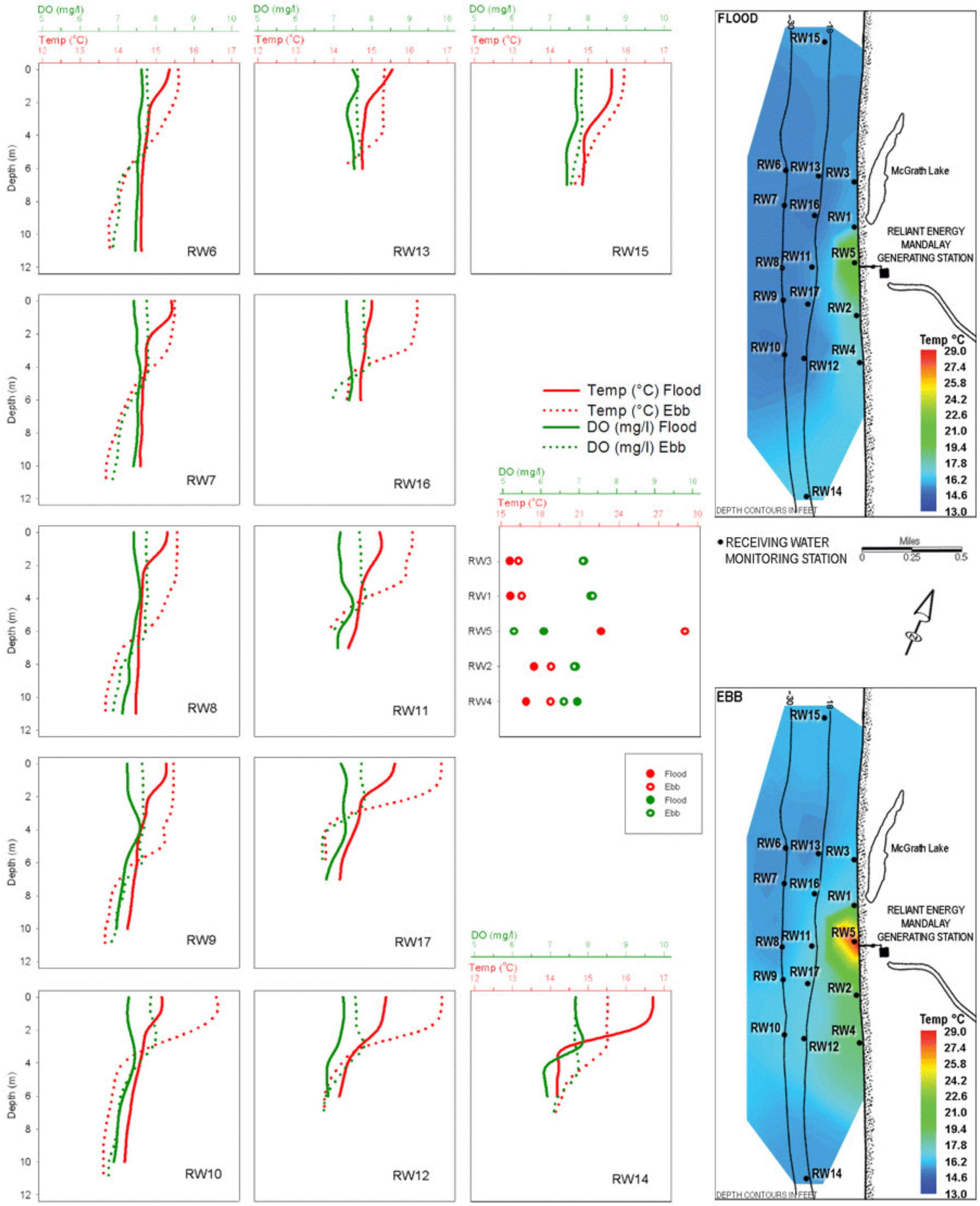



**Figure 8. False color surface temperature contour plots, surf zone water quality, and temperature and dissolved oxygen vertical profiles during flood and ebb tides, summer survey. Mandalay Generating Station NPDES, 2007.**

similar throughout the summer sampling, varying by less than 0.7 mg/l between tides and among stations and with depth, with slightly higher values found in the upper 6 m at most stations during the later ebb tide (Appendix B-2). Dissolved oxygen concentrations were relatively consistent with depth on both tides, with slight subsurface maxima in the upper 4 to 6 m at all stations with only moderate reductions or slight increases in DO with depth to the bottom. The greatest surface-to-bottom DO differential of about 0.9 mg/l was found at Station RW7 on ebb tide. Dissolved oxygen concentrations throughout the water column were slightly more variable with depth during the ebb tide. Average bottom DO values in summer were 7.16 mg/l during flood tide and 6.95 mg/l during ebb tide. Lowest bottom DO value (6.70 mg/l) was recorded at Station RW17 on ebb tide and the highest value (7.54 mg/l) was recorded at both Station RW13 on flood tide and Station RW15 on ebb tide.

At surf-zone stations in summer, surface DO concentrations during flood tide averaged 6.88 mg/l and ranged from 6.07 mg/l at Station RW5 to 7.31mg/l at Station RW1 (Table 3 and Figure 8). Surface DO concentrations during ebb tide averaged 6.64 mg/l and ranged from 5.28 mg/l at Station RW5 to 7.36 mg/l at Station RW1.

**Hydrogen Ion Concentration**

During winter monitoring, offshore surface hydrogen ion concentrations (pH) averaged 7.79 during flood tide and 7.92 during ebb tide (Table 2 and Figure 9). Flood tide pH values ranged from 7.77 at Stations RW10 and RW14 to 7.81 at Station RW16. Ebb tide pH values ranged from 7.90 at Stations RW11 and RW13 to 7.92, which occurred at nine of the remaining stations. Bottom pH values averaged 7.77 during flood tide and 7.88 on ebb tide. Flood tide bottom values ranged from 7.75 at Stations RW10 and RW14 to 7.77 at the remaining stations. Ebb tide bottom pH values ranged from 7.86 at Station RW8 to 7.91 at Station RW16. Hydrogen ion values were very consistent throughout the water column varying by less than 0.2 units among stations and depths, although generally slightly higher on ebb tide (Appendix B-1).

At surf-zone stations in winter, surface pH values averaged 7.79 during flood tide and 7.96 during ebb tide (Table 3). Hydrogen ion concentrations varied by less than 0.3 units among stations and between tides. Highest pH values were recorded at Stations RW1 and RW3 on flood tide and at Station RW3 on ebb tide (Figure 9).

Surface pH values in the summer averaged 7.90 during flood tide and 8.00 during ebb tide (Table 2 and Figure 10). Flood tide pH values ranged from 7.88 at five of the offshore stations to 7.94 at Station RW15. Ebb tide pH values ranged from 7.96 at Station RW12 to 8.04 at Station RW15. Bottom pH values averaged 7.87 during flood tide and 7.93 on ebb tide. Flood tide bottom values ranged from 7.83 found at four stations to 7.93 at Station RW15. Ebb tide bottom pH values ranged from 7.91at Stations RW7 and RW9 to 7.98 at Station RW15. Hydrogen ion values were very consistent throughout the water column, although generally slightly higher on ebb tide. In summer, pH values were notably uniform, varying by no more than 0.8 among stations, between tides and with depth.

At surf-zone stations in summer, surface pH values averaged 7.68 during flood tide and 7.82 during ebb tide (Table 3). Hydrogen ion concentrations varied by less than 0.4 units among stations and between tides. Highest pH value was recorded at Station RW3 on both tides (Figure 10).

**Salinity**

During winter monitoring, offshore surface salinity readings averaged 33.73 practical salinity units (psu) during flood tide and 33.74 psu during ebb tide (Table 2 and Figure 9). Salinity increased with depth at most stations on both tides, with slightly lower salinity values and more variability found in the upper 4 m at all stations during the morning flood tide. Bottom salinities were very similar

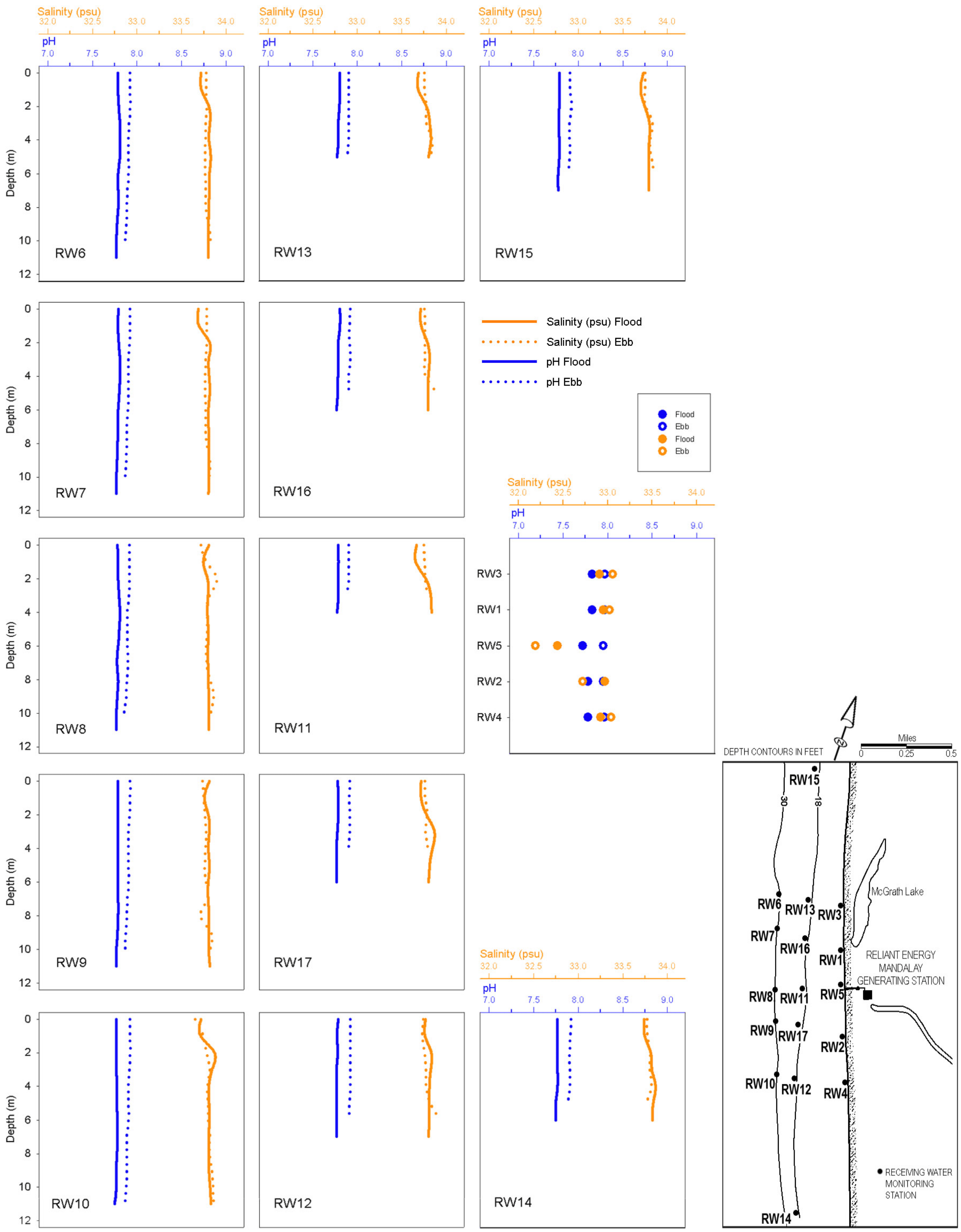



**Figure 9. Surf-zone water quality, and hydrogen ion concentration (pH) and salinity vertical profiles during flood and ebb tides, winter survey. Mandalay Generating Station NPDES, 2007.**

between tides and among stations. Average bottom salinity values were 33.81 psu during flood tide and 33.83 psu during ebb tide. Salinity values throughout the water column varied by 0.3 psu or less

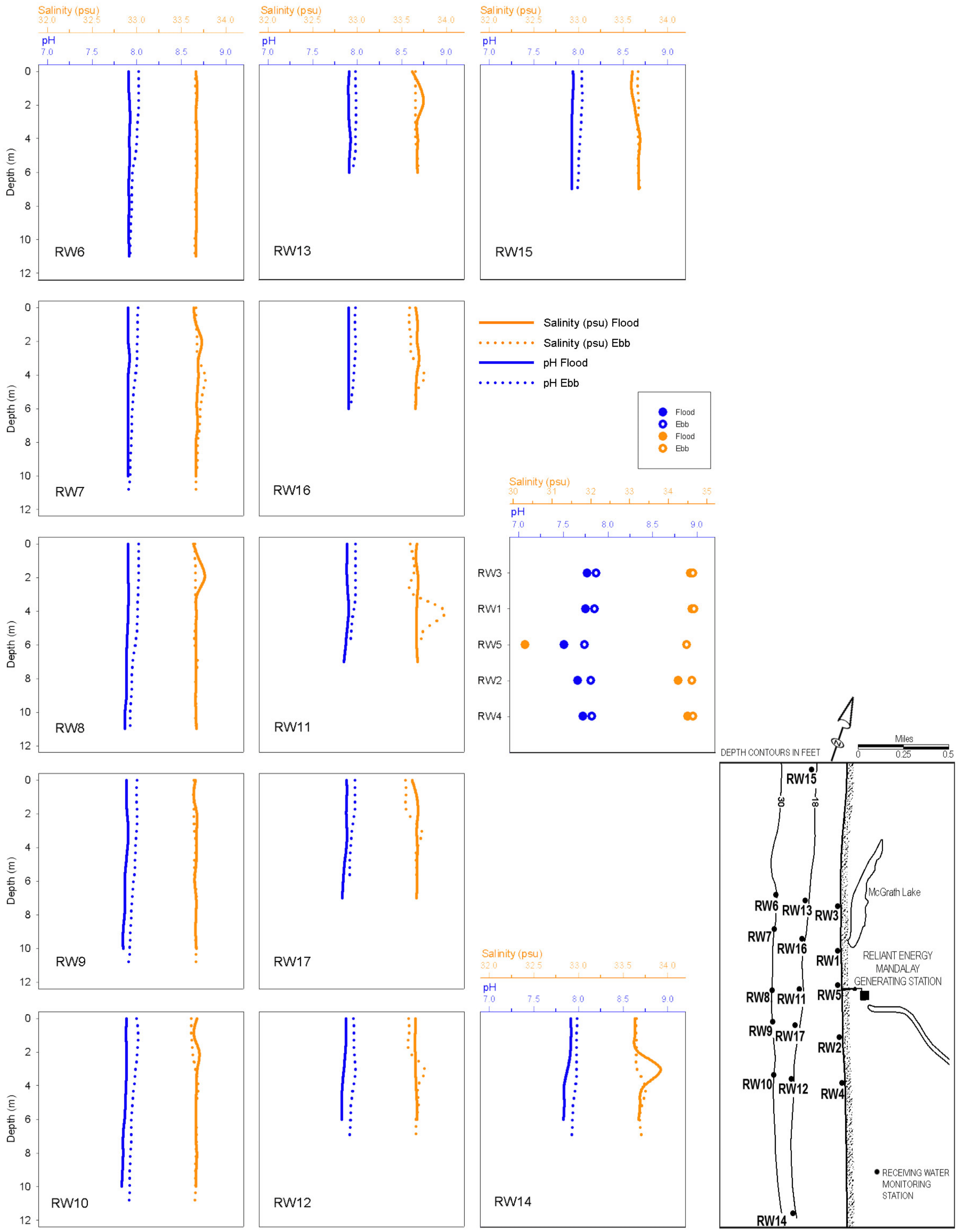



**Figure 10. Surf-zone water quality, and hydrogen ion concentration (pH) and salinity vertical profiles during flood and ebb tides, summer survey. Mandalay Generating Station NPDES, 2007.**

among stations, between tides and with depth, with a maximum surface-to-bottom difference, an increase of 0.24 psu at Station RW10 on ebb tide (Appendix B-1).

At surf-zone stations in winter, surface salinity readings averaged 32.84 psu during flood tide and 32.81 psu during ebb tide (Table 3 and Figure 9). Salinity among surf-zone stations varied by 0.53 psu during flood tide and by 0.87 psu during ebb tide (Appendix B-1). Lowest salinity values were recorded at Station RW5 on both tides. Highest salinity values were recorded at Station RW2 during flood tide and RW3 during ebb tide.

Summer surface salinity averaged 33.64 psu during flood tide and 33.62 on ebb tide (Table 2 and Figure 10). Salinity increased with depth at most stations on both tides, with slight variability in the upper 5 m. Subsurface maxima salinity values were found at some stations on both tides, most notably at Station RW14 on flood and Station RW11 on ebb. Near-bottom water salinities averaged 33.67 psu during both tides. Salinity values throughout the water column varied by 0.5 psu or less among stations, between tides and with depth, with a maximum surface-to-bottom increase of 0.13 psu at Stations RW11 and RW17 on ebb tide (Appendix B-2).

At surf-zone stations in summer, surface salinity readings averaged 33.64 psu during flood tide and 34.60 psu during ebb tide (Table 3 and Figure 10). Salinity varied by 4.31 psu during flood tide and 0.19 psu during ebb tide (Appendix B-2). Lowest salinity values were recorded at Station RW5 and highest salinity values recorded at Station RW1 during both tides.

## 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, one circulating pump was in operation with a flow of 63.4 mgd and a discharge temperature of 21.1°C, or 3.3°C above ambient intake water temperature (Siekiel-Zdzienicki 2007, pers. comm.). At all offshore stations, surface temperatures during the late morning and early afternoon ebb tide monitoring were slightly higher than early morning flood tide monitoring, likely a result of solar insolation. On average, temperatures at all stations were 0.9°C higher during the later tide, with the greatest increase between tides (1.34°C) found at Station RW15, farthest upcoast of the intake channel. Temperature decreased from surface to bottom at all stations during both tides, with mild thermal gradients in the upper 2 to 3 m of the water column at all stations 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 offshore of the discharge at the 20-ft isobath on flood tide and at 30-ft isobath of ebb tide suggest the influence of warm water from the discharge. At surf-zone stations in winter, surface water temperatures reported during the later ebb tide were about 1.6°C higher than found on flood tide. During each tide, temperatures at the discharge station were higher by about 1.4°C on flood tide and 1.0°C on ebb tide, indicating the presence of warm water from the discharge in the surf-zone. Otherwise, temperatures were similar at surf-zone stations away from the discharge, varying by less than 0.4°C among stations on either tide. Water temperatures in 2007 were typical of winter sampling results commonly reported in winter surveys and generally lower than temperatures found in the area in 2006 (MBC 1986, 1988, 1990, 1994-2001a, 2002-2006a; 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 214 mgd and a discharge temperature of 35.0°C or 14.4°C above ambient intake water temperature (Siekiel-Zdzienicki 2007, pers. comm.). As in winter, surface temperatures in 2007 were typical of summer surveys in the area and lower than values found in the area in 2006 (MBC 1986, 1988, 1990, 1994-2001a, 2002-2006a; Ogden 1991-1993). Temperatures at the offshore stations during morning flood tide were fairly consistent with depth throughout the water column with mild thermal gradients except at Station RW14, farthest downcoast, where a relatively strong thermocline was found. Temperature decreased from surface to bottom at all stations during flood tide. On ebb tide, near-bottom water temperatures were generally colder than during flood tide resulting in stronger and slightly deeper thermal gradients at most stations. Strong thermoclines were found at Stations RW10, RW12, RW16, and RW17. Surface temperatures at offshore stations along the 30-ft isobath on ebb tide were very similar to or lower than temperatures found during the early morning flood tide except at downcoast Station RW10. Similar or slightly lower flood temperatures were also found in surface waters at Stations RW13 and RW15, the farthest stations upcoast on the 20-ft isobath, and at Station RW14, farthest downcoast at the same depth. At the remaining stations on the 20-ft isobath, the two nearest downcoast stations, the station offshore of the discharge, and at the nearest station upcoast of the discharge, warmer near-surface water temperatures suggested the presence of a warm water surface lens from the thermal plume. Similarly at the surf-zone stations, temperatures were highest at the discharge channel during both tides. Temperatures were also somewhat elevated downcoast of the discharge on both tides compared with the upcoast stations, with influence from the plume decreasing with distance from the discharge. 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 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, subsurface DO concentration maxima were recorded within the upper two to four meters of the water column at all offshore stations on both tides except at Station RW8 on flood tide. Dissolved oxygen concentrations declined only slightly with depth to the bottom below the subsurface maxima. Surface and bottom DO concentrations were relatively similar among stations on both tides, with DO values slightly higher throughout the water column during the later ebb 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. The similarity of DO levels with depth suggests that during the winter sampling the water column was fairly well mixed during both tides. In 2006, a phytoplankton bloom (red tide) in winter contributed to extreme DO fluctuations in the water column at the offshore stations, with very high DO values, up to 19.23 mg/l, near surface, and some low values near 5.00 mg/l found below a depth of 5 to 8 m (MBC 2006a). In the surf-zone, DO concentrations were slightly reduced at the discharge compared to the other stations on both tides, with a greater reduction found during the earlier flood tide sampling. These reductions are likely related to the higher temperatures found at the discharge; however, DO concentrations at that station were well above the level of concern on both tides. All DO values from the winter survey were within the range previously found in the area and more typical of previous winter sampling than occurred in 2006 (MBC 1986, 1988, 1990, 1994-2001a, 2002-2006a; Ogden 1991-1993).

In summer, DO values were again similar among offshore stations, varying by less than 0.7 mg/l between tides and among stations and with depth. Slightly higher values were found in the upper 6 m at most stations during the later ebb tide. Dissolved oxygen concentrations were relatively consistent with depth on both tides, with slight subsurface maxima in the upper 4 to 6 m. Dissolved oxygen concentrations were generally more similar throughout the water column during the early morning flood tide except at Station RW14 where a relatively strong reduction in DO level was associated with the depth of the thermocline. During ebb tide sampling, DO concentrations in the upper water column were generally more variable with depth and among stations, with reduced DO levels below thermocline depths. The similarity of DO levels with depth during the early sampling suggests that the water column was fairly well mixed during flood tide. 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 reduced at the discharge compared to the other stations on both tides, with a greater reduction found during the later ebb tide sampling. These reductions are likely related to the higher temperatures found at the discharge; however, DO concentrations at that station were above the level of concern on both tides. Dissolved oxygen concentrations were in the range previously recorded offshore the generating station (MBC 1986, 1988, 1990, 1994-2001a, 2002-2006a; 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, and in both surveys slightly higher when sampled on the later ebb tides. Hydrogen ion values were slightly more consistent in winter, varying by less than 0.2 units during the survey, than during summer when pH values varied by up to 0.8 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 upcoast and downcoast during both seasons, likely a result of slightly lower salinity water in the discharge channel. In 2007, all pH values were consistent with concentrations previously recorded in the study area (MBC 1986, 1988, 1990, 1994-2001a, 2002-2006a; 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. 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 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.

In winter, salinity values at the offshore stations increased with depth at most stations on both tides, with slightly lower salinity values and more variability found within the upper 4 m at all stations during the morning flood tide. Bottom salinities were very similar between tides and among stations. In summer, salinity increased with depth at most stations on both tides, with slight variability in the upper 5 m. Subsurface maxima salinity values were found at some stations on both tides, most notably farthest downcoast on flood and offshore of the discharge on ebb tide. At the surf-zone stations, salinity was similar at the upcoast and downcoast stations during both seasons on both tides, though salinity at the discharge was consistently lower than the remaining surf-zone stations in winter and during flood tide in summer. Lower values at the surf-zone discharge suggests 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. Although generally consistent, surface salinity offshore of the discharge during flood tide in winter and in the surf-zone downcoast of the discharge on ebb tide in winter and on flood tide in summer may have been slightly reduced by flow through the discharge. Still, all values reported in 2007 were typical of the nearshore waters of southern California and within values found previously in the area (MBC 2002-2006a). While surface salinity appeared to be slightly reduced as a result of operation of the generating station, the influence was local and similar to natural conditions found commonly throughout the study area.

## CONCLUSION

In 2007, water quality parameters were relatively consistent among stations and between tides during both winter and summer. During both seasons, warmer and slightly less salty surface water was observed near the discharge, 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 cooling water discharge from the Mandalay Generating Station in 2007, the influence was localized and did not appear to have an adverse effect on receiving waters in the study area.

## 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 2007 (Figure 11). All samples were collected *in situ* by biologist-divers in conjunction with infauna sampling.

### Sediment Grain Size

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

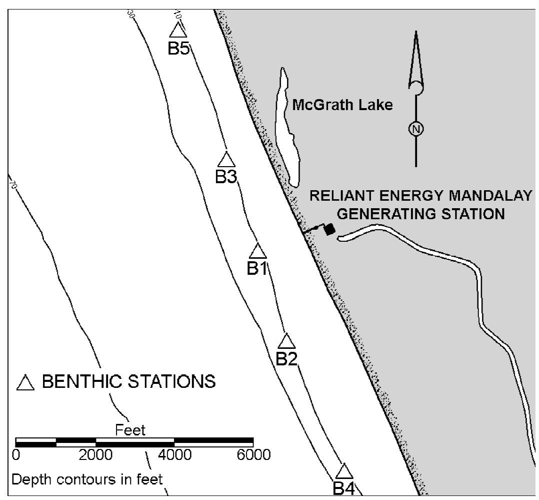



**Figure 11. Location of the benthic sampling stations. Mandalay Generating Station NPDES, 2007.**

### 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 were collected by biologist-divers at Stations B1 through B5 on 29 August 2007 between 1120 and 1340 hours. Skies were partly cloudy with winds from the northwest at 10 to 15 kn. Seas were west at 3 to 5 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 4. Grain size is expressed in phi (Φ) units, which are inversely related to grain diameter (Appendix C-1).

Sediments at the five stations in 2007 were composed primarily of sand, with smaller amounts of silt and clay (Table 4). Gravel was not collected at any station in 2007. Overall, sediments from the five stations averaged about 94% sand, 4% silt, and 2% clay, with an average mean grain size of 2.08 phi (236 µm, fine sand). Sediments were finest at Station B5, 5,910 ft upcoast of the discharge, where mean grain size was 3.00 phi (125 µm, fine sand to very fine sand). Sediments were coarsest offshore of the discharge channel at Station B1, where mean grain size was 1.25 phi (421 µm, medium sand).

**Table 4. Sediment grain size parameters. Mandalay Generating Station NPDES, 2007.**

| | 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 | 97.89 | 95.36 | 94.40 | 94.92 | 88.85 | 94.28 | 3.32 |
| % Silt | 1.55 | 3.25 | 3.93 | 3.56 | 8.57 | 4.17 | 2.62 |
| % Clay | 0.56 | 1.39 | 1.67 | 1.52 | 2.58 | 1.54 | 0.72 |
| Mean grain size | | | | | | | |
| phi | 1.25 | 2.37 | 2.41 | 2.00 | 3.00 | 2.08 | 0.64 |
| µm | 421 | 194 | 188 | 251 | 125 | 236 | 113 |
| Sorting (ϕ) | 0.902 | 0.792 | 0.886 | 0.935 | 0.884 | 0.880 | 0.053 |
| Skewness | -0.031 | 0.014 | 0.013 | 0.094 | 0.184 | 0.055 | 0.085 |
| Kurtosis | 1.099 | 1.343 | 1.464 | 1.400 | 1.540 | 1.369 | 0.168 |

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 2007, sorting averaged 0.880 phi overall, and sediments were moderately sorted at all stations (Table 4). Sediment distribution curves at all stations were essentially unimodal, with a peak in the fine sand category at all stations with variable amounts of sediments in other size categories and small secondary peaks at Station B3, 2,360 ft upcoast of the discharge, and at Station B1 (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 2007 averaged 0.055 and ranged narrowly from -0.031 at Station B1 to 0.184 at Station B5 (Table 4). Skewness values were most similar at Station B2, 2,360 ft downcoast of the discharge, and Station B3, where sediment skewness was nearly zero. At Station B1, sediments were skewed toward coarse material, while sediments at Station B4, 5,910 ft downcoast of the discharge, and Station B5 were skewed toward finer 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 were greater than 1.0, indicating leptokurtic (excessively peaked) distributions, with dominance by a narrow range of size classes (Table 4). Kurtosis in 2007 ranged from 1.099 at Station B1 to 1.540 at Station B5, and averaged 1.369.

### 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 5. Metal concentrations were similar among stations, with the highest value for chromium found at Station B2, downcoast of the discharge and highest levels for copper, nickel and zinc found at Station B5 farthest upcoast of the generating station discharge. Lowest metal concentrations were found offshore of the discharge at Station B1 and at Station B4.

**Table 5. Sediment metal concentrations (mg/dry kg). Mandalay Generating Station NPDES, 2007.**

| | Station | | | | | | | | | Reporting |
|---|---|---|---|---|---|---|---|---|---|---|
| Metal | B1 | B2 | B3 | B4 | B5 | Mean | S.D. | ERL | ERM | Limits |
| Chromium | 4.75 | 7.06 | 5.96 | 4.09 | 6.80 | 5.73 | 1.29 | 81 | 370 | 0.125 - 0.137 |
| Copper | 3.03 | 3.70 | 3.71 | 3.40 | 7.25 | 4.22 | 1.72 | 34 | 270 | 0.125 - 0.137 |
| Nickel | 6.34 | 7.84 | 6.81 | 6.03 | 10.1 | 7.42 | 1.65 | 20.9 | 51.6 | 0.125 - 0.137 |
| Zinc | 17.7 | 25.0 | 19.7 | 19.0 | 31.9 | 22.7 | 5.9 | 150 | 410 | 1.25 - 1.37 |

ERL = Effects Range Low
ERM = Effects Range Medium

**Chromium.** Sediment chromium concentrations averaged 5.73 mg/kg and ranged from 4.09 mg/kg at Station B4 to 7.06 mg/kg at Station B2 (Table 5).

**Copper.** Sediment copper concentrations averaged 4.22 mg/kg and ranged from 3.03 mg/kg at Station B1 to 7.25 mg/kg at Station B5 (Table 5).

**Nickel.** Sediment nickel concentrations averaged 7.42 mg/kg and ranged from 6.03 mg/kg at Station B4 to 10.1 mg/kg at Station B5 (Table 5).

**Zinc.** Sediment zinc concentrations averaged 22.7 mg/kg and ranged from 17.7 mg/kg at Station B1 to 31.9 mg/kg at Station B5 (Table 5).

## DISCUSSION

### Sediment Grain Size

In 2007, sediments were analyzed from five stations offshore the Mandalay Generating Station. Sediments were most similar at the two stations downcoast of the discharge channel and at the nearest upcoast station (Stations B2 through B4) where sediments were composed of about 95% sand with lesser amounts of fine material (silt and clay) and a mean grain size in the fine sand category. Sediments offshore of the discharge (Station B1) were coarsest, comprised of almost 98% sand with a mean grain size in the medium sand category. Sediments at the station farthest upcoast of the discharge (Station B5) were finest, with mean a grain size in the fine sand to very fine sand category, and a greater contribution by fine material (11%). The particle distribution curve at Station B1 was slightly skewed toward coarse material while at the stations upcoast and downcoast sediments were skewed toward finer material. At Stations B2 and B3, grain size characteristics were very similar, with low skewness values, and nearly symmetrical distributions of fine and coarse materials.

Mean grain size in 2007 was among the coarsest found in the area, and the coarsest since 1994 (Figure 12; 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. At the remaining stations, sediment grain sizes in the fine to very fine sand categories were typical of those commonly found offshore of the generating station (MBC 1990, 1994, 1997-2001a, 2002-2006a; 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 2007 or commonly in previous surveys (Schiff et al. 2006; Figure 12; Appendix C-3).

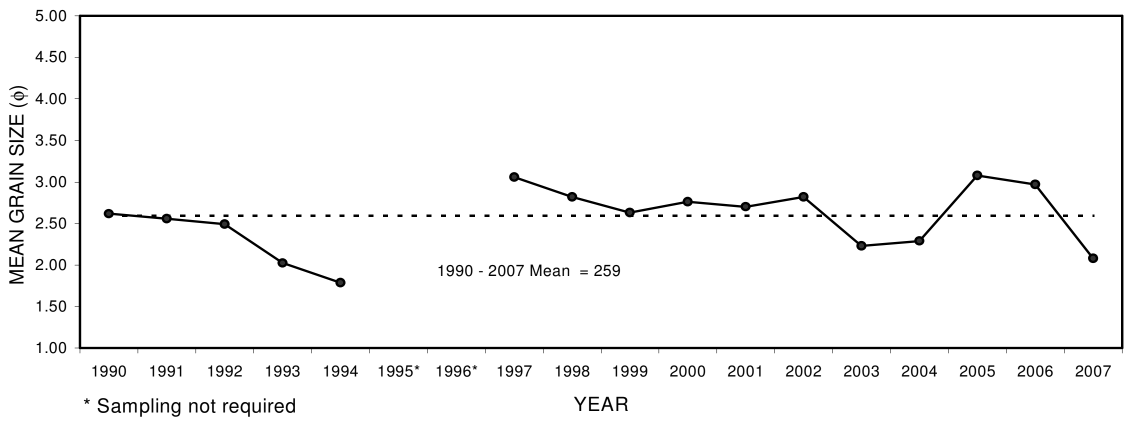



**Figure 12. Comparison of sediment mean grain size, 1990 - 2007. Mandalay Generating Station NPDES, 2007.**

In 2006, the high percentages of fine material at Stations B4 and B5 resulted in the highest overall mean contribution of fines in the area since 1980, and the finest mean grain size at Station B5 since 1997. In 2007, sediment grain size and percentage of fine material found at both of these stations were more typical of sediments found in previous studies. 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 been found at Station B5, farthest upcoast and nearest the Santa Clara River, in 14 of 18 surveys since 1978 (excluding 1998 and 2003 when the sampling program was limited to three or four stations) (Appendix C-3). Sediments in this area are likely more affected by flow and sediment deposition from the river than by generating station operations. In contrast, coarsest sediments occurred at the discharge seven times during those 18 surveys, including this year, as well as at the farthest downcoast station five times, at the intermediate upcoast station four times and at the intermediate downcoast and farthest upcoast stations once each. No annual surveys have recorded the finest sediments at the discharge.

In a pattern observed during some previous surveys, coarse sediments offshore of the discharge channel appeared be influenced by turbulence (which prevents finer sediments from settling) associated with the cooling water discharge in addition to normal nearshore processes which influence grain size such as currents, waves and sand movement. The similarity of grain size characteristics at the downcoast stations and the intermediate upcoast station suggest that sediment distribution was primarily influenced by natural causes. As in previous years, sediments at the farthest upcoast station were different than those at the remaining stations, likely a result of sediment inputs from the nearby Santa Clara River. Aside from a possible localized and transitory effect near the discharge, sediment characteristics offshore of the Mandalay Generating Station discharge in 2007 were similar to those found previously in the area and appear to be influenced primarily by natural causes.

**Sediment Chemistry**

In 2007, sediments at five stations off the Mandalay Generating Station were analyzed for the presence and concentration of chromium, copper, nickel, and zinc. Chromium levels were similar among stations while copper, nickel and zinc levels were similar at Stations B1 through B4, with higher values of these metals occurring at Station B5, farthest upcoast of the discharge where the percentage of fine material was highest (Figure 13; Appendix D-2). All sediment metal values reported in 2007 were higher than respective levels reported at the stations in 2006, when metal values were among the lowest found in the area. In 2007, the mean concentration of all metals was nearly twice to three times the levels detected in 2006, but similar to levels reported in previous years, and generally lower than the long-term means. Lowest concentrations of metals were recorded either offshore of the discharge channel or 5,910 ft downcoast of the discharge.

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 previous years, as in 2007, the largest percentages of fines (silt and clay combined) were usually recorded upcoast of the discharge at Station B5 (Figure 13). Not unexpectedly, highest concentrations of copper, nickel and zinc were found at Station B5 in 2007, while chromium was highest at Station B2, downcoast of the discharge. Lowest metal concentrations occurred either offshore of the discharge, where percent sand was highest and mean grain size was largest, or farthest downcoast where sediments were coarser than at the remaining stations. Because of an overall similarity in sediment characteristics and relatively low metal concentrations typically found in the sediments metal levels have not always appeared to relate to the amount of fine material in the sediments (MBC 1990, 1994, 1997-2001a, 2002-2006a; Ogden 1991-1993). In 2007, however, metal concentrations and percentage of fine material appeared to be somewhat related.

Metal levels reported in 2007 throughout the Mandalay study area were within the range found in sediments within the Southern California Bight and were lower than or comparable to levels found by the National Oceanographic and Atmospheric Administration (NOAA) at other sandy, offshore sites in southern California (NOAA 1991a). Mean concentrations of metals off the generating station in 2007 were also similar or lower than the mean metal concentrations found in sediments at shallow (5–30 m) coastal stations sampled in 2003 from throughout the Southern California Bight (Schiff et al. 2006).

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 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 2007 were again well below the levels of concern (Figure 13).

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

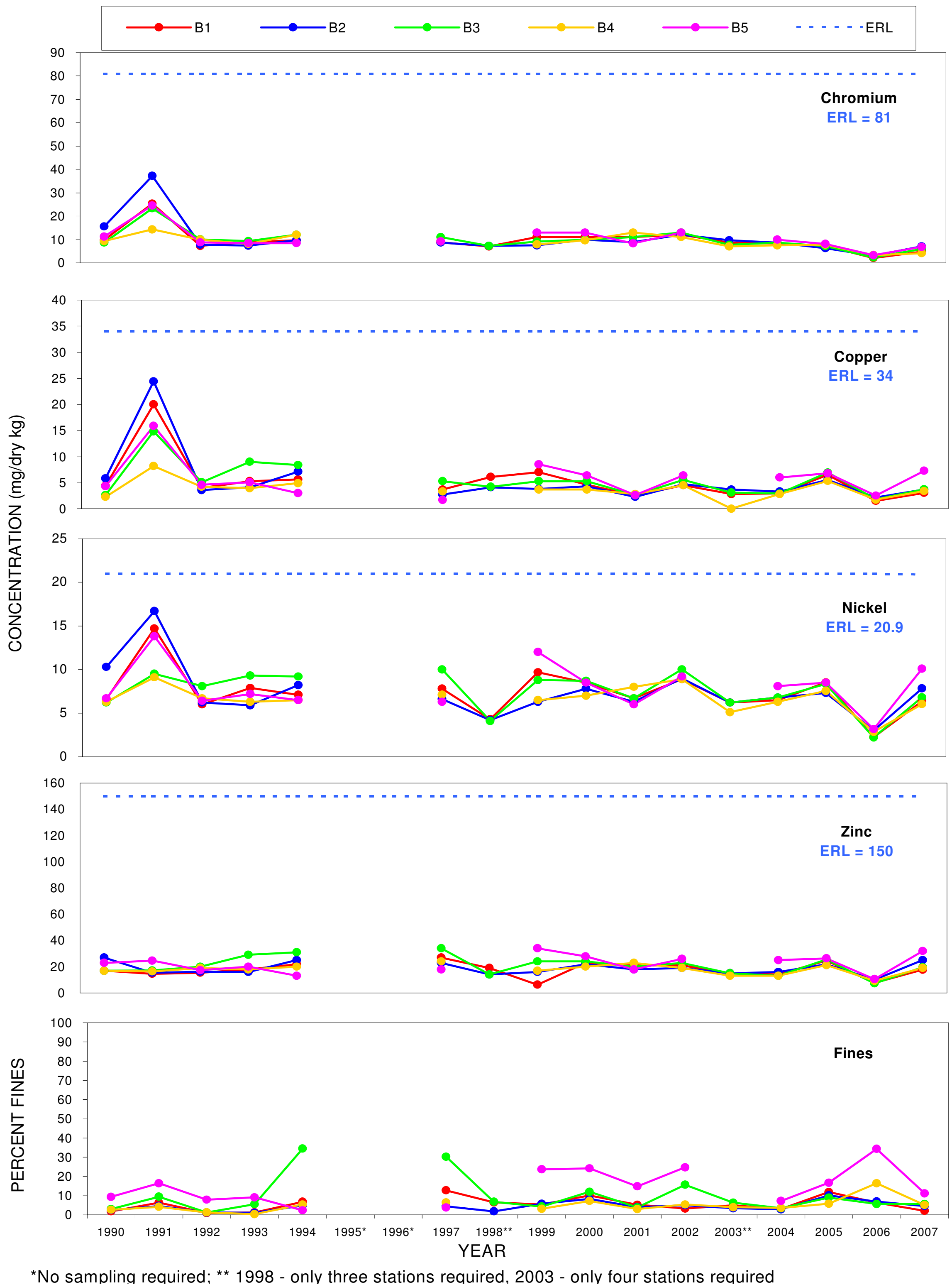



**Figure 13. Comparison of sediment metal concentrations and percent fines by station, 1990 - 2007. Mandalay Generating Station NPDES, 2007.**

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 2007 metal concentrations were generally similar among stations. Although higher than levels reported in 2006, metal concentrations in 2007 were similar to results found commonly in previous surveys. Highest metal concentrations of copper, nickel and zinc were found upcoast of the discharge where the largest percentage of fine material was found in the sediments, while lowest metal levels occurred offshore of the discharge and at the station farthest downcoast where sediments were coarsest. 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 2007 did not appear to be influenced by the operation of the Mandalay Generating Station.

## CONCLUSION

### Sediment Grain Size

In 2007, sediments were analyzed from five stations offshore the Mandalay Generating Station. Sediments were most similar at the two stations downcoast of the discharge channel and at the nearest upcoast station (Stations B2 through B4) where sediments were composed of about 95% sand with lesser amounts of fine material (silt and clay), with mean grain size in the fine sand category. Sediments offshore of the discharge (Station B1) were coarsest, comprised of almost 98% sand with a mean grain size in the medium sand category. Sediments at the station farthest upcoast of the discharge (Station B5) were finest, with mean grain size in the fine sand to very fine sand category, and a greater contribution by fine material (11%). Coarse sediments at the station offshore of the discharge channel appeared be influenced by turbulence associated with the cooling water discharge, a pattern noted during some previous surveys, while finer sediments have been consistently found at Station B5, likely a result of local inputs from the nearby Santa Clara River. The degree of influence of the discharge on local sediments varies from year to year, suggesting a localized and transitory effect near the discharge. Other than the coarser sediments found in the discharge area, sediment characteristics offshore of the Mandalay Generating Station discharge in 2007 were similar to those found previously in the area and appear to be affected primarily by natural causes.

### Sediment Chemistry

In 2007 metal concentrations were generally similar among stations, with higher copper, nickel and zinc found at the station farthest upcoast from the generating station discharge. Although higher than levels found in 2006, which were among the lowest reported in the area, metal concentrations in 2007 were similar to results found commonly in previous surveys. Highest metal concentrations of copper, nickel and zinc were found upcoast of the discharge where the largest percentage of fine material was recorded, while lowest metal levels occurred offshore of the discharge and at the station farthest downcoast where sediments were coarsest. Sediment metal concentrations have remained relatively consistent in the area since 1990. 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 2007 did not appear to be influenced by the operation of the Mandalay Generating Station.

## 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 maintained in the area since 2001 for that purpose. In previous years, donor mussels were typically collected at the Ormond Beach generating station discharge buoy located downcoast of the Mandalay Generating Station. Replacement of the Ormond buoy in early 2006, however, eliminated this site as a mussel source this year. As a result, in 2006, live bay mussels (*Mytilus galloprovincialis*) were purchased from a commercial mussel distributor, Carlsbad Aquafarms, for transplant offshore the Mandalay discharge. Donor mussels were harvested from Agua Hedionda Lagoon in Carlsbad, California on 29 March 2007, 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 31 March 2007. It was not possible to locate the mooring left in place in 2006, so a new mooring was utilized to deploy the donor mussels off the Mandalay discharge canal in 2007. (Moorings are left in place from year to year to provide habitat otherwise unavailable in the study area for the settlement of resident mussels.) Additional mussels from the donor site were frozen for later analysis and comparison with the transplanted mussels. On 29 August 2007, biologist-divers searched and were unable to locate the mooring and donor mussels located offshore of the discharge. The divers, did, however, relocate the partially buried float of the 2006 mooring, with mussels growing on the exposed area of the buoy. All mussels were retrieved and returned to the laboratory for chemical analysis. Reference mussels were collected from the Manhattan Beach Pier on 25 July 2007.

Of the bay mussels found offshore of Mandalay in 2007 only eleven mussels with shell lengths averaging 43 mm were near the target size of 50 to 75 mm used in previous sampling. Tissues from the eleven mussels were composited into a single sample replicate and 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 three replicate composites of tissues from California mussels (*Mytilus californianus*) collected at the Manhattan Beach Pier. Donor site mussel tissue concentrations were not included in 2007 results since resident mussels were collected in the study area.

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 can not 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 1999-2001a, 2002-2006a). 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 in 2007 were higher than during the previous two years, these levels are still expected to reliably report metal concentrations commonly found in local mussel tissues without reporting ND results. For QA/QC purposes, the analytical laboratory may randomly 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 2007, chromium, copper, nickel, and zinc were detected in mussel tissue from the generating station area, and in all tissue replicates at a pier reference site (Table 6 and Appendix E).

**Table 6. Mussel tissue metal concentrations (dry weight and reporting limits, mg/dry kg; wet weight and EDL, mg/wet kg). Mandalay Generating Station NPDES, 2007.**

| | 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 | 2.10 | NA | NA | 2.10 | - | 0.855 | 0.33 | NA | NA | 0.33 | - | 0.73 | 1.60 |
| Copper | 5.83 | NA | NA | 5.83 | - | 1.28 | 0.91 | NA | NA | 0.91 | - | 2.28 | 4.28 |
| Nickel | 4.28 | NA | NA | 4.28 | - | 0.427 | 0.67 | NA | NA | 0.67 | - | 0.78 | 1.06 |
| Zinc | 148 | NA | NA | 148 | - | 8.55 | 23 | NA | NA | 23 | - | 42.92 | 52.60 |
| % Solids | 15.6 | - | - | 15.6 | - | 0.100 | - | - | - | - | - | - | - |
| Manhattan Beach Pier Reference Site | | | | | | | | | | | | | |
| Chromium | 4.37 | 3.78 | 5.81 | 4.65 | 1.04 | 0.446 - 0.526 | **0.93** | **0.85** | **1.10** | **0.96** | 0.13 | 0.55 | 1.04 |
| Copper | 8.49 | 7.56 | 9.48 | 8.51 | 0.96 | 0.670 - 0.789 | **1.81** | **1.69** | **1.80** | **1.77** | 0.06 | 1.59 | 2.12 |
| Nickel | 2.46 | 1.24 | 1.74 | 1.81 | 0.61 | 0.223 - 0.263 | 0.52 | 0.28 | 0.33 | 0.38 | 0.13 | 0.63 | 0.82 |
| Zinc | 94.5 | 73.9 | 94.2 | 87.5 | 11.8 | 4.46 - 5.26 | 20.1 | 16.6 | 17.9 | 18.2 | 1.81 | 33.64 | 38.87 |
| % Solids | 21.3 | 22.4 | 19.0 | 20.9 | - | 0.100 | - | - | - | - | - | - | - |

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

NA = Not Available

Chromium concentration in mussels from the generating station was 2.10 mg/dry kg (Table 6). Mean chromium concentration at the reference site was 4.65 mg/dry kg.

Copper concentration in mussels from the discharge was 5.83 mg/dry kg (Table 6). Mean concentration at the reference site was 8.51 mg/dry kg.

Nickel in mussels from the discharge was detected at a level of 4.28 mg/dry kg (Table 6). Nickel at the reference site averaged 1.81 mg/dry kg for the three replictes.

Zinc concentration at the discharge site was 148 mg/dry kg (Table 6). Mean zinc concentration at the reference site was 87.5 mg/dry kg.

## 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 discharge. Therefore, 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 2007, mussels were not initially found in the vicinity of the Mandalay Generating Station discharge channel. For that reason, donor mussels were purchased from a commercial supplier in Carlsbad, California and transplanted to a mooring offshore of the Mandalay discharge where the mussels were allowed to acclimate. This mooring was not relocated during the return visit, but a small number of resident mussels just below the target size were found. Tissues from these mussels were composited for analysis, the method utilized in previous surveys, but it was decided that not enough mussel tissue was available for testing of more than one replicate sample. Results were compared with those from mussels collected at the Manhattan Beach Pier in Santa Monica Bay, which served as a reference site. Analytical results for the 2007 donor mussels were not included in this report since transplanted mussels were not utilized.

Chromium was reported from the generating station discharge and in all replicates at the reference site. Tissue concentrations of chromium in mussels offshore of the discharge in 2007 were detected at less than one-third the concentration reported in 2006, and at levels about 35% lower than reported in 2005 (Table 6, Figure 14). Prior to 2005, chromium levels were consistently below the reporting limits in mussel tissue from discharge and in donor site mussels, though reported at a reference site in 2002 (Appendix E; MBC 2001a, 2002-2006a). Chromium has undoubtedly occurred in tissues from the area of the discharge since sampling began, but at levels which could not reliably be reported with previous analytical reporting limits. However, all chromium concentrations found since 2005 would have been detected at pre-2005 chromium reporting limits, suggesting that the chromium levels in the area have increased from pre-2005 levels. In 2005, the mean concentration of chromium in mussel tissues from the reference site was about one-third lower than the levels found at the discharge or donor site; however, in 2006 levels from the reference site (where levels were more than seven times higher than in 2005) were about 30% higher than levels in mussels from the other sites. Higher-than-normal chromium levels were noted in mussels at the discharge, the Agua Hedionda donor site, and the Santa Monica Bay reference site, as well as from other areas throughout southern California in 2006 (MBC 2006a-g). Chromium concentrations in the project area decreased notably since 2006, and in 2007 were less than one-half of the concentrations reported at the reference site. Wet-weight chromium levels in mussels from offshore of the Mandalay Generating Station discharge were below levels considered to be elevated by the SMWP. Values at the reference site, however, were elevated above the EDL 85 values, with one replicate also exceeding the EDL 95 level for native California mussels.

Copper was detected in all replicates analyzed in 2007. Copper concentrations in mussels from the discharge were lower than levels found in the area in 2001, 2002, 2005 and 2006, higher than levels found in the area in 2003, and very similar to levels reported in 2004 (Figure 14; Appendix E-2). Copper levels at both the discharge and the reference sites have remained comparatively stable since 2001. In 2006, copper levels were similar among sites, with the highest

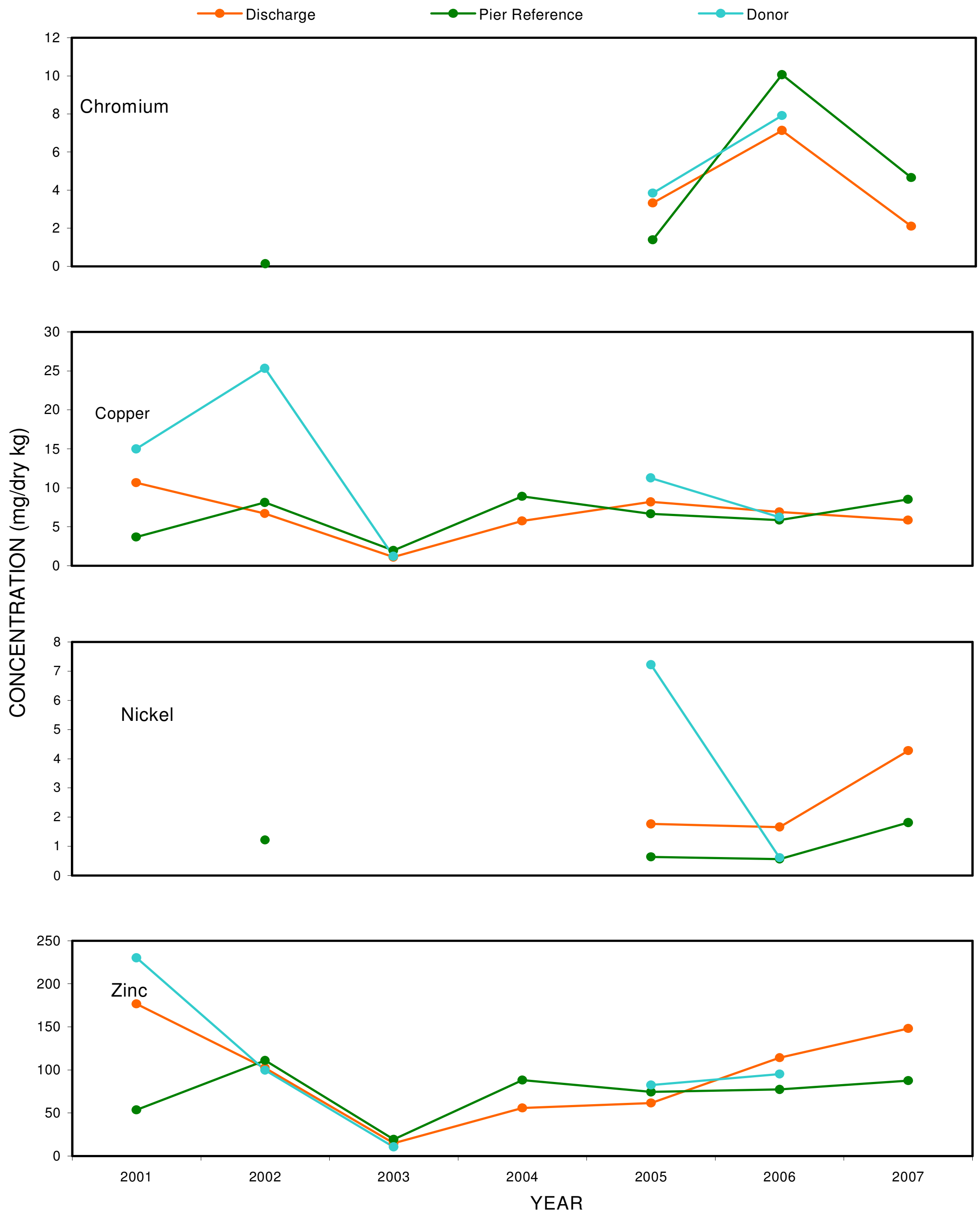



**Figure 14. Comparison of mean chromium, copper, nickel, and zinc concentrations in mussel tissue at discharge and at reference sites, 2001 - 2007. Mandalay Generating Station NPDES, 2007.**

mean concentration found at the discharge and the lowest at the reference site. In 2007, copper from the discharge area was about 30% lower than the mean concentration of copper in tissues from the reference area. Wet-weight copper levels in mussel tissue from the vicinity of the discharge were below the EDL 85 value for resident bay mussels, indicating that levels were not elevated offshore of the discharge canal. Copper values at the reference site, however, were elevated above the EDL 85 value for native California mussels.

In 2007, nickel was reported in all replicates analyzed. Prior to 2005, nickel was unreported in mussels from the discharge or donor areas. In 2005 nickel was detected in mussels from the discharge at levels below the reporting limits from most previous tissue sampling, while nickel at the donor site was notably higher (Appendix E-2, MBC 2001a, 2002-2006a). In 2006, nickel levels at both the discharge and the reference site were similar to and slightly lower than levels found in 2005, while at the donor site levels were markedly lower than in 2005 (Figure 14). In 2007, nickel concentration near the discharge was about 2.2 times the level reported from the reference site and about 2.5 times higher than nickel levels reported at the discharge in 2006 (Table 6; Figure 14; Appendix E-2). Nickel was also higher at the reference site in 2007 than in 2006. Still, nickel concentrations in mussel tissues collected from offshore of the discharge and at the reference site were below levels considered elevated by the SMWP for the respective mussel species.

Zinc was detected in all mussel tissue replicates in 2007 (Table 6). Zinc concentration from the generating station discharge area was the highest found offshore of the discharge since the first year of mussel sampling in 2001 (Figure 14 and Appendix E). This continues a trend of increasing zinc levels offshore of the discharge since 2003, while levels at the reference site have remained consistent since 2004. Zinc concentration in 2007 was about 70% higher than levels reported at the reference site in 2007. Still, wet-weight zinc concentration from the generating station was lower than the EDL 85 values for resident populations of bay mussels, indicating that zinc levels were not elevated offshore of the discharge. Similarly, zinc concentrations at the reference site were below levels considered elevated for California mussels.

## CONCLUSIONS

In 2007, concentrations of chromium in mussel tissues from offshore of the Mandalay Generating Station discharge channel declined notably from 2006 levels. Copper concentrations in mussel tissues also declined somewhat from 2006 levels. Concentrations of both metals were also lower than levels reported at a pier reference site sampled in 2007. Nickel and zinc concentrations, however, increased from 2006 levels offshore of the discharge, with both nickel and zinc values among the highest found, but within the range reported in previous studies in the area. As in 2006, both nickel and zinc levels in tissues from the discharge area exceeded those at the reference site. While elevated chromium and copper levels were found at the reference site in 2007, concentrations of all metals reported in tissues from offshore of the discharge canal were below levels considered elevated for resident bay mussels by the SMWP. The similarity of tissue metal levels among sites and previous studies suggests that the operation of the Mandalay Generating Station is not elevating metal concentrations above background levels.

## 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 all surveys except in 1998 (only three stations) and 2003 (four stations, with only two replicates each, one-half the number of replicates in all other surveys). 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).

### MATERIALS AND METHODS

Biologist-divers collected sediment cores for analysis of infaunal composition at Stations B1 through B5 on 29 August 2007 between 1120 and 1340 hours (Figure 15). Skies were partly cloudy with winds from the northwest at 10 to 15 kn, and seas were west at 3 to 5 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 16). 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.

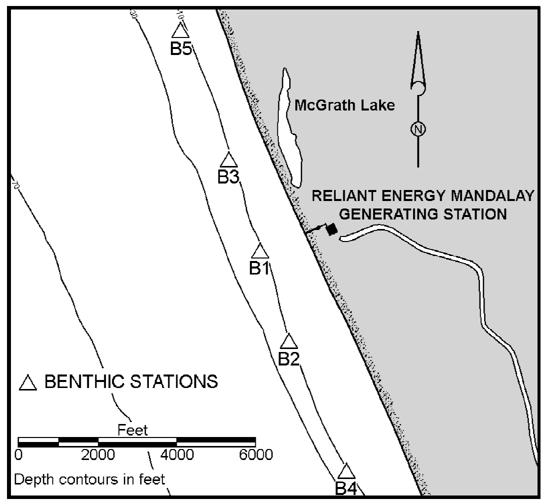



**Figure 15. Location of the benthic sampling stations. Mandalay Generating Station NPDES, 2007.**

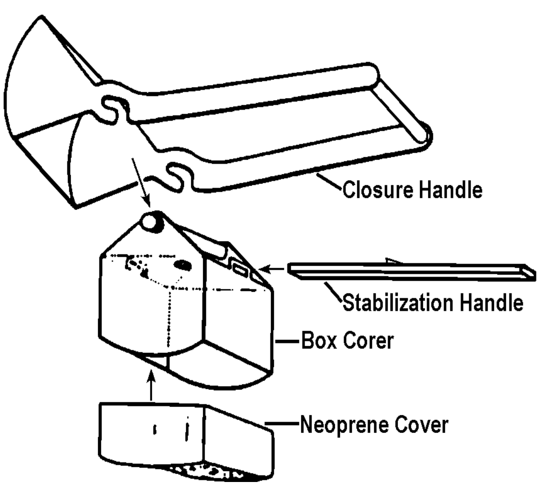



**Figure 16. Diver-operated box corer used to collect infaunal samples. Mandalay Generating Station NPDES, 2007.**

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 2001). 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, pre-weighed 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 2007, the infauna samples from the five benthic stations offshore of the Mandalay Generating Station contained a total of 1,595 individuals representing 69 species in eight phyla (major taxonomic groups) (Table 7, Appendices F-1 and F-2). Echinodermata was the most abundant phylum, with almost one-half of the individuals in the collection, although it consisted of only one species, *Dendraster excentricus*, or Pacific sand dollar. Sand dollars comprised 65% of the individuals at Station B2, immediately downcoast of the generating station discharge, but less than 8% of the individuals at Station B5, farthest upcoast. Annelids (segmented worms), arthropods, and mollusks were the next most abundant phyla, comprising 22%, 14%, and 8% of the individuals, respectively. They were also the most speciose groups, with 36%, 33%, and 11% of the species in the collection, respectively. Arthropods were rather uniformly distributed among the stations, but annelids comprised 46% of the species and 50% of the individuals at Station B5, and only 24% of the species and 10% of the individuals at Station B4, farthest downcoast. Mollusks also contributed a greater-than-average proportion of the species and individuals at Station B5, but only one individual at Station B4. The other four phyla each represented less than 2% of the species and 3% of the total abundance.

**Table 7. Number of infaunal species and individuals by phylum. Mandalay Generating Station NPDES, 2007.**

| | Station | | | | | | Percent |
|---|---|---|---|---|---|---|---|
| Parameter | B1 | B2 | B3 | B4 | B5 | Total | Total |
| Number of species | | | | | | | |
| Annelida | 6 | 17 | 15 | 5 | 17 | 25 | 36.2 |
| Arthropoda | 9 | 11 | 12 | 10 | 7 | 23 | 33.3 |
| Mollusca | 2 | 6 | 6 | 1 | 7 | 11 | 15.9 |
| Nemertea | 1 | 4 | 3 | 3 | 2 | 6 | 8.7 |
| Cnidaria | - | 1 | 1 | - | 1 | 1 | 1.4 |
| Echinodermata | 1 | 1 | 1 | 1 | 1 | 1 | 1.4 |
| Nematoda | 1 | 1 | 1 | 1 | 1 | 1 | 1.4 |
| Phorona | - | - | - | - | 1 | 1 | 1.4 |
| Total | 20 | 41 | 39 | 21 | 37 | 69 | |
| Number of individuals | | | | | | | |
| Echinodermata | 14 | 504 | 218 | 31 | 21 | 788 | 49.4 |
| Annelida | 8 | 112 | 78 | 11 | 140 | 349 | 21.9 |
| Arthropoda | 42 | 64 | 35 | 38 | 44 | 223 | 14.0 |
| Mollusca | 2 | 46 | 16 | 1 | 59 | 124 | 7.8 |
| Cnidaria | - | 34 | 2 | - | 3 | 39 | 2.4 |
| Nemertea | 1 | 13 | 7 | 8 | 10 | 39 | 2.4 |
| Nematoda | 4 | 4 | 1 | 21 | 2 | 32 | 2.0 |
| Phorona | - | - | - | - | 1 | 1 | 0.1 |
| Total | 71 | 777 | 357 | 110 | 280 | 1595 | |

**Abundance.** Abundance averaged 319 individuals per station (80 individuals per replicate, or 7,975 individuals/$m^2$), and ranged from 71 individuals at Station B1, offshore of the generating station discharge, to 777 individuals at Station B2 (Table 8, Appendices F-2 and F-3).

**Species Richness.** The number of species averaged 32 per station, or 16 species per replicate (Table 8, Appendices F-2 and F-3). Species richness ranged from 20 species at Station B1 to 41 species at Station B2.

**Table 8. Infaunal community parameters. Mandalay Generating Station NPDES, 2007.**

| | Station | | | | | | |
|---|---|---|---|---|---|---|---|
| Parameter | B1 | B2 | B3 | B4 | B5 | Total | Mean |
| Number of species | | | | | | | |
| Total | 20 | 41 | 39 | 21 | 37 | 69 | 32 |
| Rep. Mean | 8 | 23 | 18 | 11 | 21 | | 16 |
| Rep. S.D. | 4 | 3 | 4 | 3 | 2 | | |
| Number of individuals | | | | | | | |
| Total | 71 | 777 | 357 | 110 | 280 | 1595 | 319 |
| Rep. Mean | 18 | 194 | 89 | 28 | 70 | | 80 |
| Rep. S.D. | 15 | 85 | 31 | 6 | 22 | | |
| Density (#/m$^2$) | | | | | | | 7,975 |
| Diversity (H') | | | | | | | |
| Total | 2.35 | 1.72 | 1.86 | 2.39 | 2.95 | 2.43 | 2.28 |
| Rep. Mean | 1.72 | 1.73 | 1.65 | 1.96 | 2.57 | | 1.93 |
| Rep. S.D. | 0.42 | 0.58 | 0.58 | 0.29 | 0.19 | | |
| Benthic Respose Index (BRI) | | | | | | | |
| Total | 11.3 | 17.2 | 17.9 | 9.2 | 27.0 | | 16.5 |
| Biomass (g) | | | | | | | |
| Total | 0.29 | 1.77 | 1.18 | 130.12 | 4.31 | 137.68 | 27.54 |
| Rep. Mean | 0.07 | 0.44 | 0.30 | 32.53 | 1.08 | | 6.88 |
| Rep. S.D. | 0.06 | 0.27 | 0.40 | 14.71 | 0.63 | | 3.21 |
| g/m$^2$ | | | | | | | 688.41 |

**Species Diversity (H').** Shannon-Weiner species diversity averaged 2.28 per station and ranged from 1.72 at Station B2 to 2.95 at Station B5 (Table 8, Appendices F-2 and F-3). The value at the location nearest the generating station was 2.35, slightly above the area mean.

**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 16.5 for the five stations, and ranged from 9.2 at Station B4 to 27.0 at Station B5 (Table 8). The value for the station offshore of the discharge was 11.3, slightly below the area mean.

**Biomass.** Biomass totaled 137.68 g and averaged 27.54 g per station (688 g/m$^2$), ranging from 0.29 g at Station B1 to 130.12 g at Station B4 (Table 8, Appendix F-4). About 94% of the total biomass was contributed by 30 medium-sized to large Pacific sand dollars found at Station B4.

**Community Composition.** Fifteen species each represented 1% or more of the individuals in the infauna collection (Table 9 and Appendix F-2). These 15 species together were only 22% of the species in the collection but contributed 87% of the individuals. Seven of the species occurred at all stations, while three species occurred only at Station B2 and Station B5. All of the top 15 species were found at Stations B2 and B3, and all but one occurred at Station B5. Seven phyla were represented among the most abundant species. Five species were annelids, four were arthropods, two were mollusks, and one each was an echinoderm, a cnidarian, a nematode, and a nemertean. As noted above, Pacific sand dollar was overwhelmingly the most abundant species, with 49% of the individuals overall. It was least abundant at Station B1, where it was exceeded by the amphipod *Americhelidium shoemakeri*, and at Station B5 where it was less abundant than five other species.

Next most abundant were the polychaete annelid *Apoprionospio pygmaea*, the clam *Tellina modesta*, the amphipod *Rhepoxynius menziesi*, and the polychaete *Armandia brevis*. None of these species comprised more than 5% of the total collection. However, *Apoprionospio pygmaea* made up 14% of the individuals at Station B5, and *Tellina modesta*, 12%. In addition, *Americhelidium shoemakeri* contributed 27% of the individuals at Station B1, and nematodes comprised 19% of the individuals at Station B4.

**Table 9. The 15 most abundant infaunal species. Mandalay Generating Station NPDES, 2007.**

| | | Station | | | | | | Percent | Cum. |
|---|---|---|---|---|---|---|---|---|---|
| Phylum | Species | B1 | B2 | B3 | B4 | B5 | Total | Total | Percent |
| EC | *Dendraster excentricus* | 14 | 504 | 218 | 31 | 21 | 788 | 49 | 49 |
| AN | *Apoprionospio pygmaea* | 2 | 11 | 30 | 4 | 39 | 86 | 5 | 55 |
| MO | *Tellina modesta* | 1 | 17 | 4 | 1 | 34 | 57 | 4 | 58 |
| AR | *Rhepoxynius menziesi* | - | 25 | 13 | 9 | 8 | 55 | 3 | 62 |
| AN | *Armandia brevis* | - | 19 | 7 | - | 24 | 50 | 3 | 65 |
| AN | *Chone* sp SD1 Pt. Loma 1997 | 2 | 25 | 13 | 1 | 8 | 49 | 3 | 68 |
| MO | *Siliqua lucida* | 1 | 19 | 7 | - | 15 | 42 | 3 | 71 |
| CN | *Zaolutus actius* | - | 34 | 2 | - | 3 | 39 | 2 | 73 |
| AN | *Mediomastus acutus* | 1 | 4 | 2 | 1 | 30 | 38 | 2 | 75 |
| AR | *Americhelidium shoemakeri* | 19 | 3 | 1 | 11 | - | 34 | 2 | 78 |
| AR | *Diastylopsis tenuis* | 1 | 4 | 3 | - | 24 | 32 | 2 | 80 |
| NT | Nematoda | 4 | 4 | 1 | 21 | 2 | 32 | 2 | 82 |
| AN | *Owenia collaris* | - | 24 | 5 | - | 2 | 31 | 2 | 84 |
| AR | *Euphilomedes longiseta* | 1 | 19 | 4 | 6 | 1 | 31 | 2 | 86 |
| NE | *Carinoma mutabilis* | - | 9 | 3 | 4 | 7 | 23 | 1 | 87 |

AN = Annelida; AR = Arthropoda; CN = Cnidaria; EC = Echinodermata; MO = Mollusca; NE = Nemertea; NT = Nematoda

**Cluster Analyses.** Normal (station) and inverse (species) cluster analyses were performed on the 15 most abundant species in the infauna collection (Table 9). The five study-area stations clustered into two groups, based on their relative abundances of the numerically dominant species (Figure 17). Stations B1 and B4 clustered closely together in Group I; many of the dominant species were absent or less abundant at those two stations. Stations B2 and B3, in Group II, also clustered together at the same level as Stations B1 and B4; all of the dominant species were present in similar abundances at those two stations. Station B5, with a similar suite of species, clustered next with Stations B2 and B3.

The 15 most abundant species separated into three groups, based on their similarity of occurrence (Figure 17). Most of the species fell into Species Group B. Three pairs of species in Group B clustered closely: *Owenia collaris* with *Zaolutus actius*, *Diastylopsis tenuis* with *Mediomastus acutus*, and *Siliqua lucida* with *Armandia brevis*. The Group B species were more abundant at the stations in Group II than those in Group I. Species Group A contained only two species, Nematoda and *Americhelidium shoemakeri*, which were most abundant at Group I stations. *Dendraster excentricus* (Group C) clustered most distantly from the other abundant species, as it was very abundant at Stations B2 and B3 but not abundant at Station B5.

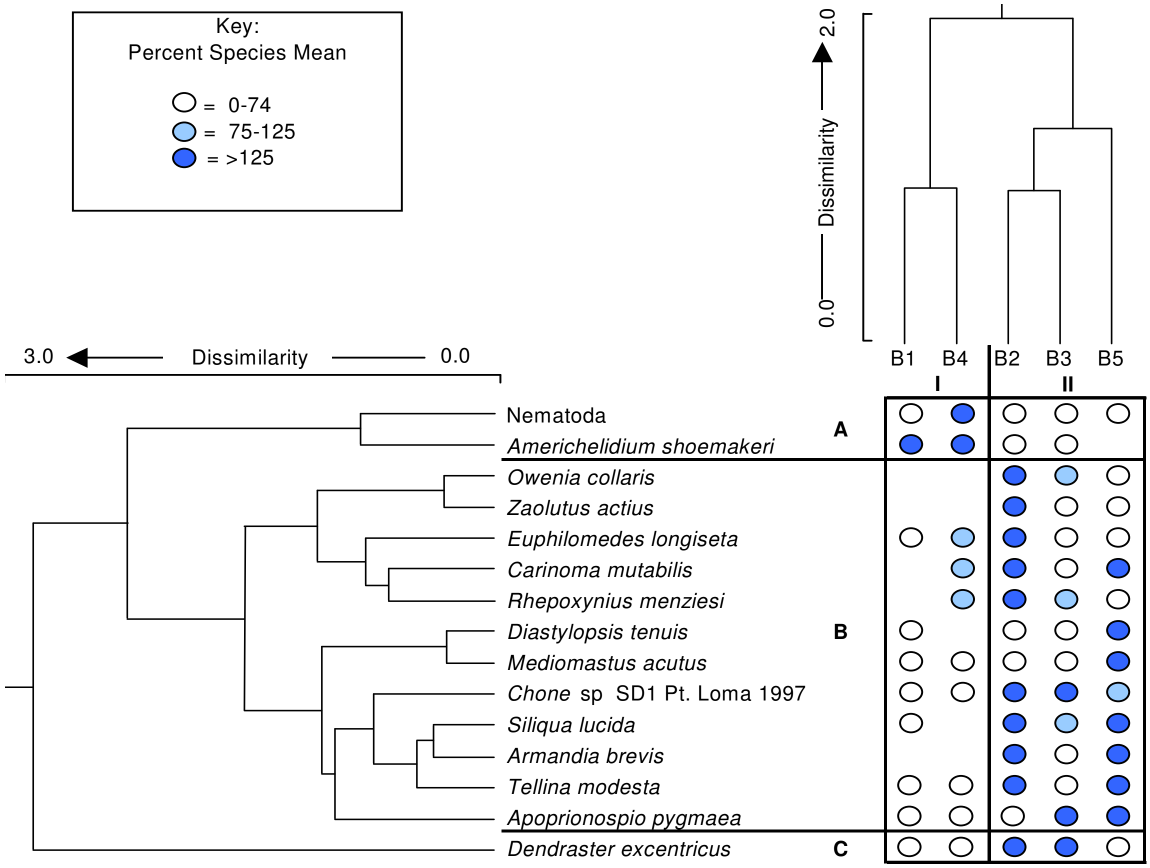



**Figure 17. Two-way coincidence table resulting from normal (station) and inverse (species) classification dendrograms for the 15 most abundant infaunal species. Mandalay Generating Station NPDES, 2007.**

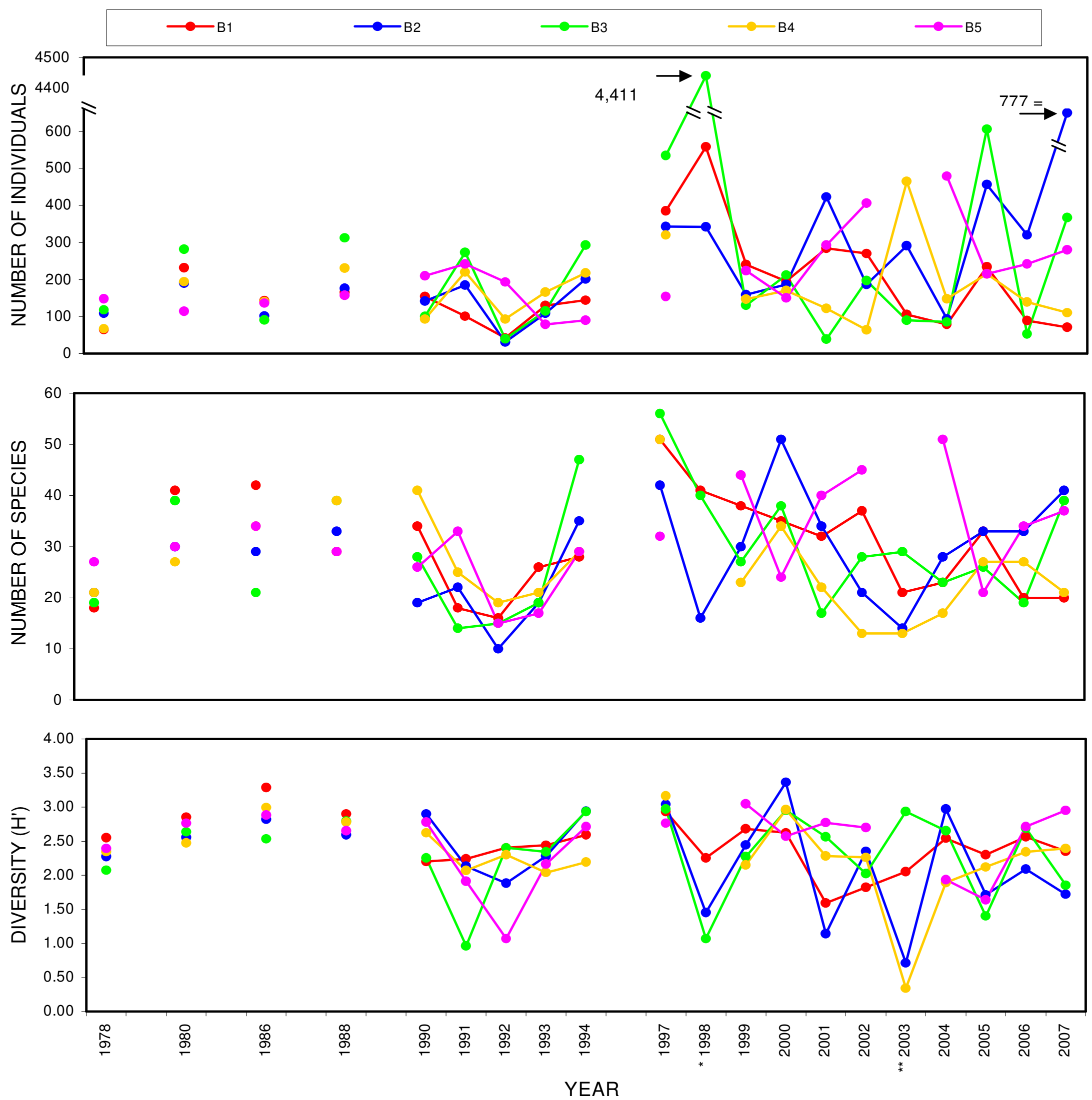
## DISCUSSION

The infauna community in the study area in 2007 was comprised primarily of small Pacific sand dollars, annelid worms, arthropods, and mollusks. Several medium to large sand dollars were also found, all of them farthest downcoast from the generating station. Abundance and species richness were higher immediately upcoast and downcoast of the generating station and farthest upcoast, and lower offshore of the generating station and farthest downcoast. Because of high abundances and strong numerical dominance of the communities by Pacific sand dollars, species diversity values were low immediately upcoast and downcoast of the generating station; diversity was high farthest upcoast, despite moderately high abundance, because no one species was particularly dominant in the community. Although abundance and species richness were lowest near the generating station, species diversity was above the mean for the study area. The Benthic Response Index was lowest farthest downcoast and highest farthest upcoast; the value near the generating station was below the area mean. Values for all but one station were low, within the Reference category for the shallow coastal shelf, indicating undisturbed, or healthy, communities. The value for the station farthest upcoast was higher, in the range for Response Level 1 (marginal deviation), suggesting some disturbance of the community, although it was at the lower end of the range. Two species considered to be disturbance indicators in the BRI assessment were more abundant at that location than elsewhere. In general, the communities nearest the generating station and farthest downcoast were alike, with low abundances and species richness, and similar community compositions. The communities immediately upcoast and downcoast of the generating station were also alike, with similar community compositions, but with high abundances and species richness. The community farthest upcoast was most similar to those immediately upcoast and downcoast of the generating station, except for the much lower numbers of Pacific sand dollars.

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). This pattern was seen to some degree in the 2007 communities, as abundance and species richness were lower where sediments were coarser. The BRI values indicated that, although these communities were small, they were the healthiest in the study area. On the other hand, abundance and species richness were only moderately high where sediments were finest. The BRI value for that community suggested that it was the least healthy, even though the species diversity value was highest. The fine sediments found farthest upcoast probably derive in part from the Santa Clara River to the north. In some circumstances, particle sorting plays a role in community characteristics, with poorly-sorted sediments providing more ecological niches. Sediments throughout the study area were moderately sorted, however, with little difference among stations. 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 2007, including the clams *Tellina modesta* and *Siliqua lucida*, *Armandia brevis*, the amphipods *Rhepoxynius menziesii* and *Americhelidium shoemakeri*, and the cumacean *Diastylopsis tenuis*. 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 2007 are typical of the shallow nearshore environment (Barnard 1963, Dexter 1978). The pattern of species dominance relating to sediment characteristics was similar to those observed several times in the past (MBC 1999, 2001a, 2002-2006a). However, Pacific sand dollars were more than seven times more abundant than in any previous survey (Appendix F-5). Almost all of the sand dollars were small, with only 30 medium to large individuals, which were found only farthest downcoast. Those 30 individuals comprised 94% of the total community biomass, however. Medium to large sand dollars were also abundant in 1999 and 2001. Large sand dollars were also taken in the 2007 winter trawl survey, although not in the summer survey (Table 13). The vast majority of those were found at the trawl station which is centered at the benthic station farthest downcoast. Because of their activities, medium- to large-sized sand dollars are important to the infaunal community. They disturb the sediment as they position themselves on edge, but also stabilize the sediment by reducing erosion and provide protection from predators for other organisms (Merrill and Hobson 1970, Smith 1981). Subtidal sand dollar beds contain similar numbers of species as the surrounding habitat, but may have a slightly different community composition. The community in which the large sand dollars were found was very similar in size and composition to the community offshore of the generating station, where only a few very small sand dollars occurred. *Apoprionospio pygmaea,* the second most abundant species, 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 2007a-d in prep). It has been the most abundant species in the study area since 1978, although it was the top species in only 11 of the 20 summer surveys (MBC 1979, 1981, 1986, 1988, 1990, 1994, 1997-2001a, 2002-2006a; Ogden 1991-1993). Other commonly occurring species include *Mediomastus acutus*, *Diastylopsis tenuis*, *Rhepoxynius menziesi*, *Scoloplos armiger*, *Chone* sp SD1, *Spiophanes bombyx*, *Owenia collaris*, *Siliqua lucida*, *Carinoma mutabilis*, and *Tellina modesta*, *Magelona pitelkai*, and *Goniada littorea*. All of these except *Scoloplos armiger* and *Magelona pitelkai* were found in the study area in 2007, and most of them were abundant. A few species have occurred only sporadically but have been highly abundant in some years. Gould beanclam (*Donax gouldii*) was extremely abundant in 1998 but it was seen in only four other years and only three individuals were found in 2007; the ostracod *Euphilomedes carcharodonta* was very abundant in 1997 but was seen in only five other surveys. Other inconsistently occurring species include *Americhelidium shoemakeri*, *Zaolutus actius*, *Euphilomedes longiseta*, and *Armandia brevis*, all of which were abundant in 2007. Despite these differences, comparison of the communities observed since 1978 shows that a core group of species has persisted.

In 2007, mean abundance for the study area was almost twice that in 2006, and was considerably greater than the mean of 6,390 individuals/m$^2$ for the summer surveys since 1978 (MBC 1979, 1981, 1986, 1988, 1990, 1994, 1997-2001a, 2002-2006a; Ogden 1991-1993). Abundances have usually been somewhat similar among stations, although values have differed considerably among stations in some years (Figure 18). Highest abundance has usually been found either immediately upcoast or downcoast of the generating station and lowest abundance near the




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

**Figure 18. Comparison of infaunal community parameters, 1978 - 2007. Mandalay Generating Station NPDES, 2007.**

generating station discharge. In 2007, abundance immediately downcoast was the highest recorded for that location, and was the second highest number ever seen for any station in the area. Abundance was also widely disparate among stations in 1997, 1998, and in all of the surveys since 2001 (values for 2003 would be about twice those indicated in Figure 18 if four replicates had been collected at each station instead of only two). The high value for Station B3 in 1998 was due to extremely high numbers of Gould beanclam; with beanclams excluded because of their extraordinary abundance in that year, mean density for the study area would be 5,630 individuals/$m^2$. Species richness and diversity have also been dissimilar among stations in some years, with extremely wide ranges in numbers of species in 1998, 2002, and 2004, and in diversity in 2001 and 2003. On average, both species richness and diversity have been highest farthest upcoast, while species richness has been lowest farthest downcoast and species diversity has been lowest immediately upcoast of the generating station. For the communities offshore of the discharge, long-term mean values for both parameters were slightly higher than the study area means. Mean species richness in 2007 was slightly above both the mean for 2006 and the long-term mean. Because of the higher abundance in 2007, mean species diversity was slightly lower than in both 2006 and the long-term mean. The BRI values for all stations were slightly greater in 2007 than those in 2006, the first year in which the index was used.

Despite the occasional disparities noted above, the long-term means have been similar throughout the study area, indicating that the infaunal community has been quite consistent. The year-to-year fluctuations have generally been area-wide. 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.

**CONCLUSION**

The infauna communities in the nearshore shallow subtidal environment in the vicinity of the Mandalay Generating Station in 2007 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 for all but the station farthest upcoast indicated that the communities were healthy. Infaunal parameters appeared to be only somewhat related to sediment characteristics, as most values were slightly lower where sediments were coarser, near the generating station and farthest downcoast. However, values were only moderately high where sediments were finest, farthest upcoast. No adverse pattern related to the generating station discharge was apparent.

## 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 inter-annual 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 at Stations T1 through T4 on 30 March and 11 September 2007 between 0800 and 1225 hours. During March sampling, skies were clear with winds from the northwest at 2 to 7 kn. Seas were west at 2 to 4 ft. During September sampling, skies were clear with winds from the west increasing to 15 kn. Seas were west at 2 to 4 ft. At Station T4, approximately 4 kg of fish skeletal remains were collected during each replicate in September.

Trawl paths for the four stations were parallel to the shoreline along the 20-ft isobath (Figure 19). 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.

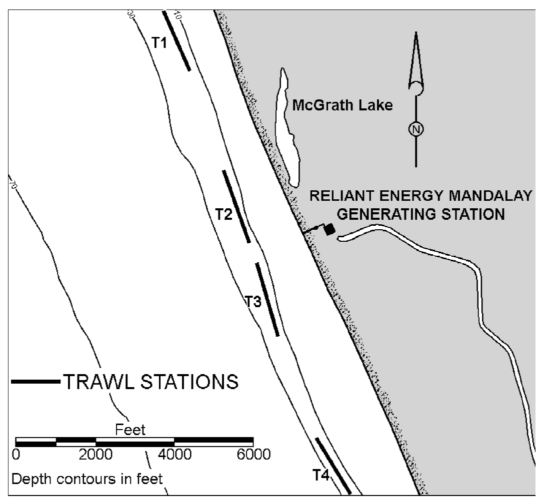



**Figure 19. Location of the trawl sampling stations. Mandalay Generating Station NPDES, 2007.**

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. Each catch was immediately separated from debris and sorted to the lowest possible taxonomic category. Fishes were identified and up to 200 individuals 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 was recorded on preprinted data sheets and later entered into Microsoft Excel 2000 spreadsheets. In-house quality assurance/quality control (QA/QC) protocols were followed to ensure accurate transcription into digital format. Checked data was archived in the MBC trawl database in Microsoft Access 2000. Parametric and non-parametric analytical statistics were performed using Number Cruncher Statistical Software 2000 (Hintze 1998). Descriptive (summary) statistics were performed using Microsoft Excel 2000. Summary statistics included abundance, biomass, number of species, Shannon-Wiener species diversity index (H'; Shannon and Weaver 1962), and evenness index (J': Pielou 1977).

Species and station relationships for fish were graphically derived through hierarchical clustering analysis and two-way coincidence tables for both winter and summer. A minimum of 10 individuals per species in each season 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.

Length frequency histograms were created to examine potential age structure of the sampled assemblage. The five most abundant species overall were included in the length frequency analysis. Species-specific lengths were rounded to the nearest 10-mm bin by season, i.e. 35-44 mm SL = 40 mm SL bin.

## RESULTS

### Fish

A total of 4,852 individuals representing 31 fish species weighing 101.6 kg was collected during the 2007 monitoring year (Tables 10 and 11). Overall diversity (H') was 1.69, while evenness (J') was 0.49, indicating a high number of species collected with a relatively few species numerically dominating the overall catch (Table 10). Summer abundance (with 4,152 individuals collected) was nearly six times greater than the winter abundance total of 700 individuals (Table 10, Figure 20). Highest abundance in winter was recorded at Station T3, with 349 individuals, or 50% of the survey total, while in summer highest abundances occurred at Stations T1 (1,882 individuals) and T3 (1,182 individuals), which together accounted for 74% of the summer abundance. No fish were reported with disease or abnormalities in 2007 (Appendix G4 and G5). The parasitic fish louse (*Elthusa vulgaris*) was noted in all replicates in winter, although none were reported associated with any individual fish (Appendix G4, G5 and G6). In summer no parasites were observed.

Speckled sanddab (*Citharichthys stigmaeus*) numerically dominated the annual total with 31% of the total abundance, or 1,481 individuals (Table 10). Shiner perch (*Cymatogaster aggregata*) was the next most abundant species with more than 26% of the annual total, or 1,277 individuals followed closely by white croaker (*Genyonemus lineatus)* contributing another 26% to total abundance with 1,255 individuals. Speckled sanddab was one of only two species in 2007 to be collected at all stations during both seasons, while only two shiner perch were taken in winter, and all of the white croaker were collected at a single station in summer. Two additional species, prickelbreast poacher (*Stellerina xyosterna*) and northern anchovy (*Engaulis mordax*), each contributed an additional 5% or more to the total abundance in 2007, with 329 and 251 individuals, respectively. The remaining 26 species together accounted for the remaining 5% of total abundance with a cumulative total of 259 individuals. Two species, rockpool blenny (*Hypsoblennius gilberti*) and Pacific chub mackerel (*Scomber japonicus*), were reported for the first time in trawl sampling since 1978, with both species represented by one individual (Appendix G-8).

**Table 10. Abundance and catch parameters for fish species taken by otter trawl. Mandalay Generating Station NPDES, 2007.**

| | Winter | | | | | Summer | | | | | Annual | Percent |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | T1 | T2 | T3 | T4 | Total | T1 | T2 | T3 | T4 | Total | Total | Total |
| speckled sanddab | 41 | 158 | 301 | 19 | 519 | 267 | 280 | 282 | 133 | 962 | 1,481 | 30.5 |
| shiner perch | - | - | 2 | - | 2 | 234 | 87 | 634 | 320 | 1,275 | 1,277 | 26.3 |
| white croaker | - | - | - | - | - | 1,255 | - | - | - | 1,255 | 1,255 | 25.9 |
| pricklebreast poacher | - | - | 1 | - | 1 | 67 | 87 | 169 | 5 | 328 | 329 | 6.8 |
| northern anchovy | - | 1 | 19 | 93 | 113 | 19 | 35 | 38 | 46 | 138 | 251 | 5.2 |
| kelp pipefish | 7 | 4 | 10 | 5 | 26 | 11 | 9 | 24 | - | 44 | 70 | 1.4 |
| barcheek pipefish | - | - | - | - | - | 10 | 7 | 8 | 11 | 36 | 36 | 0.7 |
| barred surfperch | 3 | 2 | 1 | 4 | 10 | 1 | 9 | 3 | 6 | 19 | 29 | 0.6 |
| jacksmelt | - | - | - | - | - | - | - | - | 21 | 21 | 21 | 0.4 |
| Pacific staghorn sculpin | - | - | - | - | - | 4 | 4 | 11 | - | 19 | 19 | 0.4 |
| thornback | 2 | 1 | 3 | 3 | 9 | 4 | 3 | 2 | - | 9 | 18 | 0.4 |
| bat ray | - | - | - | - | - | - | - | 3 | 11 | 14 | 14 | 0.3 |
| California lizardfish | 1 | 5 | 4 | - | 10 | - | - | - | - | - | 10 | 0.2 |
| Pacific sardine | - | - | - | - | - | 6 | - | 2 | - | 8 | 8 | 0.2 |
| California halibut | - | - | - | - | - | - | 1 | 3 | 1 | 5 | 5 | 0.1 |
| Pacific angel shark | - | - | 2 | - | 2 | - | 2 | 1 | - | 3 | 5 | 0.1 |
| queenfish | - | - | - | - | - | 1 | 1 | - | 1 | 3 | 3 | 0.1 |
| shovelnose guitarfish | - | - | - | 1 | 1 | 1 | - | - | 1 | 2 | 3 | 0.1 |
| spiny dogfish | - | - | 3 | - | 3 | - | - | - | - | - | 3 | 0.1 |
| giant kelpfish | - | - | - | - | - | - | 1 | 1 | - | 2 | 2 | 0.0 |
| Pacific pompano | - | - | - | - | - | 1 | - | - | 1 | 2 | 2 | 0.0 |
| white seabass | - | - | 2 | - | 2 | - | - | - | - | - | 2 | 0.0 |
| California corbina | - | - | - | 1 | 1 | - | - | - | - | - | 1 | 0.0 |
| California skate | - | - | - | - | - | - | - | - | 1 | 1 | 1 | 0.0 |
| diamond turbot | - | - | - | - | - | - | - | 1 | - | 1 | 1 | 0.0 |
| English sole | - | - | 1 | - | 1 | - | - | - | - | - | 1 | 0.0 |
| fantail sole | - | - | - | - | - | 1 | - | - | - | 1 | 1 | 0.0 |
| kelp perch | - | - | - | - | - | - | 1 | - | - | 1 | 1 | 0.0 |
| Pacific chub mackerel | - | - | - | - | - | - | - | - | 1 | 1 | 1 | 0.0 |
| rockpool blenny | - | - | - | - | - | - | 1 | - | - | 1 | 1 | 0.0 |
| tubesnout | - | - | - | - | - | - | 1 | - | - | 1 | 1 | 0.0 |
| Total Abundance | 54 | 171 | 349 | 126 | 700 | 1,882 | 529 | 1,182 | 559 | 4,152 | 4,852 | |
| Number of Species | 5 | 6 | 12 | 7 | 14 | 15 | 16 | 15 | 14 | 26 | 31 | |
| Diversity (H') | 0.83 | 0.38 | 0.66 | 0.91 | 0.93 | 1.09 | 1.46 | 1.31 | 1.30 | 1.63 | 1.69 | |
| Evenness (J') | 0.52 | 0.21 | 0.27 | 0.47 | 0.35 | 0.40 | 0.53 | 0.48 | 0.49 | 0.50 | 0.49 | |

In 2007, biomass was dominated by Pacific angel shark (*Squatina californica)* with 43.0 kg, or more than 42% of the total biomass, despite the collection of only five individuals (Tables 10 and 11). Bat ray (*Myliobatis californica*), another large species, contributed another 20% to the total biomass, with 20.4 kg for the 14 individuals caught. Speckled sanddab, the most abundant species in 2007, was third with 9.8 kg or 10% of the total biomass, followed by white croaker with 8.1 kg (8%), shiner perch with 7.0 kg (7%) and thornback (*Platyrhinoidis triseriata*) with 5.8 kg (6%). The remaining 25 fish species each accounted for less than 5% of the total biomass, with a combined weight of 7.6 kg.

Winter sampling collected 700 individuals of 14 species, with an overall seasonal diversity of 0.93 and evenness of 0.35 (Table 10). Speckled sanddab was the most abundant species recorded with 519 individuals, or nearly 74% of the total. Northern anchovy was the second most abundant species in winter with 113 individuals, or 16% of the total abundance. Kelp pipefish (*Syngnathus californiensis*) contributed another 4% with 26 individuals, while barred surfperch (*Amphistichus argenteus*) and California lizardfish (*Synodus lucioceps*) with ten individuals each, both contributed another 1% to the total abundance. The remaining nine species cumulatively contributed another 22 individuals to the total abundance. Species richness was highest at Station T3, the downcoast station nearest the discharge, with twelve species taken. This was more than double the number of species found at either upcoast station, and about 70% higher than found at Station T4, farthest downcoast.

**Table 11. Biomass (kg) of fish species taken by otter trawl. Mandalay Generating Station NPDES, 2007.**

| | Winter | | | | | Summer | | | | | Annual | Percent |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | T1 | T2 | T3 | T4 | Total | T1 | T2 | T3 | T4 | Total | Total | Total |
| Pacific angel shark | - | - | 22.50 | - | 22.50 | - | 12.50 | 8.00 | - | 20.50 | 43.00 | 42.3 |
| bat ray | - | - | - | - | - | - | - | 0.77 | 19.60 | 20.37 | 20.37 | 20.0 |
| speckled sanddab | 0.19 | 0.56 | 1.21 | 0.15 | 2.10 | 2.04 | 2.40 | 2.13 | 1.15 | 7.72 | 9.82 | 9.7 |
| white croaker | - | - | - | - | - | 8.06 | - | - | - | 8.06 | 8.06 | 7.9 |
| shiner perch | - | - | 0.02 | - | 0.02 | 0.62 | 0.27 | 2.56 | 3.52 | 6.96 | 6.98 | 6.9 |
| thornback | 0.74 | 0.08 | 0.67 | 0.91 | 2.40 | 1.50 | 1.04 | 0.86 | - | 3.40 | 5.80 | 5.7 |
| California halibut | - | - | - | - | - | - | 0.21 | 0.83 | 0.26 | 1.30 | 1.30 | 1.3 |
| jacksmelt | - | - | - | - | - | - | - | - | 1.21 | 1.21 | 1.21 | 1.2 |
| spiny dogfish | - | - | 0.82 | - | 0.82 | - | - | - | - | - | 0.82 | 0.8 |
| northern anchovy | - | 0.00 | 0.06 | 0.30 | 0.37 | 0.21 | 0.04 | 0.09 | 0.08 | 0.43 | 0.79 | 0.8 |
| barred surfperch | 0.07 | 0.06 | 0.05 | 0.13 | 0.31 | 0.02 | 0.19 | 0.12 | 0.09 | 0.42 | 0.74 | 0.7 |
| pricklebreast poacher | - | - | 0.01 | - | 0.01 | 0.12 | 0.17 | 0.36 | 0.02 | 0.67 | 0.68 | 0.7 |
| Pacific staghorn sculpin | - | - | - | - | - | 0.18 | 0.07 | 0.32 | - | 0.57 | 0.57 | 0.6 |
| diamond turbot | - | - | - | - | - | - | - | 0.27 | - | 0.27 | 0.27 | 0.3 |
| Pacific sardine | - | - | - | - | - | 0.18 | - | 0.06 | - | 0.24 | 0.24 | 0.2 |
| shovelnose guitarfish | - | - | - | 0.13 | 0.13 | 0.04 | - | - | 0.06 | 0.10 | 0.23 | 0.2 |
| California corbina | - | - | - | 0.17 | 0.17 | - | - | - | - | - | 0.17 | 0.2 |
| Pacific chub mackerel | - | - | - | - | - | - | - | - | 0.14 | 0.14 | 0.14 | 0.1 |
| kelp pipefish | 0.01 | 0.00 | 0.02 | 0.01 | 0.03 | 0.01 | 0.01 | 0.04 | - | 0.06 | 0.09 | 0.1 |
| California skate | - | - | - | - | - | - | - | - | 0.09 | 0.09 | 0.09 | 0.1 |
| barcheek pipefish | - | - | - | - | - | 0.02 | 0.01 | 0.01 | 0.02 | 0.06 | 0.06 | 0.1 |
| English sole | - | - | 0.06 | - | 0.06 | - | - | - | - | - | 0.06 | 0.1 |
| fantail sole | - | - | - | - | - | 0.05 | - | - | - | 0.05 | 0.05 | 0.0 |
| California lizardfish | 0.00 | 0.01 | 0.01 | - | 0.02 | - | - | - | - | - | 0.02 | 0.0 |
| queenfish | - | - | - | - | - | 0.02 | 0.00 | - | 0.00 | 0.02 | 0.02 | 0.0 |
| Pacific pompano | - | - | - | - | - | 0.01 | - | - | 0.01 | 0.01 | 0.01 | 0.0 |
| giant kelpfish | - | - | - | - | - | - | 0.01 | 0.00 | - | 0.01 | 0.01 | 0.0 |
| kelp perch | - | - | - | - | - | - | 0.01 | - | - | 0.01 | 0.01 | 0.0 |
| white seabass | - | - | 0.00 | - | 0.00 | - | - | - | - | - | 0.00 | 0.0 |
| rockpool blenny | - | - | - | - | - | - | 0.00 | - | - | 0.00 | 0.00 | 0.0 |
| tubesnout | - | - | - | - | - | - | 0.00 | - | - | 0.00 | 0.00 | 0.0 |
| Total Biomass (kg) | 1.01 | 0.72 | 25.43 | 1.79 | 28.94 | 13.07 | 16.93 | 16.42 | 26.25 | 72.67 | 101.61 | |

Note: 0.00 = < 0.005

Normal (station) and inverse (species) two-way coincidence table of the five species represented by ten or more individuals in winter segregated into two groups based on station and species abundance (Figure 21). Higher abundances of northern anchovy and barred surfperch and low abundance of speckled sanddab and California lizardfish segregated Station T4, farthest downcoast of the discharge channel, from the remaining stations to form Group II. The three remaining stations formed Group I, with abundances at Stations T1 and T2 upcoast of the discharge more similar than those at the near downcoast Station T3, where abundances of speckled sanddab, kelp pipefish and California lizardfish were higher. The five most abundant species separated into two groups based on their similarity of occurrence. Group B included only speckled sanddab, which were more common at Stations T2 and T3 than at the stations farthest upcoast and downcoast of the discharge. Group A included the remaining abundant species, though northern anchovy, most abundant at Station T4, was more dissimilar than the remaining species in the group, which were distributed relatively evenly among stations in winter.

Winter biomass was dominated by the two Pacific angel sharks caught at Station T3. Together, these sharks weighed 22.5 kg, accounting for 78% of the total winter biomass (Tables

10 and 11). Another relatively large species, thornback, contributed another 8% to the total biomass with nine individuals weighing 2.4 kg. Speckled sanddab, the most abundant species in winter accounted for another 7% of the biomass with 2.1 kg. The remaining twelve fish species each contributed less than 3% to winter biomass, cumulatively contributing about 1.9 kg to the season total. Peak biomass in winter was found at Station T3 with 88% of the seasonal biomass, while biomass at Station T2 accounted for only 2% of the survey total.

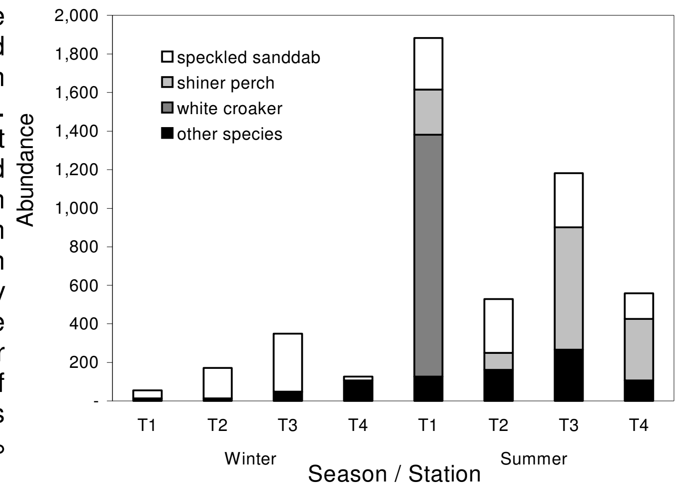



**Figure 20. Total biomass (kg) of otter trawl collected fish species by season and station. Mandalay Generating Station NPDES, 2007.**

The summer survey recorded 4,152 individuals of 26 species weighing 72.67 kg (Tables 10 and 11). Shiner perch was the most abundant species in summer with 1,275 individuals or 31% of the seasonal total abundance. White croaker were similarly abundant with 1,255 individuals or 30% of the abundance, all collected at Station T1. Speckled sanddab was the third most abundant species in summer with 962 individuals, or 23% of the total abundance, relatively evenly distributed over all stations. Pricklebreast poacher contributed another 8% with 328 individuals, while northern anchovy accounted for 3% of the summer catch with 138 individuals and kelp pipefish 1% of the total with 44 individuals. The remaining 20 species each contributed less than 1% of the total abundance with a cumulative total of 152 individuals. Species richness ranged narrowly in summer, from 14 at Station T4 to 16 at Station T2.

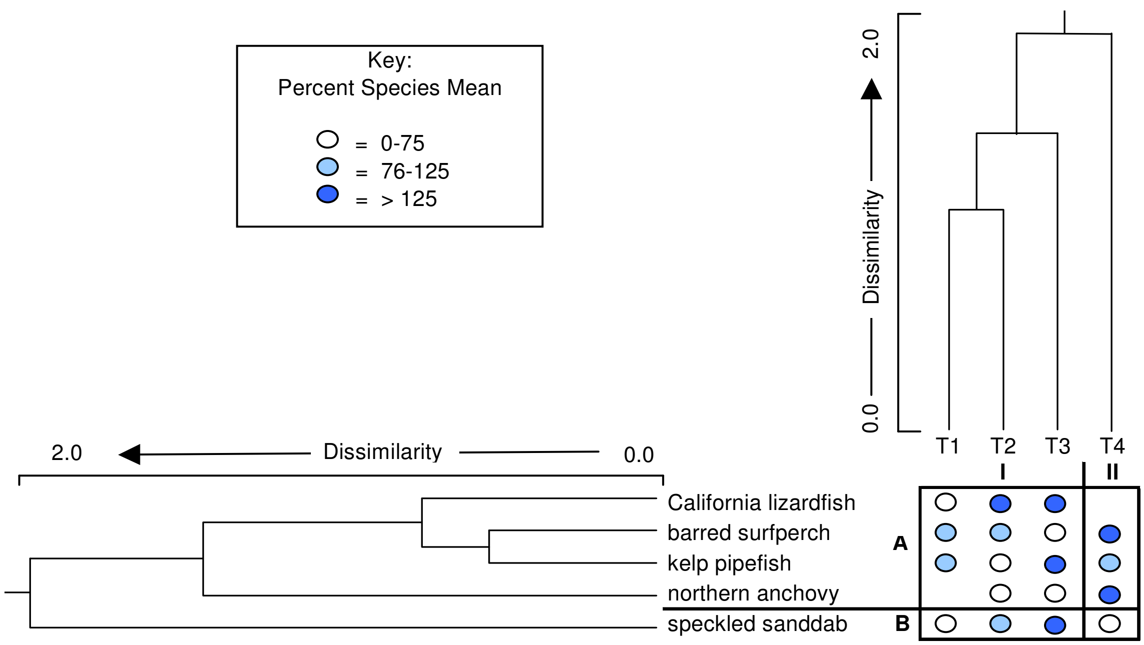



**Figure 21. Two-way coincidence table resulting from normal (station) and inverse (species) classification dendrograms for fish taken by otter trawl, winter survey. Mandalay Generating Station NPDES, 2007.**

A normal (station) and inverse (species) two-way coincidence table was based on the station occurrence and abundance of the eleven fish species represented by ten or more individuals in summer. Downcoast Station T4 separated from the remaining stations into Group II, based largely on the higher abundances of bat ray and jacksmelt (*Atherinopsis calforniensis*), as well as lower abundances of otherwise common fish such as shiner perch, speckled sanddab and pricklebreast poacher (Figure 22). The three remaining stations formed Group I. Abundances at Stations T2 and T3, the nearest stations upcoast and downcoast of the discharge, respectively, were most similar. More distantly, Station T1, farthest upcoast where white croaker was exclusively caught in 2007, grouped with Stations T2 and T3 in Group I. The most abundant species separated into three groups, based on their similarity of occurrence. Group B included only white croaker, the most abundant species during the summer survey, which, though taken in very high abundance, occurred at only one station. Species Group C included the next four most abundantly occurring fish species, all of which, though generally well distributed among stations, were taken in highest numbers at Station T3. Group A was composed of the remaining six species, which were found in relatively low abundances in summer.

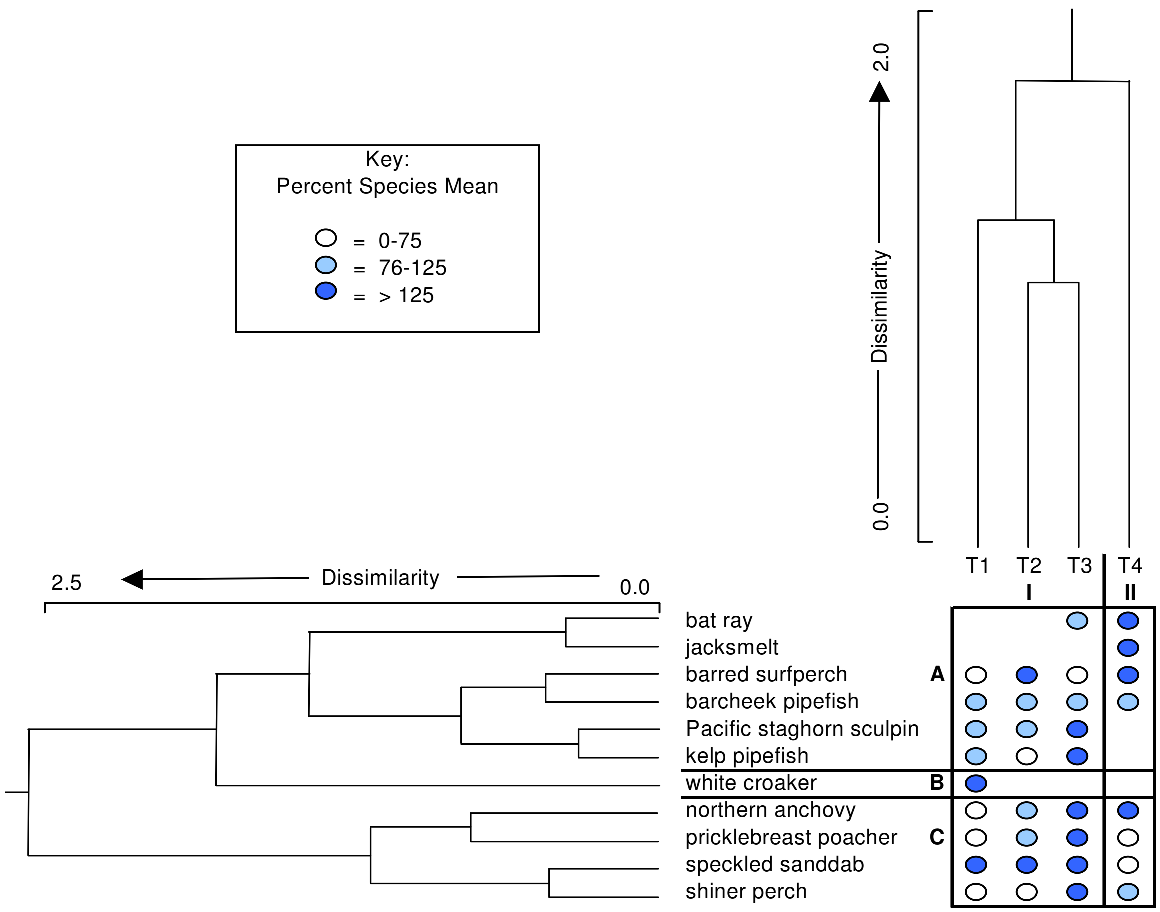



**Figure 22. Two-way coincidence table resulting from normal (station) and inverse (species) classification dendrograms for fish taken by otter trawl, summer survey. Mandalay Generating Station NPDES, 2007.**

In summer, relatively few individuals of large species again dominated biomass. Pacific angel sharks again contributed most to biomass in summer, accounting for 28% of the total with 20.5 kg, followed closely by bat ray at 20.4 kg for another 28% of the summer total. White croaker and speckled sanddab each accounted for about 11% of the biomass with 8.1 and 7.7 kg, respectively, while shiner perch contributed another 10% (7.0 kg) and thornback about 5%

(3.4 kg) to the total summer biomass. The remaining 20 fish species each contributed less than 2% to summer biomass, cumulatively contributing about 5.7 kg to the season total. Peak biomass in summer was found at Station T4 with 36% of the seasonal biomass. Biomass at Station T1 accounted for another 18%, while Stations T2 and T3 each accounted for about 23% of the survey total.

### Fish Length

Fish lengths in 2007 ranged from an 11-mm SL speckled sanddab to a 1,130-mm TL Pacific angel shark (Table 12). In 2007, five species, speckled sanddab, shiner perch, white croaker, pricklebreast poacher, and northern anchovy, occurred in sufficient abundance for length frequency analysis.

**Table 12. Measured length (mm) of fish species taken by otter trawl. Mandalay Generating Station NPDES, 2007.**

| | Winter | | | | | Summer | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Species | Number | Min | Max | Mean | SD | Number | Min | Max | Mean | SD |
| barcheek pipefish | - | - | - | - | - | 36 | 120 | 252 | 185.1 | 24.3 |
| barred surfperch | 10 | 88 | 116 | 97.4 | 9 | 19 | 76 | 136 | 92.474 | 14.4 |
| bat ray** | - | - | - | - | - | 14 | 382 | 735 | 623.6 | 116.7 |
| California corbina | 1 | 228 | 228 | 228.0 | - | - | - | - | - | - |
| California halibut | - | - | - | - | - | 5 | 207 | 310 | 246.4 | 38.2 |
| California lizardfish | 10 | 61 | 76 | 71.2 | 5.3 | - | - | - | - | - |
| California skate** | - | - | - | - | - | 1 | 240 | 240 | 240.0 | - |
| diamond turbot | - | - | - | - | - | 1 | 210 | 210 | 210.0 | - |
| English sole | 1 | 167 | 167 | 167.0 | - | - | - | - | - | - |
| fantail sole | - | - | - | - | - | 1 | 137 | 137 | 137.0 | - |
| giant kelpfish | - | - | - | - | - | 2 | 80 | 88 | 84.0 | 5.7 |
| jacksmelt | - | - | - | - | - | 21 | 152 | 195 | 168.5 | 13.0 |
| kelp perch | - | - | - | - | - | 1 | 70 | 70 | 70.0 | - |
| kelp pipefish | 26 | 123 | 220 | 173.5 | 29.9 | 44 | 133 | 239 | 180.2 | 21.0 |
| northern anchovy | 113 | 55 | 102 | 68.5 | 5.3 | 138 | 48 | 125 | 64.3 | 19.2 |
| Pacific angel shark* | 2 | 1080 | 1130 | 1105.0 | 35.4 | 3 | 732 | 1015 | 919.0 | 162.0 |
| Pacific chub mackerel | - | - | - | - | - | 1 | 237 | 237 | 237.0 | - |
| Pacific pompano | - | - | - | - | - | 2 | 66 | 75 | 70.5 | 6.4 |
| Pacific sardine | - | - | - | - | - | 8 | 132 | 157 | 139.3 | 8.0 |
| Pacific staghorn sculpin | - | - | - | - | - | 19 | 86 | 152 | 112.4 | 19.5 |
| pricklebreast poacher | 1 | 106 | 106 | 106.0 | - | 328 | 42 | 92 | 62.6 | 8.5 |
| queenfish | - | - | - | - | - | 3 | 40 | 113 | 73.0 | 37.0 |
| rockpool blenny | - | - | - | - | - | 1 | 51 | 51 | 51.0 | - |
| shiner perch | 2 | 66 | 73 | 69.5 | 4.9 | 972 | 32 | 106 | 55.8 | 16.3 |
| shovelnose guitarfish* | 1 | 314 | 314 | 314.0 | - | 2 | 230 | 245 | 237.5 | 10.6 |
| speckled sanddab | 519 | 27 | 120 | 54.2 | 20.2 | 962 | 11 | 120 | 72.0 | 16.9 |
| spiny dogfish* | 3 | 382 | 466 | 427.0 | 42.3 | - | - | - | - | - |
| thornback* | 9 | 225 | 422 | 339.8 | 70.5 | 9 | 265 | 464 | 386.1 | 60.9 |
| tubesnout | - | - | - | - | - | 1 | 105 | 105 | 105.0 | - |
| white croaker | - | - | - | - | - | 400 | 50 | 96 | 67.0 | 6.7 |
| white seabass | 2 | 33 | 34 | 33.5 | 0.7 | - | - | - | - | - |

* = Total Length, ** = Disc Width

Speckled sanddab averaged 54 mm SL during winter sampling and 72 mm SL during summer sampling (Table 12). Five hundred and nineteen individuals were collected in winter and 962 in summer, with all individuals measured (Figure 23). Both seasons showed a unimodal distribution, with peak abundance in winter in the 40-mm SL size class, and peak abundance in summer at 60 mm SL. In winter, most individuals were found within the 40 and 50 mm size classes, while in summer, most individuals were found in the range of 60 to 90 mm. Distribution during both seasons was skewed toward larger sizes, though abundance in these classes generally diminished as size increased.

During winter sampling, two shiner perch were collected, with both in the 70-mm size class (Table 12 and Figure 24). In summer, 972 of the 1,277 individuals taken were measured, with a mean length of 56 mm SL. The length frequency distribution in summer was weakly bimodal, with the primary mode centered at 50 mm SL, and a secondary peak at 90 mm SL.

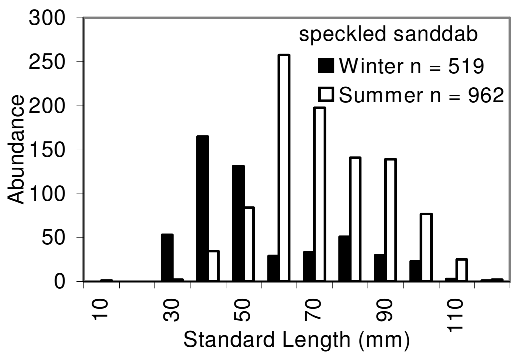



**Figure 23. Length frequency analysis for speckled sanddab (*Citharichthys stigmaeus*) collected by otter trawl during winter and summer sampling. Mandalay Generating Station NPDES, 2007.**

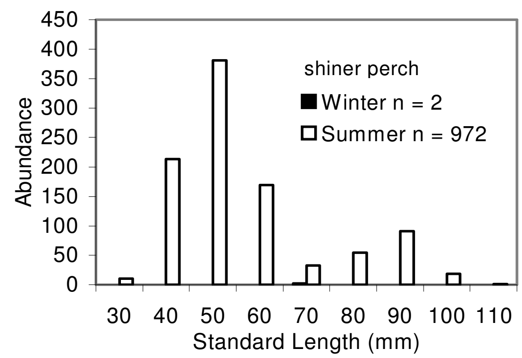



**Figure 24. Length frequency analysis for shiner perch (*Cymatogaster aggregata*) collected by otter trawl during winter and summer sampling. Mandalay Generating Station NPDES, 2007.**

White croaker were not collected in winter and occurred at only Station T1 in summer. A total of 1,255 individuals were caught in 2007, and of those 400 were measured, with a mean length of 67 mm SL (Table 12). Length frequency analysis for white croaker was unimodal with the distribution centered at 70 mm SL, with high abundance also noted in the 60-mm size class (Figure 25).

During winter sampling, one pricklebreast poacher was collected with a length of 106 mm (Table 12 and Figure 26). In summer, 328 individuals were measured, with a mean length of 63 mm SL. Length frequency analysis for pricklebreast poacher was unimodal with the distribution centered at 60 mm SL, with high abundance also noted in the 70-mm size class.

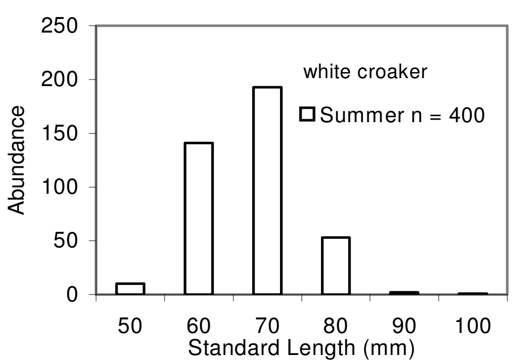



**Figure 25. Length frequency analysis for white croaker (*Genyonemus lineatus*) collected by otter trawl during summer sampling. Mandalay Generating Station NPDES, 2007.**

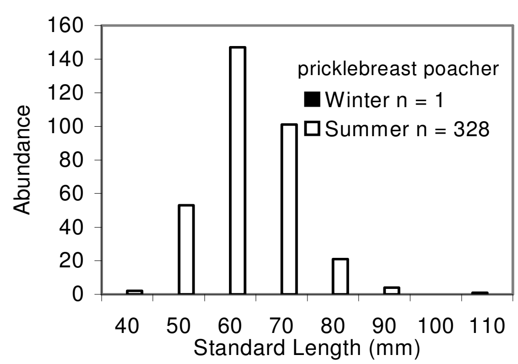



**Figure 26. Length frequency analysis for pricklebreast poacher (*Stellerina xyosterna*) collected by otter trawl during winter and summer sampling. Mandalay Generating Station NPDES, 2007.**

During winter sampling, one pricklebreast poacher was collected with a length of 106 mm (Table 12 and Figure 26). In summer, 328 individuals were measured, with a mean length of 63 mm SL. Length frequency analysis for pricklebreast poacher was unimodal with the distribution centered at 60 mm SL, with high abundance also noted in the 70-mm size class.

Northern anchovy averaged 69 mm SL during winter sampling and 64 mm SL during summer sampling (Table 12). One hundred and thirteen individuals were collected in winter and 138 in summer, with all individuals measured (Figure 27). Winter abundance was strongly unimodal, with a peak in the 70-mm SL size class. In summer, distribution was weakly bimodal, with a primary peak at 50 to 60 mm SL, and a weak secondary peak in abundance at 100 to 110 mm SL.

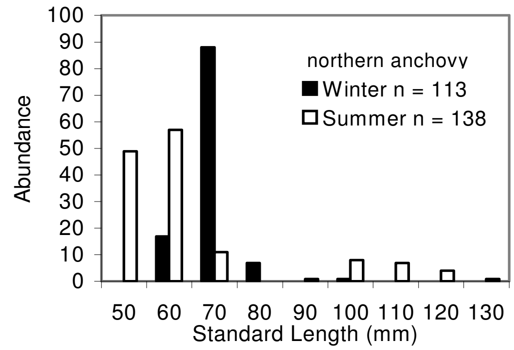



**Figure 27. Length frequency analysis for northern anchovy (*Engraulis mordax*) collected by otter trawl during winter and summer sampling. Mandalay Generating Station NPDES, 2007.**

## Macroinvertebrates

A total of 5,924 individuals of 17 macroinvertebrate species weighing 15.3 kg were collected during the 2007 monitoring year (Table 13). Overall species diversity was 0.32 and evenness was 0.11, both indices reflecting low species richness with overall abundance numerically dominated by one species.

**Table 13. Abundance and catch parameters for macroinvertebrates species taken by otter trawl. Mandalay Generating Station NPDES, 2007.**

| | Winter | | | | | Summer | | | | | Annual | Percent |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | T1 | T2 | T3 | T4 | Total | T1 | T2 | T3 | T4 | Total | Total | Total |
| blackspotted bay shrimp | 64 | 161 | 587 | 29 | 841 | 1,058 | 1,200 | 2,354 | 93 | 4,705 | 5,546 | 93.6 |
| graceful crab | - | 11 | 10 | 5 | 26 | 9 | 15 | 78 | 36 | 138 | 164 | 2.8 |
| Pacific sand dollar | - | 2 | - | 156 | 158 | - | - | - | - | - | 158 | 2.7 |
| Stimpson coastal shrimp | - | - | 1 | - | 1 | - | - | 11 | 3 | 14 | 15 | 0.3 |
| tuberculate pear crab | - | 4 | 7 | - | 11 | 1 | 1 | 1 | - | 3 | 14 | 0.2 |
| sheep crab | - | - | - | 1 | 1 | - | 3 | 1 | 1 | 5 | 6 | 0.1 |
| California spiny lobster | - | 2 | 1 | 2 | 5 | - | - | - | - | - | 5 | 0.1 |
| yellow crab | - | - | - | - | - | 1 | 1 | 1 | 1 | 4 | 4 | 0.1 |
| yellowleg shrimp | - | 1 | 1 | 1 | 3 | - | - | - | - | - | 3 | 0.1 |
| hairy rock crab | - | - | - | - | - | - | - | 2 | - | 2 | 2 | 0.0 |
| East Pacific red octopus | 1 | - | - | - | 1 | - | - | - | - | - | 1 | 0.0 |
| fat western nassa | - | - | - | - | - | - | 1 | - | - | 1 | 1 | 0.0 |
| intertidal coastal shrimp | - | - | - | - | - | - | - | 1 | - | 1 | 1 | 0.0 |
| mottled pea crab | - | - | - | - | - | - | - | 1 | - | 1 | 1 | 0.0 |
| red jellyfish | - | - | 1 | - | 1 | - | - | - | - | - | 1 | 0.0 |
| sweet potatoe sea cucumber | - | 1 | - | - | 1 | - | - | - | - | - | 1 | 0.0 |
| Xantus swimming crab | - | 1 | - | - | 1 | - | - | - | - | - | 1 | 0.0 |
| Total Abundance | 65 | 183 | 608 | 194 | 1,050 | 1,069 | 1,221 | 2,450 | 134 | 4,874 | 5,924 | |
| Number of species | 2 | 8 | 7 | 6 | 12 | 4 | 6 | 9 | 5 | 10 | 17 | |
| Diversity (H') | 0.08 | 0.55 | 0.20 | 0.66 | 0.68 | 0.06 | 0.10 | 0.19 | 0.76 | 0.18 | 0.32 | |
| Evenness (J') | 0.11 | 0.26 | 0.10 | 0.37 | 0.28 | 0.05 | 0.06 | 0.09 | 0.48 | 0.08 | 0.11 | |
| Biomass (kg) | 0.17 | 1.23 | 1.67 | 2.70 | 5.77 | 1.69 | 2.63 | 4.65 | 0.57 | 9.54 | 15.30 | |
| Fish parasites (not included above): | | | | | | | | | | | | |
| fish louse | 12 | 13 | 15 | 3 | 43 | - | - | - | - | - | 43 | |

Blackspotted bay shrimp (*Crangon nigromaculata*) dominated the annual abundance with nearly 94% of the total or 5,546 individuals (Table 13). Graceful crab (*Cancer gracilis*) and Pacific sand dollar (*Dendraster excentricus*) were a distant second and third in abundance with 164 and 158 individuals taken, respectively, or about 3% of the total abundance each. The remaining 14 species collectively accounted for less than 1% of the total annual abundance. Two species, hairy rock crab (*Cancer jordani*) and East Pacific red octopus (*Octopus rubescens*) were reported for the first time in trawl sampling since 1978 (Appendix G-9).

Winter sampling recorded 1,050 individuals from 12 species weighing 5.8 kg (Table 13). Blackspotted bay shrimp accounted for over 80% of the total seasonal abundance with 841 individuals, followed by Pacific sand dollar with 158 individuals or 15% of the winter total. The remaining ten species together contributed less that 5% to total abundance.

Abundance at Station T3 in winter was more than three times the number taken at Stations T2 and T4, where abundances were similar (Table 13 and Figure 28). Blackspotted bay shrimp were most abundant at Station T3, where 70% of the seasonal total for the species was collected. Overall, trawl-caught abundances were lower upcoast of the generating station discharge than downcoast. Total seasonal species diversity and evenness indices were low at 0.68 and 0.28, respectively (Table 13). Both indices were lowest at Station T1, where blackspotted bay shrimp represented nearly 98% of the entire macroinvertebrate catch. Peak diversity (0.66) and evenness values (0.37) were calculated for the macroinvertebrate community at Station T4 where Pacific sand dollar dominated, but both blackspotted bay shrimp and graceful crab occurred in moderate numbers (Table 13 and Figure 28). Macroinvertebrate biomass peaked at Station T4 (2.7 kg), while lowest biomass was recorded at Station T1 (0.2 kg).

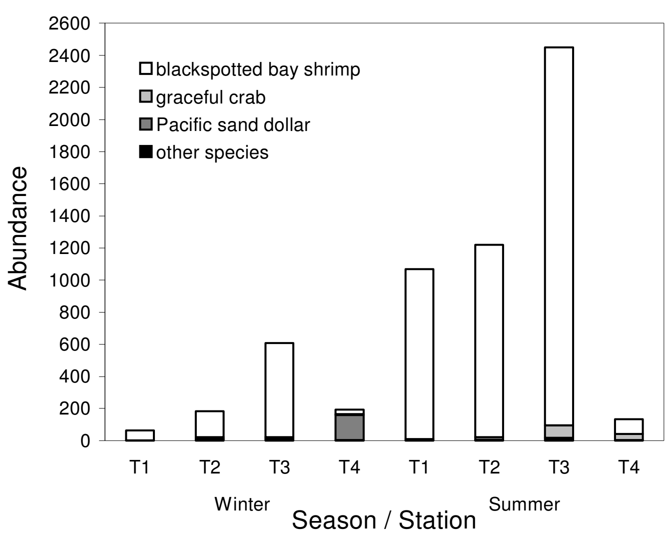



**Figure 28. Abundance of macroinvertebrates collected by otter trawl by season and station. Mandalay Generating Station NPDES, 2007.**

Summer survey abundance was nearly five times that reported in the winter survey with 4,874 individuals collected (Table 13). Species richness, however was slightly lower than in winter with ten species collected, while biomass at 9.5 kg in summer was nearly twice the winter value. Overall species diversity during summer sampling was 0.18 while evenness was 0.08, indicating a strong dominance by the most abundant species blackspotted bay shrimp.

Blackspotted bay shrimp was again the most abundant macroinvertebrate species in summer, which with 4,705 individuals accounted for 96% of the summer catch and was more than five times the abundance collected in winter (Table 13). Graceful crab with 138 individuals was the second most abundant species in summer, contributing another 3% to the total summer abundance. The remaining ten species collectively represented a total abundance of 31 individuals, or less than 1% of the total catch.

In the summer, abundances at Station T3 were again highest, with the 2,354 blackspotted bay shrimp nearly twice the number collected at any other station (Table 13 and Figure 28). Lowest summer macroinvertebrate abundance was reported at Station T4, farthest downcoast of the discharge. Assemblages and abundances among stations were most similar at Stations T1 and T2, both upcoast of the discharge. Abundance was lowest at Station T4, with 134 individual collected, or about 3% of the summer total.

Species diversity in summer increased with distance downcoast from Station T1, ranging from 0.06 at Station T1 to a yearly peak of 0.76 at Station T4 (Table 13). Species evenness followed a similar pattern. This trend approximated graceful crab abundance across the sampling array, despite the relatively small contribution of the species to abundance (Figure 28). Macroinvertebrate biomass was highest during summer sampling at Station T3 with 4.6 kg, followed by the assemblages at Station T2 (2.6 kg) and Station T1 (1.7 kg) (Table 13). Lowest biomass was recorded at Station T4 with 0.6 kg.

Several fish lice were collected free from host species during the winter surveys; none were collected in summer (Table 13). Forty-three individuals were collected during the winter surveys, with most occurring at Station T3.

## DISCUSSION

In 2007, 4,852 individual fish from 31 species weighing 101.6 kg were collected during trawl surveys of the demersal community in the receiving waters offshore of the Mandalay Generating Station discharge channel. Seasonal variation of observed fish species was observed throughout the area, with differences more likely a result of natural fish distribution and activity patterns than anthropogenic impacts. The consistency of species taken in winter and summer suggest a continued habitat preferences for the species caught, while differences in densities between the seasons is attributable to natural movement patterns associated with any of a number of natural influences, such as reproduction or seasonal migration patterns.

Abundances in 2007 were lower than numbers reported in 2006 and less than the long-term mean since 1990 (excluding 1997 and 2003, when winter surveys were not conducted) of 7,064 individuals per year, or 442 individuals per trawl (Table 14, Figure 29). Abundance in 2007 continued a trend in decline in fish numbers since 2005, though 2007 abundances were well within the range of previous inter-annual variation. During both seasonal surveys in 2007, abundance was dominated by speckled sanddab for only the second time since 1978, and abundance of the species increased to an all-time high (Table 14, MBC 1979, 1981,1986, 1988, 1990,1994, 1997-2001a, 2002-2006a, Ogden 1991-1993). Shiner perch was the second most abundant fish species in 2007, with the highest abundance reported since 1978, more than doubling the previous high recorded in 2002. White croaker, third in abundance in 2007, commonly are the most abundant species taken in surveys in the area, but were not as widely distributed in 2007 as in past surveys (Table 14 and Figure 29). A new record abundance was also noted for pricklebreast poacher, the fourth most abundant species in 2007, with more than thirteen times the abundance reported in 2006, the previous high (Appendix G-8). Northern anchovy, fifth in abundance in 2007, have shown considerably variability in the area since 1978, with abundance similar to those found in 2005 and 2006, but still at less than one-half the long-term mean for the species in previous surveys (Table 14). Another long-term dominant, queenfish (*Seriphus politus*), was notably reduced from long-term levels in 2007 as it was in 2006, but this species has been highly variable among years, and very low abundances and absences in surveys have been observed previously (Table 14 and Figure 29).

In 2007, speckled sanddab was the most abundant fish species collected with 1,481 individuals recorded (Table 10). Speckled sanddab was one of two fish species present at all four stations during both seasons. It is the fourth most abundant species in the area long-term and has been taken during every survey year (Table 14). In 2007, speckled sanddab abundances were the highest on record for the area, an increase over the previous record from 2006 by over 300 individuals. In regional demersal fish sampling conducted throughout the Southern California Bight, speckled sanddab abundances increased between 1998 and 2003, accounting for 1.8 and

11% of the total fish catch (Allen et al. 2002, Allen et al. 2007), suggesting that the species has recently increased in abundance in southern California.

**Table 14. The 20 most abundant fish species taken during trawl surveys, 1978 - 2007. Mandalay Generating Station NPDES, 2007.**

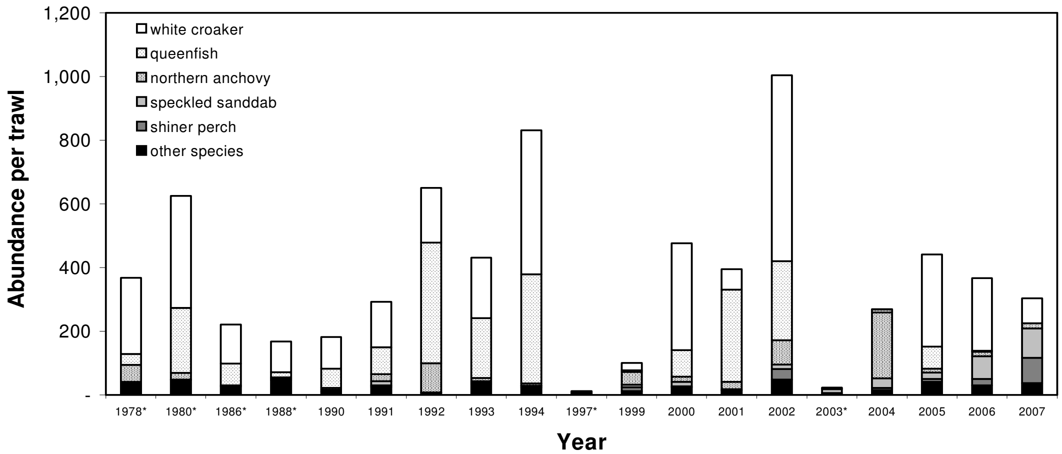
| | Year | | | | | | | | | | | | | | | | | | | Grand | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | 1978 | 1980 | 1986 | 1988 | 1990 | 1991 | 1992 | 1993 | 1994 | 1997 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | Total | Total |
| white croaker | 6,713 | 8,446 | 1,464 | 1,150 | 1,592 | 2,291 | 2,756 | 3,043 | 7,237 | 20 | 363 | 5,363 | 1,033 | 9,342 | - | 16 | 4,632 | 3,656 | 1,255 | 60,372 | 49.5 |
| queenfish | 966 | 4,889 | 830 | 195 | 957 | 1,341 | 6,049 | 3,009 | 5,483 | - | 76 | 1,352 | 4,630 | 3,971 | 8 | 138 | 1,106 | 34 | 3 | 35,037 | 28.7 |
| northern anchovy | 1,476 | 494 | 2 | 52 | 88 | 359 | 1,469 | 159 | 115 | - | 640 | 256 | 383 | 1,216 | 9 | 3,322 | 202 | 231 | 251 | 10,724 | 8.8 |
| speckled sanddab | 36 | 8 | 40 | 64 | 76 | 217 | 4 | 75 | 16 | 7 | 143 | 219 | 38 | 224 | 51 | 476 | 325 | 1,148 | 1,481 | 4,648 | 3.8 |
| shiner surfperch | 107 | 24 | - | 4 | 33 | 63 | 4 | 58 | 88 | 17 | 190 | 42 | 11 | 529 | 18 | 118 | 135 | 330 | 1,277 | 3,048 | 2.5 |
| kelp pipefish | - | - | - | - | - | - | - | - | - | - | 80 | 149 | 104 | 179 | 3 | 118 | 346 | 245 | 70 | 1,294 | 1.1 |
| barred surfperch | 210 | 172 | 46 | 223 | 38 | 95 | 29 | 115 | 41 | 18 | 1 | 33 | 9 | 42 | - | 45 | 67 | 4 | 29 | 1,217 | 1.0 |
| white seaperch | 245 | 321 | 2 | 17 | 18 | 26 | 5 | 5 | 80 | 12 | 25 | - | 1 | 225 | - | - | 23 | 39 | - | 1,044 | 0.9 |
| walleye surfperch | 335 | 340 | 8 | 18 | - | 50 | 5 | 26 | 28 | 1 | 1 | 16 | 37 | 28 | 1 | 9 | 53 | 67 | - | 1,023 | 0.8 |
| thornback | 27 | 21 | 12 | 16 | 6 | 56 | 4 | 167 | 2 | 3 | 13 | 14 | 6 | 52 | - | 2 | 24 | 15 | 18 | 458 | 0.4 |
| pricklebreast poacher | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 15 | - | 25 | 329 | 369 | 0.3 |
| California halibut | 25 | 54 | 66 | 58 | 21 | 27 | 1 | 8 | 11 | - | 2 | 5 | 1 | 4 | - | - | 1 | 6 | 5 | 295 | 0.2 |
| California corbina | 15 | 3 | 79 | - | - | 3 | 2 | 33 | 19 | - | 2 | 73 | 24 | 9 | - | 8 | 6 | 3 | 1 | 280 | 0.2 |
| California lizardfish | 17 | 5 | - | - | 8 | - | 1 | 2 | 4 | - | 1 | 1 | 26 | 115 | - | 1 | 9 | - | 10 | 200 | 0.2 |
| barcheek pipefish | 3 | - | - | 77 | 5 | - | - | - | 58 | - | - | - | - | - | - | - | - | - | 36 | 179 | 0.1 |
| yellowfin croaker | 2 | - | 11 | 1 | - | 1 | - | 79 | 50 | - | - | - | 3 | - | - | - | - | - | - | 147 | 0.1 |
| English sole | 22 | 8 | 5 | 49 | 7 | - | - | 1 | 4 | 1 | 7 | - | - | 15 | - | 1 | 13 | 10 | 1 | 144 | 0.1 |
| fantail sole | - | 10 | 17 | 10 | 1 | 3 | 1 | 1 | 5 | 1 | 39 | 27 | 1 | 16 | - | - | 1 | - | 1 | 134 | 0.1 |
| basketweave cusk-eel | 1 | 3 | 9 | - | 8 | 45 | - | 28 | 4 | - | 1 | 5 | - | - | - | - | 18 | - | - | 122 | 0.1 |
| shovelnose guitarfish | 6 | 11 | 6 | 22 | 13 | 18 | - | 19 | 2 | - | 1 | 2 | - | 2 | - | - | 1 | 4 | 3 | 110 | 0.1 |
| Survey totals | | | | | | | | | | | | | | | | | | | | | |
| Number of individuals | 10,299 | 14,986 | 2,648 | 2,009 | 2,896 | 4,674 | 10,399 | 6,892 | 13,296 | 89 | 1,597 | 7,616 | 6,324 | 16,056 | 91 | 4,304 | 7,062 | 5,866 | 4,852 | 121,956 | |
| Number of species | 41 | 35 | 29 | 24 | 23 | 30 | 21 | 28 | 33 | 10 | 25 | 22 | 24 | 27 | 7 | 23 | 33 | 25 | 31 | 69 | |
| 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 | | |
| 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 | | |
| Number of Trawls | 28 | 24 | 12 | 12 | 16 | 16 | 16 | 16 | 16 | 8 | 16 | 16 | 16 | 16 | 4 | 16 | 16 | 16 | 16 | | |

W = winter, S = summer

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 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. Unfortunately, no age at length data is available for speckled sanddab in the primary literature, although the progression of size and abundance noted between surveys suggests that both surveys were sampling the same population (Figure 23).

Shiner perch was the second most abundant species in 2007. Shiner perch was taken predominantly in the summer survey in 2007 in abundances nearly four times higher than in 2006 (Table 14). It has been periodically abundant in southern California, especially during colder water years such as 1999 and 2000, and ranges from San Quintin, Baja California, to Alaska, in depths from the surface to 480 ft (Miller and Lea 1972). Allen (1985) observed shiner perch distribution to encompass all soft substrates throughout its range, with a notably low abundance in the vicinity of kelp bed and rocky reef habitats. There is no targeted fishery for shiner perch due to their small size, although they do occur as incidental catches in many of the soft-bottom fisheries, such as the California halibut (*Paralichthys californicus*) trawl fishery. Shiner perch is fifth in long-term abundance overall in trawl surveys since 1978, with more than 40% of its long-term abundance taken in 2007 (Table 14). In regional monitoring, shiner perch were somewhat more abundant in 1998, accounting for 0.7% demersal fish catch, than in 2003 when they contributed 0.4% to the overall abundance (Allen et al. 2002, Allen et al. 2007). Previous age and growth information

(Odenweller 1975) reported shiner perch in the Age-I class to average 56.8 mm SL and Age-II class fish to average 87.8 mm SL. These data indicate most of the individuals caught in 2007 were one year old or less with a second smaller group at approximately two years old (Figure 24).




* Variable methods from standard survey program, 1990 to present. 1997 and 2003, no winter

**Figure 29. Long-term abundance of fishes collected by otter trawl by season and station. Mandalay Generating Station NPDES, 2007.**

White croaker was the third most abundant fish collected in 2007, despite being taken at only one station in summer (Table 10). It has been the most abundant fish species collected by trawl in 13 of 19 sampling years since 1978, including in 2006 (Table 14). Variations in abundance are common in schooling species such as white croaker, which are reported to undergo seasonal onshore/offshore movements associated with spawning (Love et al. 1984). Similar to 2007, nearly the entire catch occurred during summer surveys in 2006, while they were nearly absent in winter. In 2005, however, the majority of the annual white croaker catch occurred during the winter. White croaker are occasionally very abundant throughout the Southern California Bight, but as noted above their distribution can be highly variable. This is supported by the regional demersal fish surveys conducted throughout southern California with white croaker accounting for 28% of the total fish catch in 1998, while in 2003 abundance was only one-twentieth of 1998 levels, accounting for 1.4% of the total 2003 demersal fish abundance (Allen et al. 2002, Allen et al. 2007).

White croaker 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), and is an important sport fish commonly caught from piers and jetties throughout the Southern California Bight (Eschmeyer et al. 1983). Most of the commercial catch is sold as fresh fish, although a small amount is used for live bait. White croaker are common from British Columbia to Baja California in loose schools from the surf zone to depths of 600 ft, and in shallow bays, sloughs, and lagoons (Love et al. 1984, Moore and Wild 2001). 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.

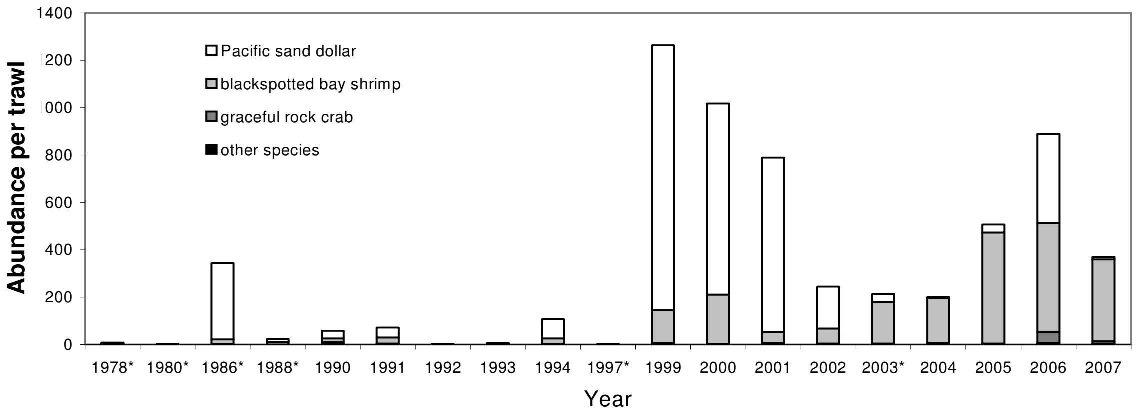
Although white croaker spawning can occur throughout the year, distinct seasonal peaks are generally found January through April (Goldberg 1976, Love et al. 1984). White croaker typically mature at approximately one year at a length of 120 to 130 mm SL (Love et al. 1984). Length frequency analysis of the fish collected in the summer survey indicated the community sampled was comprised of young of the year (YOY) (Figure 25).

Pricklebreast poacher was the fourth most abundant fish species taken in 2007, with all but one individual taken during the summer survey (Table 10). Pricklebreast poacher was one of several species noted to occur uniquely in the discharge area in Thermal Effects studies conducted in the early 1970s (IRC 1973). However, it was first taken offshore of the generating station in NPDES receiving water studies in 2004 and again in 2006 in moderate numbers. The high abundance in summer 2007 resulted in the pricklebreast poacher becoming the eleventh most abundant species in the area since 1978 despite occurring during only three monitoring years (Table 14). Pricklebreast poacher ranges from the northern Gulf of Alaska to northern Baja California, though generally considered a colder water species uncommon in southern California (Miller and Lea, 1972, Mecklenburg et al. 2002). The species is typically associated with nearshore mud and sand bottom at depths of 2 to 91 m, though more common at depths less than 75 m. Individuals of the species may live ten years and grow to 165 mm total length (TL), and though age/length information is not known, a specimen of 21 mm TL is considered juvenile (BIO 2006, Mecklenburg et al. 2002). In 2007, length frequency analysis for pricklebreast poacher centered at the 60 mm SL size class, with high abundances also noted in the 70-mm size class, suggesting a relatively young population in the area (Figure 26).

Northern anchovy was the fifth most abundant fish collected in 2007, and occurred in three stations in winter and at all four in summer (Table 10). It has been the most abundant fish species collected by trawl twice since 1978, although numbers in 2007 were moderate compared to most years. Northern anchovy is a schooling species that maintains tight schools during the day, feeding in the water column. It is common in the Southern California Bight and is one of the species most frequently captured in sampling conducted by otter trawls and other trawled gear, indicating that it is rather evenly distributed over the mainland shelf of southern California. It is usually among the most abundant and common species in summer surveys in the study area. In a region-wide demersal fish survey of the Southern California Bight conducted in 1998, northern anchovy was found to be a common constituent of the fish fauna of southern California accounting for 5% the fish abundance (Allen et al 2002), although it was not among the most abundant species in 2003 Bight-wide monitoring (Allen et al. 2007). Northern anchovy is also an important component of the nearshore ecosystem in southern California. Anchovy eggs and larvae are prey for vertebrate and invertebrate planktivores (Leet et al. 2001). Juveniles in nearshore areas support a variety of predators, including birds and other fish. Northern anchovy is also important commercially; it is used in conversion to meal, oil, and protein products, and as live bait (Leet et al. 2001).

Northern anchovy mature at one to two years at a length of 80 to 130 mm SL (Hunter and Macewitz 1980) and reach 50 to 60 mm in the first two months of life (Sakagawa and Kimura 1976). Although northern anchovy may spawn throughout the year, most spawning occurs from January to May (Brewer 1978, Hunter and Macewicz 1980). Size distribution for northern anchovy collected in winter suggests a population composed of prereproductive fish, though some older fish were also noted. In summer, most of the northern anchovy corresponded to YOY, though a secondary group of adults were also collected (Figure 27). Juvenile northern anchovy are typically found in large schools in nearshore waters and embayments and probably use these areas as nurseries (Allen and DeMartini 1983), while larger adults usually form smaller schools offshore (Fitch and Lavenberg 1971).

In 2007, a total of 5,924 macroinvertebrate individuals were collected from 17 species. Macroinvertebrate abundance in 2007 was higher than the long-term mean abundance, but less than one-half of the total abundance taken in 2006 (Figure 30). Blackspotted bay shrimp overwhelmingly dominated the annual abundance with nearly 94% of the total abundance. Graceful crab and Pacific sand dollar were a distant second and third in abundance with about 3% of the total abundance each. The remaining 14 species collectively accounted for less than 1% of the total annual abundance.




* Variable methods from standard survey program, 1990 to present. 1997 and 2003, no winter sampling.

**Figure 30. Long-term abundance of macroinvertebrates collected by otter trawl by season and station. Mandalay Generating Station NPDES, 2007.**

Winter macroinvertebrate abundances in 2007 accounted for less than one-fifth of the yearly total. Among stations, abundance at Station T3 in winter was more than three times the abundance at Stations T2 and T4, where abundances and species composition were similar to each other. Lowest totals in winter were found at Station T1, farthest upcoast. Overall, trawl-caught abundances were lower upcoast of the generating station discharge than downcoast. Blackspotted bay shrimp was the most abundant species in winter, particularly at Station T3, where 70% of the seasonal total for the species was collected. Pacific sand dollar, however, were most abundant at Station T4, where 99% of the seasonally total occurred. Graceful crab occurred in low numbers at three stations in winter.

Summer survey abundance was nearly five times that reported in the winter survey. Abundances at Station T3 were again highest, with blackspotted bay shrimp abundance nearly twice that collected at any other station. Assemblages and abundances among stations were most similar at Stations T1 and T2, both upcoast of the discharge. Lowest summer macroinvertebrate abundance was reported at Station T4, farthest downcoast of the discharge. Blackspotted bay shrimp again strongly dominated the summer assemblage, occurring at all stations, usually in very high abundances. Graceful crab, however, occurred in low to moderate abundances at all stations in summer and was the second most abundant species in summer. Pacific sand dollar was not taken in summer.

Surveys in 2007 continued a trend beginning in 2003 of blackspotted bay shrimp replacing Pacific sand dollar as the dominant macroinvertebrate species in the area (Figure 30). Blackspotted bay shrimp have been the most abundant species collected in seven of the 19 survey years since 1978, including between 2003 and 2007 and have been taken during every survey year (Appendix G-9). The species 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, and accounted for 0.7% of the total macroinvertebrate catch (Allen et al. 2002). In Bight-wide monitoring conducted in 2003, 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).

Graceful crab was the second most abundant species in 2007, and is third in abundance in the area since 1978 (Appendix G-9). It has occurred in 17 of the 19 surveys since 1978, although abundances have been variable among years. Numbers in 2007 were less than one-quarter the record high abundance found in 2006, but still were twice the long-term mean for the crab caught offshore of the discharge. Graceful crab ranges between Prince William Sound, Alaska, and Bahia Playa Maria, Baja California. It is found in the lower intertidal zone in bays, on mud flats, in eelgrass beds, and subtidally to 174 m (571 ft). Cancrid crabs function as both scavengers and predators in the marine environment. Prey varies as a function of age and size of the individual but animal remains, soft-bottom benthic invertebrates such as clams, worms, and snails, and sessile hard-bottom species such as barnacles likely comprise the majority of prey species. Juvenile rock crabs are an important prey item for a variety of fishes and invertebrates. In southern California, this includes barred sand bass (*Paralabrax nebulifer*), shovelnose guitarfish (*Rhinobatos productus*) and the sand star (*Astropecten verrilli*) (Roberts et al. 1984; VanBlaricom 1979). Mating occurs in November, with ovigerous females appearing in July and August. Males remain with the females after mating, and are thought to protect them (Morris et al. 1980). Females produce one batch of 143,000 to one million eggs per year, and can spawn two or three seasons over their lifetime (Orensanz and Gallucci 1988). Their carapace width measures up to 115 mm (4.5 inches) in males and up to 87 mm (3.4 inches) in females (Jensen 1995). It is estimated that graceful crab matures at a size of about 60 mm CW (2.4 inches) and at approximately 10 months of age (post-settlement) (Orensanz and Gallucci 1988). Graceful crab molt approximately 11 to 12 times and live for about four years.

Pacific sand dollar have been collected in 18 of the 19 survey years since 1978 and were the most abundant macroinvertebrate during ten years, including from 1986 to 1991 and from 1994 to 2002 (Figure 30, Appendix G-9). A large recruitment of Pacific sand dollars occurred off Mandalay between the summer 1997 and winter 1999 trawl surveys. Average size of the sand dollars off Mandalay increased from 0.13 and 0.12 kg per 100 individuals in winter and summer 1999 to 0.18 and 0.26 kg per 100 individuals in winter and summer 2000 and then doubled to 0.40 and 0.56 kg in winter and summer 2001. (MBC 1997-2001a, 2002-2006a). Average size of the sand dollars collected by trawl again increased to 0.68 kg and 0.94 kg per 100 individuals in winter and summer 2002. At the same time that the size of the individuals was increasing, the number of individuals caught in trawl surveys declined every year from 1990 to 2004, with only 47 Pacific sand dollars taken in 2004 trawls. Pacific sand dollar abundance increased in both 2005 and 2006. In 2007, Pacific sand dollar again declined, with only about one-fortieth the abundance reported in 2006. 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).

## CONCLUSION

Fish and macroinvertebrate species composition were similar to those in past surveys in the study area. This similarity of species composed primarily of frequently occurring and long-term dominant species indicates a relatively stable assemblage typical of the nearshore, soft-bottom community remains in the area. In both winter and summer, abundance of fish and invertebrates was highest or among the highest at the stations nearest the discharge and lowest at the downcoast station. While spatial differences were apparent, variability in fish and macroinvertebrate communities in the area appeared to be related to natural and seasonal differences in local fish and macroinvertebrates populations. There is no indication that plant operations have adversely affected the fish or macroinvertebrate populations offshore of the Mandalay Generating Station.

# IMPINGEMENT

Mandalay Generating Station is located on the coast approximately 4.8 km west of the City of Oxnard, California. There are two units (1 and 2) which employ the use of once through cooling (OTC). 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. Cooling water enters the plant through two angled intake bays. To remove debris cooling water passes through two pairs of trash racks with 57 mm mesh as well as two pairs of vertical slide screens, which are 3.5 meters wide by 6.4 meters high with 12.7 mm mesh. The slide screens are positioned parallel to one another and perpendicular to the intake flow. One slide screen is deployed while the other is cleaned of debris by the use of a high pressure wash, which is activated automatically by pressure differential across the screen. All debris is discharged into a trash basket. Fish and macroinvertebrates are collected from these baskets.

Fish 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. Normal operation fish impingement surveys determine the number of organisms caught on the screens during a set time period, usually over 24 hours. Coastal generating stations with OTC water systems periodically recirculate hot water from the condensers to reduce biofouling. This is achieved by maintaining a temperature which exceeds the critical thermal tolerance of the biofouling organism, such as mussels. The use of hot water is more commonly referred to as a heat treatment. In this process, fish and macroinvertebrates unable to escape the intake area are similarly exposed to elevated temperatures, usually causing mortality.

## MATERIALS AND METHODS

At Mandalay Generating Station, one heat treatment was monitored in 2007, on 7 May 2007. During the heat treatment, 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]), and aggregate biomass (kg) was recorded for all measured and unmeasured individuals. Total abundance for species with greater 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 taken. California spiny lobster (*Panulirus interruptus*) were counted, carapace length (CL) measured to the nearest millimeter, and an aggregate weight recorded.

Normal operation surveys were performed in addition to heat treatment monitoring. To assess the impingement of organisms during periods of normal operation at the generating station, 24-hr surveys were conducted during representative periods of operation. During such surveys, the sliding screens and trash baskets were cleared of all accumulated debris at the start of the sampling period. At the end of the 24-hour period all accumulated material was processed using the same method as during the heat treatment survey, with up to 50 individuals of each fish species measured per event. No surveys were conducted in October 2006, three surveys were conducted in November 2006, and two in December 2006. One survey was conducted every two months from January to September 2007.

Due to variation in daily operating patterns, all normal operation survey fish and macroinvertebrate data was standardized to circulated water flow rates to determine the rate of impingement by the following equation: Impingement Rate = Value/Circulated Water Volume in million gallons. Volume of water circulated was based on the water flow rate during the period surveyed. Monthly estimated impingement represents the impingement rate multiplied by an analysis flow representing the sampling frequency. November estimates represent the summation of each survey-specific impingement rate multiplied by one third of the total cooling water flow rate for October and November combined. December estimates were calculated as each survey-specific impingement rate multiplied by one-half of the total monthly flow rate. Estimates for January through July 2007 represent the month-specific impingement rate multiplied by the total flow for the survey month and the subsequent month, e.g. January estimate = Jan. Impingement rate X (January total flow + February total flow). The estimate for September 2007 was calculated as the September rate multiplied by the total flow for the month. This was done because August 2007 was incorporated into the July estimate and October 2007 was outside of the monitoring period. The estimated annual impinged abundance represents the summation of each estimated monthly abundance. Biomass was calculated as was described for abundance.

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. Data were uploaded to the MBC fish impingement long-term database. Length frequency distributions for those fishes examined were derived by rounding (1 to 4 = 0, 5 to 9 = 10) the recorded length to the nearest ten millimeters for each measurement type (SL, TL, or DW). Abundance per size class was plotted using MS Excel. Data from both survey types were utilized for length frequency analysis.

## RESULTS

### Fish

One heat treatment and ten normal operation surveys were conducted during the 2007 monitoring year at Mandalay Generating Station. An estimated 5,270 individuals of 26 fish taxa with an estimated biomass of 131.9 kg were impinged during the 2007 monitoring year (Table 15). Heat treatment impingement accounted for less than 1% of the total abundance (33 individuals), 1% of the biomass (1.4 kg), and five species. Estimated normal operation impingement accounted for the remaining abundance and biomass. Black perch (*Embiotoca jacksoni*) was taken only during the heat treatment survey.

The most abundant fish species was shiner perch (*Cymatogaster aggregata*) with an estimated 2,295 individuals or 44% of the total abundance, with most attributed to normal operations (Table 15). The 24 individuals recorded during heat treatment accounted for 73% of the total heat treatment abundance. Topsmelt (*Atherinops affinis*), bay pipefish (*Syngnathus leptorhynchus*), and Pacific staghorn sculpin (*Leptocottus armatus*) each contributed about 8% to total abundance with an estimated 463, 429, and 404 individuals each, respectively. Four additional species contributed about another 5% each to estimated abundance: bat ray (*Myliobatis californica*) with an estimated 299 individuals; crevice kelpfish (*Gibbonsia montereyensis*) with 272 individuals; northern anchovy (*Engraulis mordax*) with 263 individuals; and yellowfin croaker (*Umbrina roncador*) with 203 individuals. The remaining 18 taxa contributed less than 5% to the total abundance or 200 individuals or less each.

Bat ray contributed the most to impinged biomass with an estimated 48.6 kg, or 37% of the yearly total (Table 15). Three additional species accounted for 10% or more of the total estimated biomass, including yellowfin croaker (27 kg), Pacific staghorn sculpin (16 kg), and shiner perch (14 kg). The remaining 22 taxa each contributed less than 5% to the total, or less than 6 kg each. All but 0.8 kg of the annual biomass for shiner perch was estimated based on normal operations. Shiner perch contributed 54% to the recorded impinged biomass during the heat treatment, followed by black perch with 0.5 kg, or 38% of the survey total.

**Table 15. Estimated abundance and biomass (kg) of fish taxa impinged during heat treatment and normal operation surveys. Mandalay Generating Station NPDES, 2007.**

| | Heat Treat. | | Obser. Norm. Op. | | Est. Norm. Op. | | Annual Total | | Percent Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| Taxa | Abu. | Biom. (kg) | Abu. | Biom. (kg) | Abu. | Biom. (kg) | Abu. | Biom. (kg) | Abu. | Biom. (kg) |
| shiner perch | 24 | 0.781 | 448 | 2.072 | 2,271 | 13.177 | 2,295 | 13.958 | 43.5 | 10.6 |
| topsmelt | 1 | 0.010 | 25 | 0.285 | 462 | 5.530 | 463 | 5.540 | 8.8 | 4.2 |
| bay pipefish | - | - | 6 | 0.009 | 429 | 0.444 | 429 | 0.444 | 8.1 | 0.3 |
| Pacific staghorn sculpin | - | - | 29 | 1.531 | 404 | 16.306 | 404 | 16.306 | 7.7 | 12.4 |
| bat ray | - | - | 5 | 1.308 | 299 | 48.578 | 299 | 48.578 | 5.7 | 36.8 |
| crevice kelpfish | - | - | 5 | 0.068 | 272 | 1.582 | 272 | 1.582 | 5.2 | 1.2 |
| northern anchovy | - | - | 58 | 0.088 | 263 | 0.577 | 263 | 0.577 | 5.0 | 0.4 |
| yellowfin croaker | - | - | 1 | 0.133 | 203 | 26.957 | 203 | 26.957 | 3.9 | 20.4 |
| sargo | - | - | 51 | 0.134 | 189 | 0.508 | 189 | 0.508 | 3.6 | 0.4 |
| Pacific sardine | - | - | 15 | 0.276 | 135 | 2.727 | 135 | 2.727 | 2.6 | 2.1 |
| queenfish | - | - | 9 | 0.012 | 111 | 0.193 | 111 | 0.193 | 2.1 | 0.1 |
| deepbody anchovy | - | - | 2 | 0.016 | 43 | 0.344 | 43 | 0.344 | 0.8 | 0.3 |
| kelp greenling | - | - | 2 | 0.029 | 20 | 0.290 | 20 | 0.290 | 0.4 | 0.2 |
| California halibut | - | - | 2 | 0.090 | 19 | 0.859 | 19 | 0.859 | 0.4 | 0.7 |
| opaleye | - | - | 2 | 0.364 | 19 | 3.475 | 19 | 3.475 | 0.4 | 2.6 |
| kelp bass | 1 | 0.070 | 2 | 0.097 | 17 | 0.699 | 18 | 0.769 | 0.3 | 0.6 |
| rubberlip seaperch | - | - | 2 | 0.599 | 15 | 5.713 | 15 | 5.713 | 0.3 | 4.3 |
| walleye surfperch | - | - | 2 | 0.126 | 14 | 0.949 | 14 | 0.949 | 0.3 | 0.7 |
| spotted kelpfish | 3 | 0.035 | 2 | 0.010 | 10 | 0.041 | 13 | 0.076 | 0.2 | 0.1 |
| barred sand bass | - | - | 1 | 0.093 | 10 | 0.888 | 10 | 0.888 | 0.2 | 0.7 |
| sand flounder unid | - | - | 1 | 0.006 | 10 | 0.060 | 10 | 0.060 | 0.2 | 0.0 |
| white seaperch | - | - | 1 | 0.031 | 10 | 0.296 | 10 | 0.296 | 0.2 | 0.2 |
| bay goby | - | - | 1 | 0.035 | 4 | 0.132 | 4 | 0.132 | 0.1 | 0.1 |
| black perch | 4 | 0.539 | - | - | - | - | 4 | 0.539 | 0.1 | 0.4 |
| giant kelpfish | - | - | 1 | 0.017 | 4 | 0.064 | 4 | 0.064 | 0.1 | 0.0 |
| yellowfin goby | - | - | 1 | 0.013 | 4 | 0.049 | 4 | 0.049 | 0.1 | 0.0 |
| Total | 33 | 1.435 | 674 | 7.442 | 5,237 | 130.438 | 5,270 | 131.873 | | |
| Number of taxa | 5 | | 25 | | 25 | | 26 | | | |

### Length Frequency Analysis

Three fish species were measured in sufficient abundance to discuss population characteristics using length frequently analysis. Shiner perch (n = 173) exhibited a bimodal distribution among impinged individuals, peaking at 50 mm SL, with a smaller peak at 100 to 110 mm SL (Figure 31). Recorded lengths of northern anchovy (n = 58) indicate a unimodal distribution, dominated by the 40- and 50-mm SL size classes, with a few individuals ranging as large as the 120-mm SL size class (Figure 32). Sargo (*Anisotremus davidsonii*) lengths (n = 51) exhibited a unimodal distribution centered at the 50-mm SL size class (Figure 31).

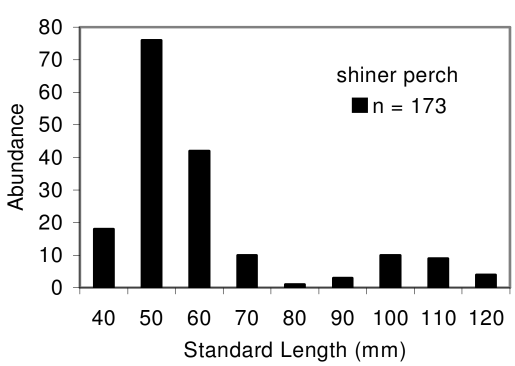



**Figure 31. Length frequency of shiner perch (*Cymatogaster aggregata*) impinged during heat treatment and normal operation surveys. Mandalay Generating Station NPDES, 2007.**

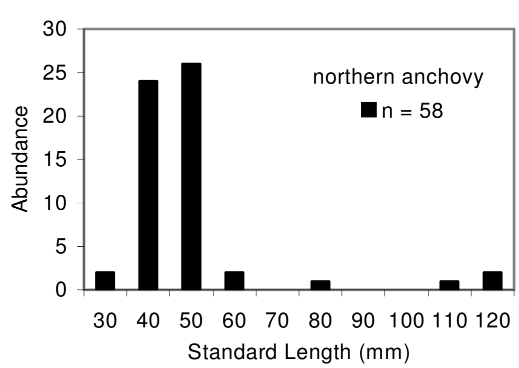



**Figure 32. Length frequency of northern anchovy (*Engraulis mordax*) impinged during heat treatment and normal operation surveys. Mandalay Generating Station NPDES, 2007.**

### Macroinvertebrates

An estimated 488 individuals of four macroinvertebrate species with an estimated biomass of 10.5 kg were impinged during the 2007 monitoring year at Mandalay Generating Station (Table 16). Heat treatment impingement accounted for 15% of the annual abundance and 77% of the biomass. California spiny lobster and stout coastal shrimp (*Heptacarpus brevirostris*) were taken only during the heat treatment, while the California two-spot octopus (*Octopus bimaculatus/bimaculoides*) occurred during a normal operation survey. Striped shore crab (*Pachygrapsus crassipes*) was recorded during both survey types.

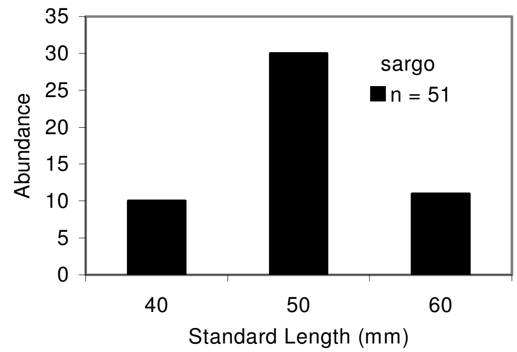



**Figure 33. Length frequency of sargo (*Anisotremus davidsonii*) impinged during heat treatment and normal operation surveys. Mandalay Generating Station NPDES, 2007.**

Striped shore crab was the most abundant species with an estimated 451 individuals impinged during the year, with 46 recorded during the heat treatment, and the remaining 405 impinged attributed to normal operations, based on cooling water flow rates (Table 16). California spiny lobster was the next most abundant with 26 individuals, all recorded during the heat treatment, along with a single stout coastal shrimp. An estimated ten California two-spot octopus were impinged during normal operations. Approximately 73% of all impinged biomass was contributed by California spiny lobster with 7.7 kg, followed by striped shore crab with 21% (2.2 kg), California two-spot octopus with 6% (0.6 kg), and the single stout coastal shrimp at less than 1% of the yearly total.

**Table 16. Estimated abundance and biomass (kg) of macroinvertebrate species impinged during heat treatment and normal operation surveys. Mandalay Generating Station NPDES, 2007.**

| | Heat Treat. | | Obser. Norm. Op. | | Est. Norm. Op. | | Annual Total | | Percent Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| Species | Abu. | Biom. (kg) | Abu. | Biom. (kg) | Abu. | Biom. (kg) | Abu. | Biom. (kg) | Abu. | Biom. (kg) |
| striped shore crab | 46 | 0.350 | 2 | 0.009 | 405 | 1.824 | 451 | 2.174 | 92.4 | 20.7 |
| California spiny lobster | 26 | 7.699 | - | - | - | - | 26 | 7.699 | 5.3 | 73.3 |
| California two-spot octopus | - | - | 1 | 0.066 | 10 | 0.630 | 10 | 0.630 | 2.0 | 6.0 |
| stout coastal shrimp | 1 | 0.003 | - | - | - | - | 1 | 0.003 | 0.2 | 0.0 |
| Total | 73 | 8.052 | 3 | 0.075 | 415 | 2.454 | 488 | 10.506 | | |
| Number of Species | 3 | | 2 | | 2 | | 4 | | | |

## DISCUSSION

To evaluate fish loss at the Mandalay Generating Station, fish impingement was monitored during one heat treatment and ten normal operation surveys during the 2007 monitoring year. Based on these surveys, a calculated total of 5,270 individuals representing 26 fish taxa and weighing more than 131 kg were impinged at the generating station. Overall, impinged abundance estimates for the 2007 monitoring year were the second lowest since 2001, despite a marked increase in annual cooling water flow (Figure 34; MBC 2001a, 2002-2006a). In addition, a calculated 488 individuals representing four macroinvertebrate species and weighing more than 10 kg were impinged, the second highest total since impingement data was first reported in 2001 (Appendix H-1). From 2001-2005 the average number of normal operation surveys per year was five. For the 2007 monitoring year, however, the number normal operation surveys performed was partially increased as part of a special study which completed in December 2006.

Shiner perch abundances since 2001 have fluctuated greatly, from a high of 48,209 in 2006 to a low of 27 in 2001, with an overall mean annual impinged abundance of 12,713 (Appendix H-11), while Herbinson (1981) reported 105,942 individuals for two years of impingement surveys conducted from October 1978 to September 1980. Shiner perch have been reported as one of the two most abundant fish species every year since 2001 (MBC 2001a, 2002-2006a). In 2007, estimates of impinged shiner perch abundance represented the third lowest since 2001, but the species was still the most abundant fish taken during the survey year.

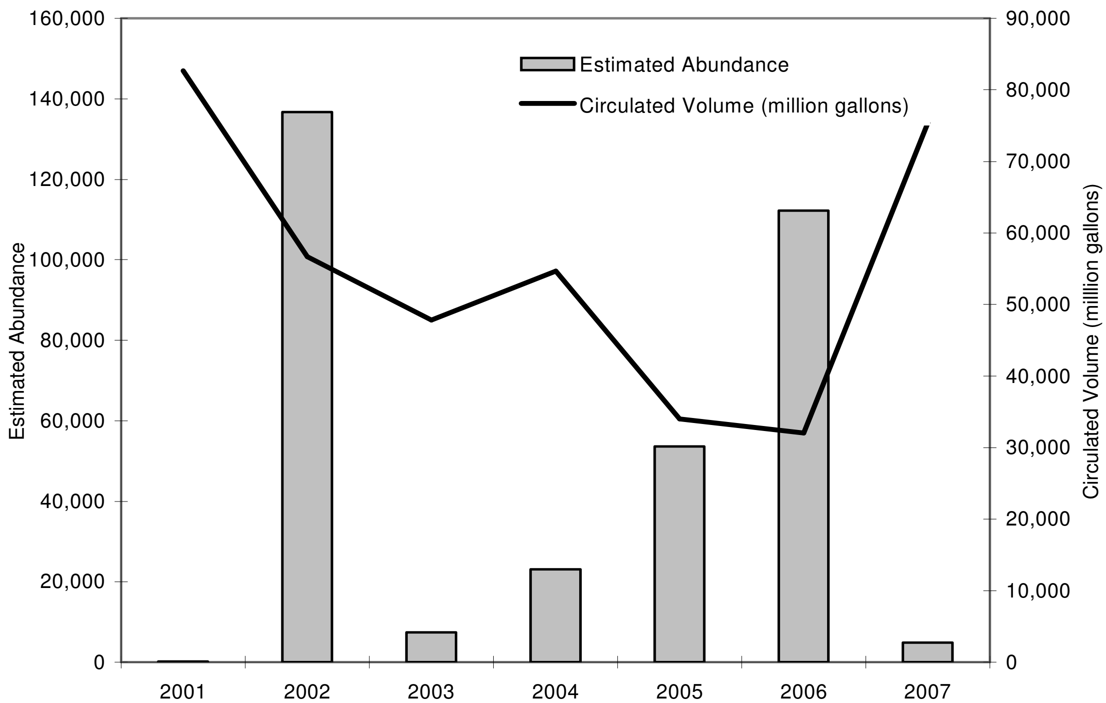



**Figure 34. Annual estimated abundance of fish impinged during heat treatment and normal operation surveys and annual reported circulating water volume (million gallons). Mandalay Generating Station NPDES, 2007.**

The size of the shiner perch impinged in 2007 (Figure 31) indicates multiple year classes were impinged, with most in the 50-mm and 60-mm size classes, representing young-of-the-year (YOY), with a few individuals up to four years old (Anderson and Bryan 1970, Eckmayer 1979). Shiner perch range from San Quintin Bay, Baja California to Sitka, Alaska (Love et al. 2005). Shiner perch occurs primarily in shallow-water marine, bay, and estuarine habitats, and is demersal on sandy and muddy bottoms (Emmett et al. 1991).

Shiner perch abundances declined in some impingement and trawl catches in southern California after the 1970s (MBC 2001b, Stull and Tang 1996). This decline could be related to a measurable shift in oceanic temperature regimes from a cool water to a warmer water offshore of California in the 1980s and 1990s (MBC 2001c). In southern California, zooplankton (a food source for shiner perch) decreased in biomass by about 80% between 1951 and 1993, with most of the decline occurring after the 1970s (Allen 1982, Roemmich and McGowan 1995).

Topsmelt was the second most abundant fish species in 2007, although most were attributed to estimated normal operation impingement, so insufficient individuals were measured to warrant length frequency analysis. Topsmelt are common in nearshore tidal waters, ranging from the Gulf of California to Vancouver Island, British Columbia (Miller and Lea 1972). Common around soft-bottom habitat, topsmelt are frequent residents of bays and harbors throughout southern California such as Channel Islands Harbor (Allen 1985). Topsmelt spawn in late spring and early summer, attaching eggs in a mass on marine vegetation, including eelgrass and low-growing algae in bays and harbors, and possibly on kelp (Gregory 2001). Topsmelt can grow to lengths of 360 mm, attaining a length of 100 mm in the first year and 185 mm by its second year, growing proportionally less during each subsequent year (Hart 1973, Gregory 2001).

In 2007, bay pipefish was the third most abundant fish species reported for the year based on annual flow volumes. They commonly occur throughout the nearshore waters of southern California, though largely limited to inshore embayments. Bay pipefish range from at least central Baja California, Mexico to northern California, with a depth limit from the surface to about 5 m (16 ft) (Love et al. 2005). Bay pipefish commonly inhabit eelgrass beds within bays, harbors, and estuaries within southern California, and were reported in 49% of samples collected Alamitos Bay, and as the tenth most abundant fish species in San Diego Bay (Eschmeyer et al.1983, Valle et al. 1999; Allen et al. 2002). Pipefish as a group have been reported to exhibit unique reproductive activities. Fitch and Lavenberg (1975) suggest that fertilization of the eggs occurs as the female transfers the eggs to a brood pouch located on the male's abdomen, after which the male provides all parental care and broods the eggs until hatching, with "pregnant" male pipefish generally observed from September to December in southern California (Coleman 1999).

Pacific staghorn sculpin was the forth most abundant fish species taken in impingement sampling at the Mandalay Generating Station in 2007, although it did not occur in sufficient numbers perform a length frequency analysis. Pacific staghorn sculpin ranges 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 Kalamath River mouth to Bahia de San Quintin and has been commonly observed during impingement sampling at stations withdrawing seawater from bays and harbors (Allen et al. 2006, MBC unpubl. data). 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). Tasto (1975) indicated that spawning takes place between mid-December and mid-March with peaks in January and February.

Northern anchovy is among the most frequently impinged species at Mandalay Generating Station since 2001, with annual abundances ranging from 1 to 45,950 (Appendix H-1), though in 2007, it was only seventh in abundance which was much lower than occurred between 2004 and 2006. Recorded lengths for northern anchovy were predominantly within the 40- to 50-mm SL size classes representing YOY (Figure 32; Parrish et al. 1985). Northern anchovy range from Cape San Lucas, Baja California to Queen Charlotte Islands, British Columbia and offshore to 480 km, primarily in association with soft substrate habitat (Allen 1985). Juveniles are generally more common inshore and in estuaries, and larvae are found from the surface to 75 m in epipelagic and neritic waters (Garrison and Miller 1982). Live baitfish for the sportfishing community is the principle fishery for northern anchovy within southern California, with only a limited fishery currently operating (Bergen and Jacobson 2001). Adults offshore are preyed upon by marine fishes, mammals, and birds, especially California brown pelican (*Pelecanus occidentalis californicus*) (Bergen and Jacobson 2001). Links between breeding success of the endangered California brown pelican and northern anchovy abundance have been observed.

Although sargo were the ninth most abundant impinged taxa, sufficient individuals were observed during normal operation surveys to warrant length frequency analysis (Table16, Figure 33). Their impingement in 2007 represents the first recorded occurrence of sargo at Mandalay Generating Station since 2001. Although no age at length information is available, they are estimated to live 12 - 15 years (Cailliet et al. 2000). Based on preliminary information on a similar species, salema (*Xenistius californiensis*), the impinged individuals were less than one year old (E. F. Miller, unpublished data). Adult sargo have been found to reach lengths of 58 cm (23 in) (Eschmeyer et al. 1983, Thomson et al. 2000). The diet of sargo is comprised of invertebrates such as crustaceans and mollusks (Eschmeyer et al. 1983). Unfortunately there is not much else known about the life history of these fish. There is no targeted recreational or commercial fishery for this species in California (Thomson et al. 2000). Sargo are occasionally taken by fishermen targeting reef-associated species such as kelp bass (*Paralabrax clathratus*).

In 2007, one yellowfin goby (*Acanthogobius flavimanus*) was taken during normal operation surveys in November. This individual extrapolated to a flow-adjusted four individuals impinged for the year. This represents the third recorded occurrence at Mandalay Generating Station, and the second consecutive annual observation (Appendix H-11). Yellowfin goby were introduced from Asia, with the first recorded occurrence in California in San Francisco Bay in 1963 (Haaker 1979). The earliest record of the species in Los Angeles Harbor was a photograph taken in 1977, with a specimen first collected in 1978. The northern extent of the species is Tomales Bay, with the southern extent San Diego Bay, where in 2002 yellowfin goby was ranked as the 46$^{th}$ most abundant fish species in the bay (Miller and Lea 1972, Williams et al. 1998, Allen et al. 2002). Yellowfin goby have wide thermal (11-28°C) and salinity tolerances, from freshwater (<5 psu) to marine (>25 psu) while the scattered occurrence of the species in California suggests multiple introductions (Dill and Cordone 1997).

The most abundant macroinvertebrate species during the 2007 impingement surveys was striped shore crab, with an estimated 451 individuals, the highest recorded abundance since 2001 (MBC 2001a, 2002-2006a). With the exception of an anomalous heat treatment in 2006 when 27,020 Pacific littleneck clams (*Protothaca staminea*) were impinged, striped shore crab ranks as the most abundant impinged macroinvertebrate at Mandalay Generating Station, occurring in all but one year since 2001 (Appendix H-1). Striped shore crab range from Ecola State Park, Oregon to the Gulf of California, with principal habitat in the upper and middle rocky intertidal zone (Jensen 1995).

California spiny lobster, a commercially important macroinvertebrate, was collected exclusively during heat treatments, where it contributed 73% to the total impinged biomass for the year. Occurring every year since 2002, impinged abundance in 2007 represents the second highest value, following 2006 (Appendix H-1). Since the mid-1970s, California spiny lobster abundances appear to be generally increasing within the Southern California Bight based on commercial landings (Barsky 2001). This highly valued crustacean is commonly found within caves and crevices of rocky substrate throughout its range from Monterey Bay, California to Manzanillo, Mexico (Barsky 2001). Fishing, both recreational and commercial, within State of California waters is regulated by the California Department of Fish and Game, with a limited harvest season from early October to mid-March (Barsky 2001).

Overall, fish species impinged in 2007 were similar to those collected in previous surveys, but were generally less abundant than was recorded in recent annual surveys (Appendix H-1). Macroinvertebrates, however, were similar in species composition, though generally higher in abundance than previous years except 2006 (Appendix H-1). However, if Pacific littleneck clams are excluded, macroinvertebrate impingement in 2007 slightly exceeded that of 2006, with 488 and 455 individuals, respectively.

The decline in fish abundance despite increases in cooling water flow volumes suggests variability in local communities in the intake canal. In 2001, when fish impingement totals were the lowest reported in the current monitoring program, cooling water flow rates were the highest recorded, however, the highest impingement occurred in 2002, when cooling water flow volumes were lower than in either 2001 or 2007 (Figure 34). In addition, the second highest impingement abundance was recorded in 2006, which coincided with the lowest annual cooling water volume since 2001. This suggests that the local populations, or at least impingement abundance, were fluctuating independently of station operations.

Annual fish impingement at Mandalay Generating Station has been highly variable since 2001. Much of the variability in fish abundance has been generated by the presence or absence of schooling species, such as northern anchovy, California grunion (*Leuresthes tenuis*), and shiner perch. Impingement studies at Alamitos Generating Station, which withdraws cooling water from canals similar to that at Mandalay Generating Station, found impingement of silversides (topsmelt, California grunion, jacksmelt [*Atherinopsis californiensis*]) and shiner perch were significantly correlated with precipitation (MBC 2006b). Some of these high impingement abundances are most likely attributable to the impingement of stressed fish during, or just after, a precipitation event. Similar inter-annual variability has been observed offshore of Mandalay Generating Station where trawl-caught fish assemblages fluctuate based on the relative abundance of white croaker (*Genyonemus lineatus*) and queenfish (*Seriphus politus*) (MBC 2006a).

## CONCLUSION

Overall, fish species impinged in 2007 were similar to those collected in previous surveys, but were generally less abundant than recorded in recent annual surveys. This decline in fish abundance despite increases in cooling water flow volumes suggests variability in the local populations, and is consistent with previous years when fish impingement abundances appeared to fluctuate independently of station operations. Macroinvertebrate composition in 2007 was similar to previous years, though with generally higher abundances. The similarity of species composed primarily of frequently occurring and long-term dominant species indicates a relatively stable assemblage typical of southern California embayments. Variability in fish and macroinvertebrate communities in the area appeared to be related to natural differences in local populations with no distinct distributional pattern of fish or macroinvertebrates evident in relation to the intake. 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.

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**PERSONAL COMMUNICATION**

Siekiel-Zdzienicki, B.J. 2007. Reliant Energy Mandalay Generating Station.

# 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, 5th 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 | impingement | 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.).

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

CA0001180

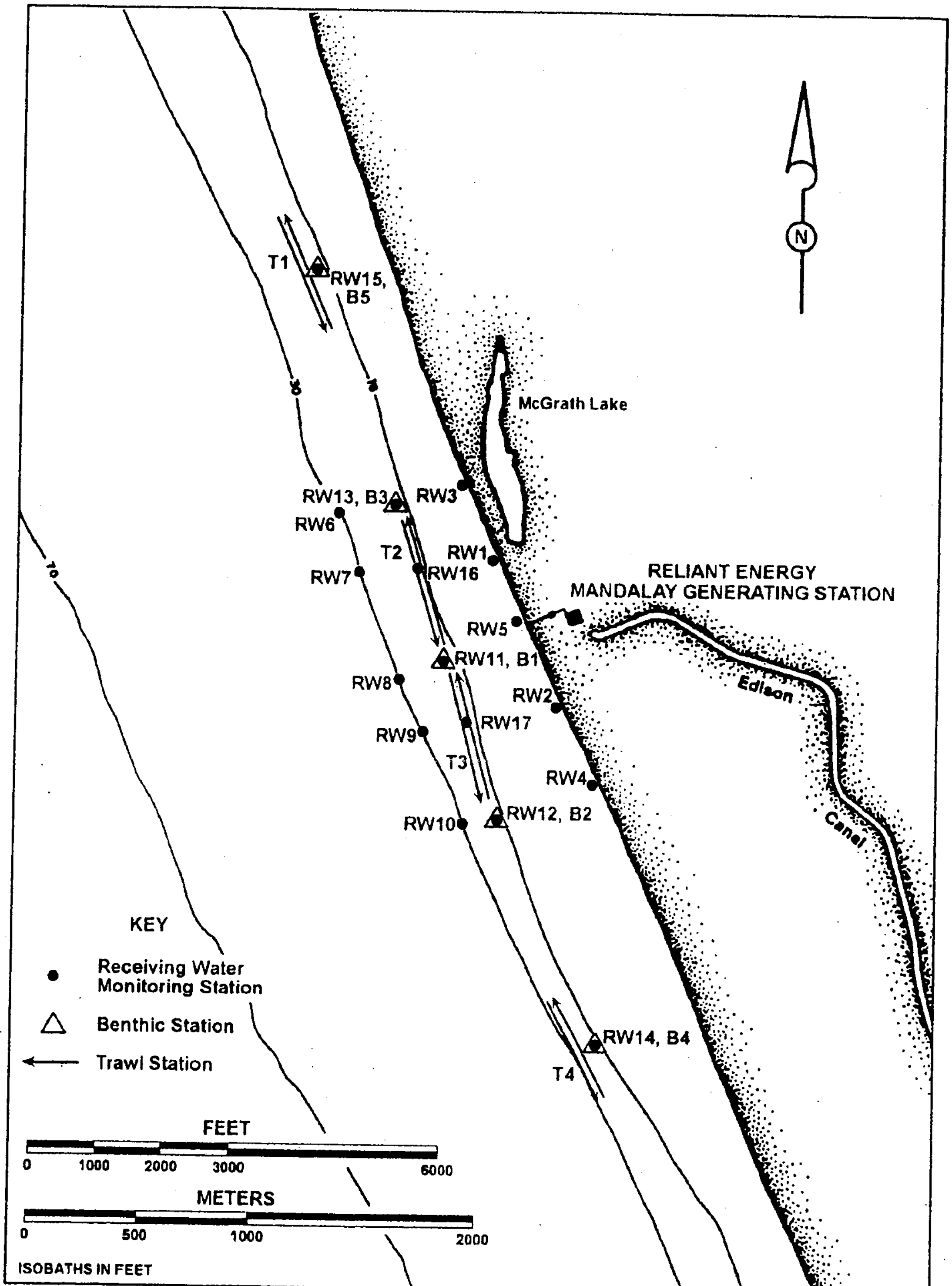



Figure 1. Locations of the sampling stations. Reliant Energy Mandalay Generating Station.

# 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 2007.**

| | 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 |
|---|---|---|---|---|---|---|---|---|---|
| **Surf Zone** | | | | | | | | | |
| RW1 | 0 | 12.64 | 14.36 | 8.23 | 7.30 | 7.83 | 7.96 | 32.95 | 33.02 |
| RW2 | 0 | 12.78 | 14.33 | 8.00 | 7.29 | 7.78 | 7.95 | 32.97 | 32.72 |
| RW3 | 0 | 12.64 | 14.21 | 8.05 | 7.37 | 7.83 | 7.97 | 32.91 | 33.06 |
| RW4 | 0 | 12.36 | 14.21 | 8.17 | 7.32 | 7.78 | 7.96 | 32.92 | 33.04 |
| RW5 | 0 | 14.03 | 15.32 | 7.86 | 7.20 | 7.72 | 7.95 | 32.44 | 32.19 |
| **Offshore** | | | | | | | | | |
| RW6 | 0 | 12.80 | 13.75 | 7.82 | 8.04 | 7.79 | 7.92 | 33.72 | 33.77 |
| | 1 | 12.79 | 13.67 | 7.82 | 8.11 | 7.79 | 7.92 | 33.72 | 33.78 |
| | 2 | 12.56 | 13.23 | 7.85 | 8.19 | 7.79 | 7.92 | 33.81 | 33.78 |
| | 3 | 12.32 | 13.01 | 7.67 | 8.09 | 7.81 | 7.91 | 33.82 | 33.77 |
| | 4 | 12.24 | 12.95 | 7.55 | 7.98 | 7.81 | 7.91 | 33.81 | 33.77 |
| | 5 | 12.18 | 12.93 | 7.57 | 7.95 | 7.81 | 7.91 | 33.83 | 33.77 |
| | 6 | 12.15 | 12.91 | 7.49 | 7.88 | 7.79 | 7.91 | 33.81 | 33.76 |
| | 7 | 12.12 | 12.87 | 7.37 | 7.87 | 7.79 | 7.89 | 33.81 | 33.77 |
| | 8 | 12.08 | 12.84 | 7.35 | 7.84 | 7.79 | 7.89 | 33.80 | 33.77 |
| | 9 | 12.05 | 12.41 | 7.27 | 7.83 | 7.78 | 7.88 | 33.80 | 33.81 |
| | 10 | 12.05 | 12.24 | 7.26 | 7.56 | 7.77 | 7.87 | 33.80 | 33.83 |
| | 11 | 12.05 | | 7.22 | | 7.77 | | 33.80 | |
| RW7 | 0 | 13.06 | 13.65 | 7.84 | 8.10 | 7.79 | 7.92 | 33.69 | 33.78 |
| | 1 | 13.04 | 13.69 | 7.94 | 8.13 | 7.79 | 7.92 | 33.69 | 33.78 |
| | 2 | 12.50 | 13.21 | 7.98 | 8.22 | 7.79 | 7.92 | 33.82 | 33.78 |
| | 3 | 12.33 | 12.99 | 7.60 | 8.11 | 7.81 | 7.91 | 33.80 | 33.77 |
| | 4 | 12.29 | 12.97 | 7.56 | 7.99 | 7.81 | 7.91 | 33.81 | 33.77 |
| | 5 | 12.16 | 12.95 | 7.59 | 7.97 | 7.80 | 7.91 | 33.82 | 33.77 |
| | 6 | 12.15 | 12.93 | 7.44 | 7.93 | 7.79 | 7.90 | 33.80 | 33.77 |
| | 7 | 12.14 | 12.88 | 7.34 | 7.91 | 7.79 | 7.89 | 33.80 | 33.77 |
| | 8 | 12.12 | 12.80 | 7.35 | 7.88 | 7.78 | 7.89 | 33.81 | 33.78 |
| | 9 | 12.08 | 12.26 | 7.31 | 7.89 | 7.78 | 7.88 | 33.81 | 33.82 |
| | 10 | 12.06 | 12.32 | 7.28 | 7.51 | 7.77 | 7.87 | 33.81 | 33.81 |
| | 11 | 12.05 | | 7.25 | | 7.77 | | 33.80 | |
| RW8 | 0 | 12.90 | 14.10 | 8.01 | 8.10 | 7.78 | 7.92 | 33.81 | 33.72 |
| | 1 | 12.88 | 14.05 | 7.80 | 8.13 | 7.79 | 7.92 | 33.74 | 33.78 |
| | 2 | 12.48 | 13.61 | 7.72 | 8.21 | 7.79 | 7.91 | 33.79 | 33.90 |
| | 3 | 12.36 | 13.11 | 7.43 | 8.20 | 7.80 | 7.91 | 33.80 | 33.81 |
| | 4 | 12.32 | 13.03 | 7.48 | 8.00 | 7.81 | 7.89 | 33.79 | 33.79 |
| | 5 | 12.25 | 12.98 | 7.58 | 7.97 | 7.80 | 7.89 | 33.80 | 33.79 |
| | 6 | 12.21 | 12.95 | 7.49 | 7.91 | 7.79 | 7.89 | 33.80 | 33.78 |
| | 7 | 12.18 | 12.89 | 7.43 | 7.89 | 7.77 | 7.90 | 33.80 | 33.78 |
| | 8 | 12.15 | 12.72 | 7.41 | 7.86 | 7.79 | 7.89 | 33.80 | 33.82 |
| | 9 | 12.11 | 12.32 | 7.37 | 7.76 | 7.78 | 7.88 | 33.80 | 33.86 |
| | 10 | 12.05 | 12.20 | 7.33 | 7.56 | 7.77 | 7.86 | 33.81 | 33.83 |
| | 11 | 12.06 | | 7.26 | | 7.77 | | 33.80 | |

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

| | | Temp. (°C) | | Oxygen (mg/l) | | pH | | Salinity (psu) | |
|---|---|---|---|---|---|---|---|---|---|
| | Depth (m) | FLOOD | EBB | FLOOD | EBB | FLOOD | EBB | FLOOD | EBB |
| RW9 | 0 | 12.93 | 13.58 | 7.69 | 8.15 | 7.79 | 7.92 | 33.81 | 33.74 |
| | 1 | 12.90 | 13.53 | 7.78 | 8.12 | 7.79 | 7.92 | 33.76 | 33.75 |
| | 2 | 12.57 | 13.31 | 7.76 | 8.16 | 7.79 | 7.92 | 33.80 | 33.76 |
| | 3 | 12.43 | 13.18 | 7.53 | 8.09 | 7.79 | 7.91 | 33.81 | 33.78 |
| | 4 | 12.35 | 13.14 | 7.42 | 8.06 | 7.79 | 7.91 | 33.80 | 33.77 |
| | 5 | 12.32 | 13.08 | 7.46 | 7.99 | 7.79 | 7.91 | 33.81 | 33.76 |
| | 6 | 12.28 | 12.96 | 7.48 | 8.00 | 7.79 | 7.91 | 33.80 | 33.78 |
| | 7 | 12.26 | 12.83 | 7.52 | 7.93 | 7.79 | 7.89 | 33.80 | 33.79 |
| | 8 | 12.19 | 12.67 | 7.47 | 7.90 | 7.79 | 7.89 | 33.81 | 33.71 |
| | 9 | 12.14 | 12.28 | 7.41 | 7.70 | 7.78 | 7.87 | 33.80 | 33.83 |
| | 10 | 12.07 | 12.19 | 7.40 | 7.50 | 7.77 | 7.87 | 33.81 | 33.82 |
| | 11 | 12.03 | | 7.33 | | 7.77 | | 33.82 | |
| RW10 | 0 | 13.02 | 13.91 | 7.85 | 8.16 | 7.77 | 7.92 | 33.72 | 33.65 |
| | 1 | 13.03 | 13.77 | 7.90 | 8.22 | 7.77 | 7.92 | 33.71 | 33.74 |
| | 2 | 12.68 | 13.38 | 8.03 | 8.29 | 7.77 | 7.92 | 33.87 | 33.78 |
| | 3 | 12.48 | 13.15 | 7.88 | 8.18 | 7.77 | 7.92 | 33.84 | 33.82 |
| | 4 | 12.38 | 13.10 | 7.60 | 8.08 | 7.77 | 7.91 | 33.81 | 33.79 |
| | 5 | 12.34 | 13.07 | 7.55 | 8.07 | 7.77 | 7.91 | 33.81 | 33.80 |
| | 6 | 12.30 | 12.98 | 7.56 | 8.06 | 7.78 | 7.91 | 33.81 | 33.80 |
| | 7 | 12.26 | 12.88 | 7.52 | 7.99 | 7.78 | 7.89 | 33.81 | 33.82 |
| | 8 | 12.24 | 12.65 | 7.56 | 7.96 | 7.77 | 7.89 | 33.81 | 33.81 |
| | 9 | 12.17 | 12.45 | 7.54 | 7.80 | 7.77 | 7.89 | 33.81 | 33.84 |
| | 10 | 12.05 | 12.26 | 7.49 | 7.67 | 7.77 | 7.88 | 33.82 | 33.85 |
| | 11 | 12.00 | 12.33 | 7.40 | 7.46 | 7.75 | 7.87 | 33.83 | 33.86 |
| RW11 | 0 | 13.24 | 13.89 | 8.13 | 8.09 | 7.79 | 7.90 | 33.67 | 33.75 |
| | 1 | 13.26 | 13.74 | 8.17 | 8.12 | 7.79 | 7.90 | 33.66 | 33.76 |
| | 2 | 12.79 | 13.33 | 8.26 | 8.15 | 7.79 | 7.90 | 33.77 | 33.76 |
| | 3 | 12.37 | 12.95 | 7.86 | 8.09 | 7.79 | 7.89 | 33.82 | 33.79 |
| | 4 | 12.38 | | 7.43 | | 7.77 | | 33.83 | |
| RW12 | 0 | 12.79 | 14.09 | 7.85 | 8.23 | 7.79 | 7.92 | 33.77 | 33.74 |
| | 1 | 12.76 | 14.08 | 7.88 | 8.23 | 7.77 | 7.92 | 33.76 | 33.73 |
| | 2 | 12.60 | 13.98 | 7.83 | 8.20 | 7.78 | 7.92 | 33.83 | 33.75 |
| | 3 | 12.34 | 13.83 | 7.76 | 8.25 | 7.77 | 7.92 | 33.82 | 33.77 |
| | 4 | 12.29 | 13.75 | 7.49 | 8.22 | 7.77 | 7.92 | 33.81 | 33.77 |
| | 5 | 12.26 | 13.60 | 7.46 | 8.20 | 7.77 | 7.91 | 33.81 | 33.82 |
| | 6 | 12.26 | 13.42 | 7.44 | 8.19 | 7.77 | 7.90 | 33.81 | 33.92 |
| | 7 | 12.26 | | 7.43 | | 7.77 | | 33.80 | |
| RW13 | 0 | 13.03 | 13.71 | 8.05 | 8.09 | 7.80 | 7.90 | 33.69 | 33.75 |
| | 1 | 13.03 | 13.71 | 8.04 | 8.09 | 7.80 | 7.90 | 33.68 | 33.76 |
| | 2 | 12.83 | 13.67 | 8.10 | 8.10 | 7.80 | 7.90 | 33.78 | 33.77 |
| | 3 | 12.31 | 13.60 | 8.04 | 8.13 | 7.79 | 7.90 | 33.81 | 33.78 |
| | 4 | 12.33 | 13.43 | 7.52 | 8.13 | 7.79 | 7.90 | 33.83 | 33.84 |
| | 5 | 12.27 | 13.46 | 7.43 | 8.06 | 7.77 | 7.89 | 33.80 | 33.82 |

**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 |
|---|---|---|---|---|---|---|---|---|---|
| RW14 | 0 | 13.04 | 13.85 | 8.18 | 8.21 | 7.77 | 7.92 | 33.74 | 33.77 |
| | 1 | 13.04 | 13.83 | 8.17 | 8.23 | 7.77 | 7.91 | 33.75 | 33.78 |
| | 2 | 12.81 | 13.67 | 8.22 | 8.27 | 7.77 | 7.90 | 33.81 | 33.81 |
| | 3 | 12.46 | 13.62 | 8.19 | 8.22 | 7.77 | 7.90 | 33.83 | 33.80 |
| | 4 | 12.30 | 13.48 | 7.80 | 8.24 | 7.77 | 7.90 | 33.87 | 33.82 |
| | 5 | 12.21 | 13.53 | 7.56 | 8.19 | 7.75 | 7.88 | 33.84 | 33.77 |
| | 6 | 12.20 | | 7.55 | | 7.75 | | 33.83 | |
| RW15 | 0 | 12.55 | 13.89 | 7.78 | 8.14 | 7.79 | 7.91 | 33.73 | 33.75 |
| | 1 | 12.54 | 13.88 | 7.80 | 8.12 | 7.79 | 7.91 | 33.70 | 33.75 |
| | 2 | 12.46 | 13.85 | 7.72 | 8.14 | 7.79 | 7.92 | 33.75 | 33.76 |
| | 3 | 12.27 | 13.62 | 7.67 | 8.19 | 7.78 | 7.90 | 33.80 | 33.83 |
| | 4 | 12.21 | 13.42 | 7.47 | 8.16 | 7.79 | 7.90 | 33.80 | 33.80 |
| | 5 | 12.20 | 13.26 | 7.34 | 8.06 | 7.79 | 7.91 | 33.79 | 33.82 |
| | 6 | 12.20 | 13.01 | 7.36 | 7.95 | 7.77 | 7.89 | 33.79 | 33.85 |
| | 7 | 12.20 | | 7.34 | | 7.77 | | 33.79 | |
| RW16 | 0 | 12.94 | 13.71 | 7.80 | 8.10 | 7.81 | 7.92 | 33.71 | 33.75 |
| | 1 | 12.90 | 13.68 | 7.78 | 8.13 | 7.81 | 7.91 | 33.72 | 33.76 |
| | 2 | 12.52 | 13.62 | 7.81 | 8.14 | 7.79 | 7.91 | 33.79 | 33.76 |
| | 3 | 12.31 | 13.59 | 7.55 | 8.15 | 7.79 | 7.92 | 33.81 | 33.76 |
| | 4 | 12.26 | 13.54 | 7.38 | 8.12 | 7.78 | 7.90 | 33.80 | 33.77 |
| | 5 | 12.25 | 13.29 | 7.36 | 8.17 | 7.78 | 7.91 | 33.80 | 33.89 |
| | 6 | 12.25 | | 7.36 | | 7.77 | | 33.80 | |
| RW17 | 0 | 13.00 | 13.92 | 8.05 | 8.09 | 7.78 | 7.92 | 33.72 | 33.76 |
| | 1 | 13.01 | 13.91 | 8.03 | 8.14 | 7.79 | 7.91 | 33.72 | 33.76 |
| | 2 | 12.89 | 13.77 | 8.09 | 8.14 | 7.79 | 7.92 | 33.78 | 33.79 |
| | 3 | 12.40 | 13.69 | 7.93 | 8.13 | 7.78 | 7.92 | 33.87 | 33.77 |
| | 4 | 12.30 | 13.41 | 7.56 | 8.16 | 7.77 | 7.90 | 33.84 | 33.79 |
| | 5 | 12.33 | | 7.47 | | 7.77 | | 33.81 | |
| | 6 | 12.30 | | 7.47 | | 7.77 | | 33.80 | |

**Appendix B-2. Water quality parameters at each receiving water monitoring station during flood and ebb tides. Mandalay Generating Station NPDES, summer 2007.**

| | | Temp. (°C) | | Oxygen (mg/l) | | pH | | Salinity (psu) | |
|---|---|---|---|---|---|---|---|---|---|
| | Depth (m) | FLOOD | EBB | FLOOD | EBB | FLOOD | EBB | FLOOD | EBB |
| **Surf Zone** | | | | | | | | | |
| RW1 | 0 | 15.72 | 16.60 | 7.31 | 7.36 | 7.75 | 7.85 | 34.61 | 34.66 |
| RW2 | 0 | 17.54 | 18.85 | 6.92 | 6.87 | 7.66 | 7.81 | 34.25 | 34.61 |
| RW3 | 0 | 15.68 | 16.35 | 7.13 | 7.10 | 7.77 | 7.87 | 34.56 | 34.63 |
| RW4 | 0 | 16.93 | 18.78 | 6.96 | 6.60 | 7.72 | 7.82 | 34.50 | 34.63 |
| RW5 | 0 | 22.63 | 29.04 | 6.07 | 5.28 | 7.51 | 7.74 | 30.30 | 34.47 |
| **Offshore** | | | | | | | | | |
| RW6 | 0 | 15.35 | 15.59 | 7.62 | 7.76 | 7.91 | 8.02 | 33.66 | 33.66 |
| | 1 | 15.21 | 15.59 | 7.64 | 7.76 | 7.91 | 8.02 | 33.68 | 33.66 |
| | 2 | 14.90 | 15.48 | 7.63 | 7.79 | 7.92 | 8.02 | 33.67 | 33.67 |
| | 3 | 14.80 | 15.25 | 7.55 | 7.79 | 7.93 | 8.01 | 33.67 | 33.66 |
| | 4 | 14.76 | 15.01 | 7.57 | 7.74 | 7.92 | 8.00 | 33.68 | 33.67 |
| | 5 | 14.70 | 14.62 | 7.54 | 7.72 | 7.92 | 7.98 | 33.67 | 33.66 |
| | 6 | 14.65 | 14.27 | 7.51 | 7.28 | 7.92 | 7.95 | 33.68 | 33.67 |
| | 7 | 14.63 | 14.11 | 7.53 | 7.01 | 7.91 | 7.95 | 33.67 | 33.67 |
| | 8 | 14.62 | 13.98 | 7.50 | 7.02 | 7.92 | 7.94 | 33.67 | 33.66 |
| | 9 | 14.61 | 13.78 | 7.48 | 7.00 | 7.91 | 7.93 | 33.67 | 33.67 |
| | 10 | 14.60 | 13.76 | 7.47 | 6.90 | 7.91 | 7.93 | 33.67 | 33.65 |
| | 11 | 14.61 | 13.78 | 7.45 | 6.86 | 7.92 | 7.93 | 33.66 | 33.65 |
| RW7 | 0 | 15.41 | 15.49 | 7.42 | 7.75 | 7.90 | 8.01 | 33.64 | 33.66 |
| | 1 | 15.35 | 15.49 | 7.44 | 7.77 | 7.90 | 8.01 | 33.67 | 33.66 |
| | 2 | 14.90 | 15.41 | 7.50 | 7.79 | 7.90 | 8.01 | 33.73 | 33.68 |
| | 3 | 14.74 | 15.30 | 7.49 | 7.78 | 7.92 | 8.00 | 33.69 | 33.69 |
| | 4 | 14.73 | 14.92 | 7.58 | 7.80 | 7.91 | 7.99 | 33.69 | 33.77 |
| | 5 | 14.66 | 14.49 | 7.57 | 7.66 | 7.91 | 7.97 | 33.68 | 33.74 |
| | 6 | 14.65 | 14.27 | 7.52 | 7.36 | 7.91 | 7.95 | 33.67 | 33.71 |
| | 7 | 14.62 | 14.06 | 7.52 | 7.16 | 7.91 | 7.95 | 33.68 | 33.71 |
| | 8 | 14.63 | 13.94 | 7.51 | 7.04 | 7.91 | 7.94 | 33.66 | 33.69 |
| | 9 | 14.59 | 13.78 | 7.47 | 7.00 | 7.90 | 7.93 | 33.67 | 33.68 |
| | 10 | 14.60 | 13.70 | 7.41 | 6.94 | 7.90 | 7.92 | 33.66 | 33.67 |
| | 11 | | 13.68 | | 6.83 | | 7.91 | | 33.66 |
| RW8 | 0 | 15.30 | 15.55 | 7.41 | 7.76 | 7.90 | 8.02 | 33.63 | 33.65 |
| | 1 | 15.16 | 15.55 | 7.42 | 7.74 | 7.90 | 8.02 | 33.71 | 33.65 |
| | 2 | 14.76 | 15.55 | 7.49 | 7.76 | 7.91 | 8.02 | 33.76 | 33.66 |
| | 3 | 14.65 | 15.49 | 7.55 | 7.75 | 7.91 | 8.01 | 33.68 | 33.66 |
| | 4 | 14.62 | 15.29 | 7.58 | 7.77 | 7.91 | 8.01 | 33.67 | 33.66 |
| | 5 | 14.59 | 15.11 | 7.49 | 7.71 | 7.90 | 8.00 | 33.66 | 33.66 |
| | 6 | 14.56 | 14.70 | 7.43 | 7.72 | 7.89 | 7.98 | 33.66 | 33.65 |
| | 7 | 14.54 | 14.11 | 7.35 | 7.51 | 7.89 | 7.95 | 33.67 | 33.68 |
| | 8 | 14.53 | 13.93 | 7.28 | 7.11 | 7.89 | 7.94 | 33.67 | 33.66 |
| | 9 | 14.51 | 13.78 | 7.29 | 7.05 | 7.89 | 7.94 | 33.66 | 33.66 |
| | 10 | 14.47 | 13.68 | 7.17 | 6.93 | 7.87 | 7.93 | 33.66 | 33.66 |
| | 11 | 14.47 | 13.66 | 7.11 | 6.86 | 7.87 | 7.93 | 33.67 | 33.66 |

Appendix B-2. (Cont.).

| | | Temp. (°C) | | Oxygen (mg/l) | | pH | | Salinity (psu) | |
|---|---|---|---|---|---|---|---|---|---|
| | Depth (m) | FLOOD | EBB | FLOOD | EBB | FLOOD | EBB | FLOOD | EBB |
| RW9 | 0 | 15.27 | 15.46 | 7.24 | 7.63 | 7.88 | 8.00 | 33.66 | 33.64 |
| | 1 | 15.20 | 15.46 | 7.25 | 7.66 | 7.88 | 8.00 | 33.64 | 33.64 |
| | 2 | 14.82 | 15.45 | 7.29 | 7.67 | 7.89 | 8.00 | 33.67 | 33.64 |
| | 3 | 14.74 | 15.38 | 7.47 | 7.67 | 7.91 | 8.00 | 33.67 | 33.65 |
| | 4 | 14.60 | 15.20 | 7.58 | 7.68 | 7.90 | 7.99 | 33.67 | 33.66 |
| | 5 | 14.51 | 15.18 | 7.39 | 7.56 | 7.88 | 7.98 | 33.66 | 33.65 |
| | 6 | 14.49 | 14.43 | 7.21 | 7.63 | 7.87 | 7.97 | 33.65 | 33.65 |
| | 7 | 14.42 | 14.04 | 7.14 | 7.23 | 7.87 | 7.95 | 33.67 | 33.67 |
| | 8 | 14.37 | 13.81 | 7.07 | 7.15 | 7.86 | 7.94 | 33.66 | 33.66 |
| | 9 | 14.32 | 13.77 | 7.00 | 6.97 | 7.85 | 7.93 | 33.66 | 33.66 |
| | 10 | 14.24 | 13.67 | 6.96 | 6.95 | 7.85 | 7.92 | 33.67 | 33.66 |
| | 11 | | 13.66 | | 6.80 | | 7.91 | | 33.66 |
| RW10 | 0 | 15.16 | 16.59 | 7.28 | 7.87 | 7.88 | 8.00 | 33.68 | 33.61 |
| | 1 | 15.10 | 16.59 | 7.24 | 7.87 | 7.88 | 8.01 | 33.64 | 33.61 |
| | 2 | 14.77 | 16.00 | 7.31 | 8.00 | 7.89 | 8.01 | 33.70 | 33.63 |
| | 3 | 14.67 | 14.89 | 7.42 | 7.92 | 7.89 | 7.99 | 33.68 | 33.66 |
| | 4 | 14.57 | 14.14 | 7.43 | 7.55 | 7.88 | 7.97 | 33.67 | 33.69 |
| | 5 | 14.47 | 13.91 | 7.30 | 7.26 | 7.87 | 7.95 | 33.67 | 33.67 |
| | 6 | 14.37 | 13.84 | 7.14 | 7.07 | 7.86 | 7.94 | 33.67 | 33.66 |
| | 7 | 14.32 | 13.75 | 7.03 | 7.02 | 7.85 | 7.94 | 33.66 | 33.67 |
| | 8 | 14.24 | 13.67 | 6.99 | 6.98 | 7.85 | 7.93 | 33.67 | 33.66 |
| | 9 | 14.21 | 13.62 | 6.95 | 6.89 | 7.84 | 7.92 | 33.67 | 33.66 |
| | 10 | 14.18 | 13.61 | 6.89 | 6.77 | 7.83 | 7.92 | 33.67 | 33.66 |
| | 11 | | 13.62 | | 6.76 | | 7.92 | | 33.65 |
| RW11 | 0 | 15.21 | 16.08 | 7.18 | 7.67 | 7.88 | 7.98 | 33.67 | 33.59 |
| | 1 | 15.25 | 16.05 | 7.14 | 7.71 | 7.88 | 7.98 | 33.66 | 33.63 |
| | 2 | 15.00 | 15.90 | 7.19 | 7.72 | 7.88 | 7.98 | 33.68 | 33.62 |
| | 3 | 14.78 | 15.78 | 7.24 | 7.74 | 7.90 | 7.98 | 33.68 | 33.63 |
| | 4 | 14.70 | 14.83 | 7.48 | 7.85 | 7.91 | 7.96 | 33.67 | 33.99 |
| | 5 | 14.64 | 14.21 | 7.43 | 7.45 | 7.89 | 7.93 | 33.66 | 33.77 |
| | 6 | 14.56 | 13.83 | 7.15 | 6.96 | 7.87 | 7.93 | 33.67 | 33.72 |
| | 7 | 14.39 | | 7.11 | | 7.85 | | 33.68 | |
| RW12 | 0 | 15.38 | 16.85 | 7.25 | 7.57 | 7.88 | 7.96 | 33.65 | 33.57 |
| | 1 | 15.31 | 16.81 | 7.27 | 7.59 | 7.88 | 7.96 | 33.65 | 33.58 |
| | 2 | 15.15 | 16.35 | 7.21 | 7.63 | 7.87 | 7.97 | 33.65 | 33.59 |
| | 3 | 14.67 | 14.83 | 7.09 | 7.80 | 7.85 | 7.98 | 33.65 | 33.76 |
| | 4 | 14.37 | 14.21 | 6.85 | 7.41 | 7.83 | 7.96 | 33.66 | 33.68 |
| | 5 | 14.25 | 13.90 | 6.82 | 7.08 | 7.83 | 7.93 | 33.67 | 33.69 |
| | 6 | 14.15 | 13.76 | 6.85 | 6.79 | 7.83 | 7.92 | 33.67 | 33.66 |
| | 7 | | 13.75 | | 6.73 | | 7.92 | | 33.66 |
| RW13 | 0 | 15.54 | 15.34 | 7.50 | 7.63 | 7.91 | 7.98 | 33.61 | 33.65 |
| | 1 | 15.26 | 15.32 | 7.63 | 7.63 | 7.90 | 7.98 | 33.71 | 33.65 |
| | 2 | 14.90 | 15.30 | 7.42 | 7.61 | 7.90 | 7.99 | 33.74 | 33.65 |
| | 3 | 14.82 | 15.31 | 7.37 | 7.62 | 7.91 | 7.99 | 33.67 | 33.65 |
| | 4 | 14.76 | 15.24 | 7.48 | 7.64 | 7.93 | 7.98 | 33.68 | 33.66 |
| | 5 | 14.74 | 14.75 | 7.52 | 7.70 | 7.92 | 7.98 | 33.67 | 33.67 |
| | 6 | 14.76 | 14.20 | 7.54 | 7.37 | 7.91 | 7.94 | 33.68 | 33.69 |

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

| | | Temp. (°C) | | Oxygen (mg/l) | | pH | | Salinity (psu) | |
|---|---|---|---|---|---|---|---|---|---|
| | Depth (m) | FLOOD | EBB | FLOOD | EBB | FLOOD | EBB | FLOOD | EBB |
| RW14 | 0 | 16.71 | 15.50 | 7.66 | 7.67 | 7.92 | 7.98 | 33.63 | 33.65 |
| | 1 | 16.66 | 15.50 | 7.67 | 7.66 | 7.92 | 7.98 | 33.63 | 33.64 |
| | 2 | 16.11 | 15.50 | 7.77 | 7.65 | 7.91 | 7.97 | 33.67 | 33.65 |
| | 3 | 14.46 | 15.48 | 7.78 | 7.66 | 7.88 | 7.98 | 33.92 | 33.66 |
| | 4 | 14.22 | 15.03 | 6.98 | 7.75 | 7.84 | 7.97 | 33.74 | 33.75 |
| | 5 | 14.18 | 14.49 | 6.85 | 7.61 | 7.84 | 7.94 | 33.69 | 33.72 |
| | 6 | 14.17 | 14.32 | 6.91 | 7.21 | 7.83 | 7.93 | 33.67 | 33.69 |
| | 7 | | 14.12 | | 7.08 | | 7.93 | | 33.71 |
| RW15 | 0 | 15.62 | 15.94 | 7.68 | 7.82 | 7.94 | 8.04 | 33.61 | 33.67 |
| | 1 | 15.62 | 15.93 | 7.68 | 7.82 | 7.94 | 8.04 | 33.59 | 33.66 |
| | 2 | 15.52 | 15.82 | 7.67 | 7.82 | 7.93 | 8.04 | 33.62 | 33.68 |
| | 3 | 15.21 | 15.57 | 7.71 | 7.84 | 7.93 | 8.03 | 33.65 | 33.66 |
| | 4 | 14.92 | 15.24 | 7.56 | 7.80 | 7.92 | 8.02 | 33.69 | 33.67 |
| | 5 | 14.89 | 15.03 | 7.43 | 7.72 | 7.92 | 8.00 | 33.68 | 33.67 |
| | 6 | 14.88 | 14.87 | 7.44 | 7.62 | 7.92 | 8.00 | 33.67 | 33.67 |
| | 7 | 14.84 | 14.63 | 7.44 | 7.54 | 7.93 | 7.98 | 33.67 | 33.69 |
| RW16 | 0 | 15.00 | 16.20 | 7.34 | 7.79 | 7.90 | 7.98 | 33.66 | 33.59 |
| | 1 | 14.97 | 16.20 | 7.35 | 7.79 | 7.90 | 7.98 | 33.68 | 33.58 |
| | 2 | 14.85 | 16.11 | 7.38 | 7.80 | 7.91 | 7.98 | 33.67 | 33.60 |
| | 3 | 14.83 | 15.86 | 7.40 | 7.82 | 7.91 | 7.98 | 33.69 | 33.63 |
| | 4 | 14.75 | 14.72 | 7.45 | 7.91 | 7.91 | 7.96 | 33.67 | 33.76 |
| | 5 | 14.70 | 14.40 | 7.48 | 7.21 | 7.91 | 7.95 | 33.66 | 33.66 |
| | 6 | 14.71 | 14.35 | 7.40 | 6.96 | 7.91 | 7.93 | 33.66 | 33.66 |
| RW17 | 0 | 15.61 | 16.84 | 7.19 | 7.73 | 7.88 | 7.98 | 33.62 | 33.54 |
| | 1 | 15.40 | 16.79 | 7.34 | 7.73 | 7.88 | 7.98 | 33.67 | 33.55 |
| | 2 | 14.80 | 16.17 | 7.28 | 7.82 | 7.88 | 7.97 | 33.68 | 33.57 |
| | 3 | 14.69 | 14.45 | 7.26 | 7.58 | 7.89 | 7.94 | 33.67 | 33.72 |
| | 4 | 14.56 | 13.79 | 7.31 | 6.84 | 7.88 | 7.93 | 33.68 | 33.67 |
| | 5 | 14.36 | 13.78 | 7.17 | 6.70 | 7.86 | 7.92 | 33.67 | 33.66 |
| | 6 | 14.21 | 13.77 | 6.94 | 6.70 | 7.84 | 7.92 | 33.67 | 33.67 |
| | 7 | 14.17 | | 6.80 | | 7.83 | | 33.66 | |

# 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 $\div$ 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.

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

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 0.35$\phi$ 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 4.0$\phi$ 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.

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

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).

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

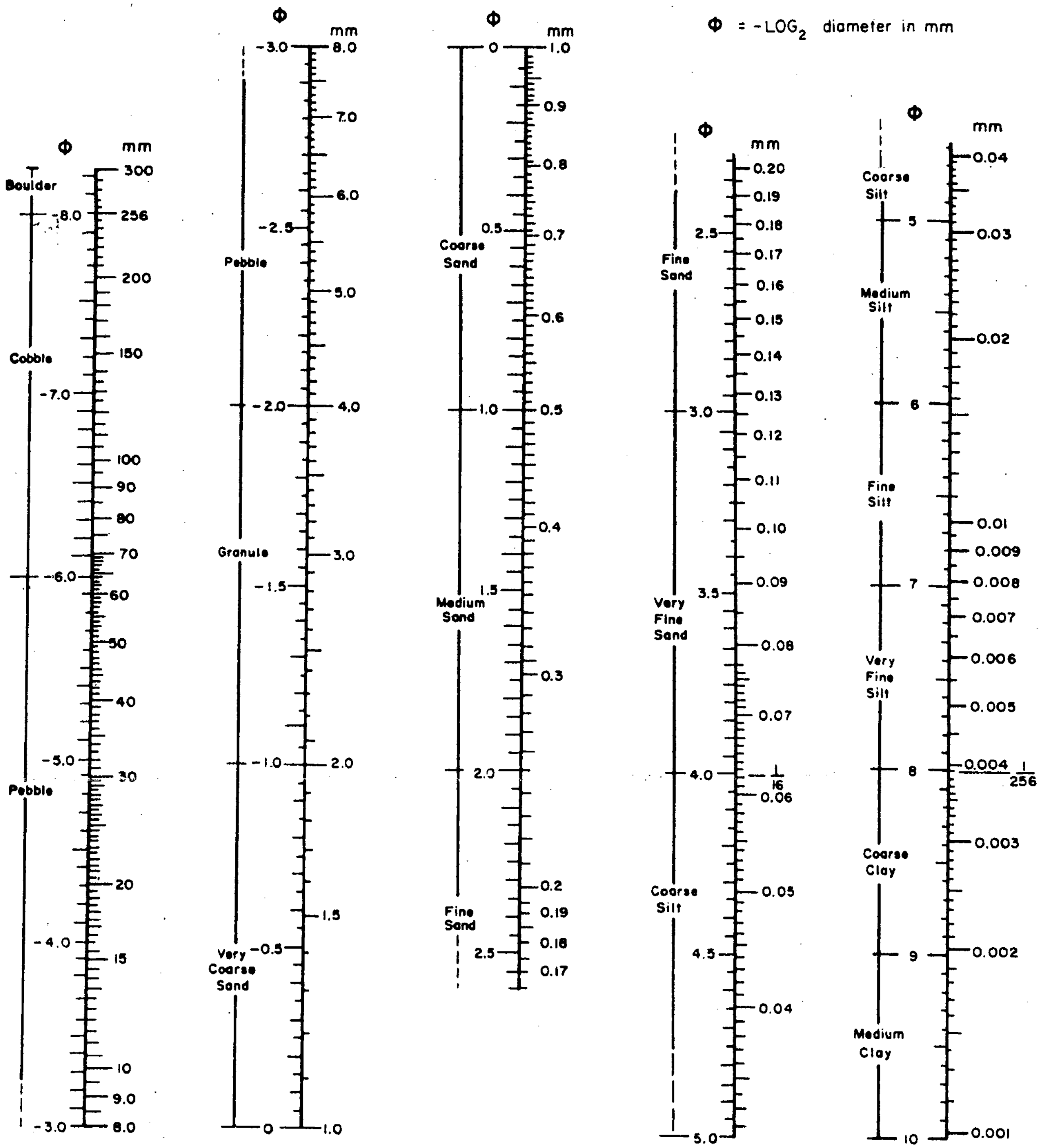
LITERATURE CITED

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:

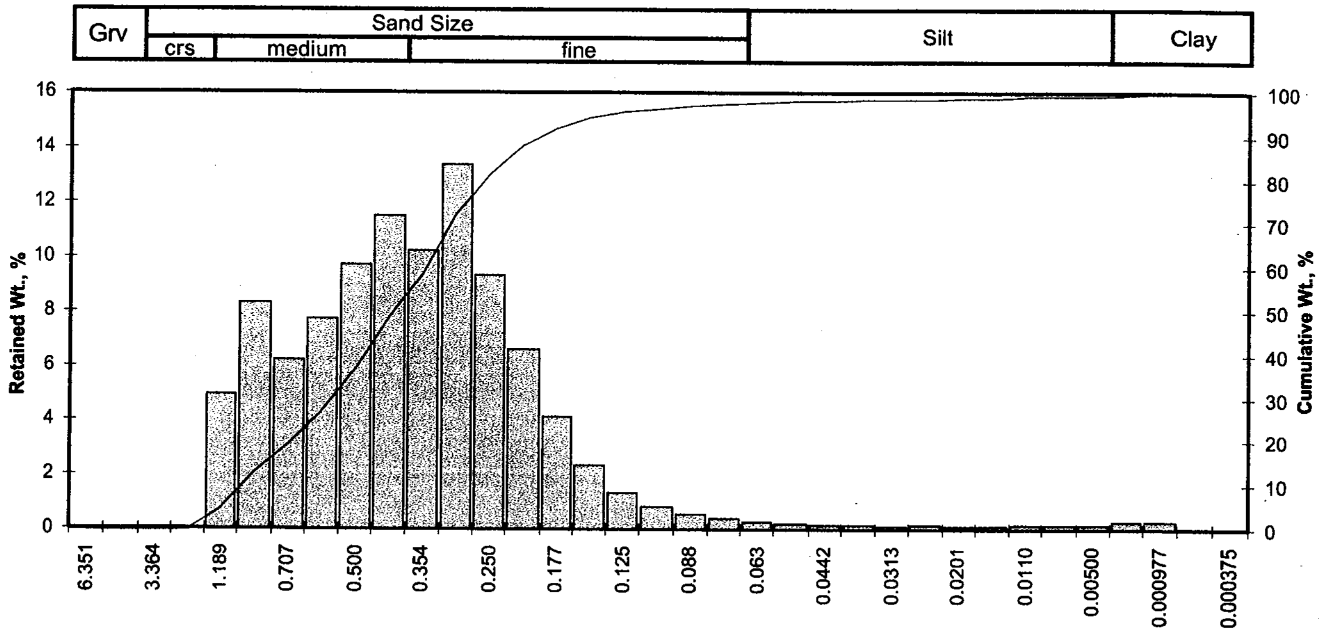
| | | |
|---|---|---|
| $\sigma_I$ under | .35 φ, | very well sorted |
| | .35-.50 φ, | well sorted |
| | .50-.71 φ, | moderately well sorted |
| | .71-1.0 φ | moderately sorted |
| | 1.0-2.0 φ, | poorly sorted |
| | 2.0-4.0 φ, | very poorly sorted |
| | over 4.0 φ, | extremely poorly sorted |

Appendix C-2. Sediment grain size distribution and statistical parameters by station. Mandalay Generating Station NPDES, 2007.

**PTS** Laboratories, Inc.

**Particle Size Analysis - ASTM D4464M**

| | | | |
|---|---|---|---|
| **Client:** | Calscience | **PTS File No:** | 37791 |
| **Project:** | N/A | **Sample ID:** | MGS B1 |
| **Project No:** | 07-09-1308 | **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 | 4.94 | 4.94 | 4.94 |
| 0.0331 | 0.841 | 0.25 | 20 | 8.36 | 8.36 | 13.30 |
| 0.0278 | 0.707 | 0.50 | 25 | 6.21 | 6.21 | 19.51 |
| 0.0234 | 0.595 | 0.75 | 30 | 7.74 | 7.74 | 27.25 |
| 0.0197 | 0.500 | 1.00 | 35 | 9.74 | 9.74 | 36.99 |
| 0.0166 | 0.420 | 1.25 | 40 | 11.50 | 11.50 | 48.49 |
| 0.0139 | 0.354 | 1.50 | 45 | 10.20 | 10.20 | 58.69 |
| 0.0117 | 0.297 | 1.75 | 50 | 13.40 | 13.40 | 72.09 |
| 0.0098 | 0.250 | 2.00 | 60 | 9.34 | 9.34 | 81.43 |
| 0.0083 | 0.210 | 2.25 | 70 | 6.63 | 6.63 | 88.05 |
| 0.0070 | 0.177 | 2.50 | 80 | 4.13 | 4.13 | 92.18 |
| 0.0059 | 0.149 | 2.75 | 100 | 2.34 | 2.34 | 94.52 |
| 0.0049 | 0.125 | 3.00 | 120 | 1.34 | 1.34 | 95.86 |
| 0.0041 | 0.105 | 3.25 | 140 | 0.81 | 0.81 | 96.67 |
| 0.0035 | 0.088 | 3.50 | 170 | 0.54 | 0.54 | 97.21 |
| 0.0029 | 0.074 | 3.75 | 200 | 0.39 | 0.39 | 97.60 |
| 0.0025 | 0.063 | 4.00 | 230 | 0.29 | 0.29 | 97.89 |
| 0.0021 | 0.053 | 4.25 | 270 | 0.23 | 0.23 | 98.12 |
| 0.00174 | 0.0442 | 4.50 | 325 | 0.19 | 0.19 | 98.31 |
| 0.00146 | 0.0372 | 4.75 | 400 | 0.16 | 0.16 | 98.47 |
| 0.00123 | 0.0313 | 5.00 | 450 | 0.13 | 0.13 | 98.60 |
| 0.000986 | 0.0250 | 5.32 | 500 | 0.14 | 0.14 | 98.74 |
| 0.000790 | 0.0201 | 5.64 | 635 | 0.13 | 0.13 | 98.87 |
| 0.000615 | 0.0156 | 6.00 | | 0.12 | 0.12 | 98.99 |
| 0.000435 | 0.0110 | 6.50 | | 0.15 | 0.15 | 99.14 |
| 0.000308 | 0.00781 | 7.00 | | 0.14 | 0.14 | 99.28 |
| 0.000197 | 0.00500 | 7.65 | | 0.16 | 0.16 | 99.44 |
| 0.000077 | 0.00195 | 9.00 | | 0.27 | 0.27 | 99.71 |
| 0.000038 | 0.000977 | 10.00 | | 0.26 | 0.26 | 99.97 |
| 0.000019 | 0.000488 | 11.00 | | 0.03 | 0.03 | 100.00 |
| 0.000015 | 0.000375 | 11.38 | | 0.00 | 0.00 | 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 | -0.25 | 0.0467 | 1.186 |
| 10 | 0.05 | 0.0380 | 0.964 |
| 16 | 0.36 | 0.0307 | 0.780 |
| 25 | 0.68 | 0.0246 | 0.625 |
| 40 | 1.07 | 0.0188 | 0.478 |
| 50 | 1.29 | 0.0161 | 0.410 |
| 60 | 1.52 | 0.0137 | 0.348 |
| 75 | 1.83 | 0.0111 | 0.282 |
| 84 | 2.10 | 0.0092 | 0.234 |
| 90 | 2.37 | 0.0076 | 0.194 |
| 95 | 2.84 | 0.0055 | 0.140 |

| Measure | Trask | Inman | Folk-Ward |
|---|---|---|---|
| Median, phi | 1.29 | 1.29 | 1.29 |
| Median, in. | 0.0161 | 0.0161 | 0.0161 |
| Median, mm | 0.410 | 0.410 | 0.410 |
| Mean, phi | 1.14 | 1.23 | 1.25 |
| Mean, in. | 0.0179 | 0.0168 | 0.0166 |
| Mean, mm | 0.453 | 0.427 | 0.421 |
| Sorting | 1.490 | 0.869 | 0.902 |
| Skewness | 1.024 | -0.068 | -0.031 |
| Kurtosis | 0.223 | 0.775 | 1.099 |

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

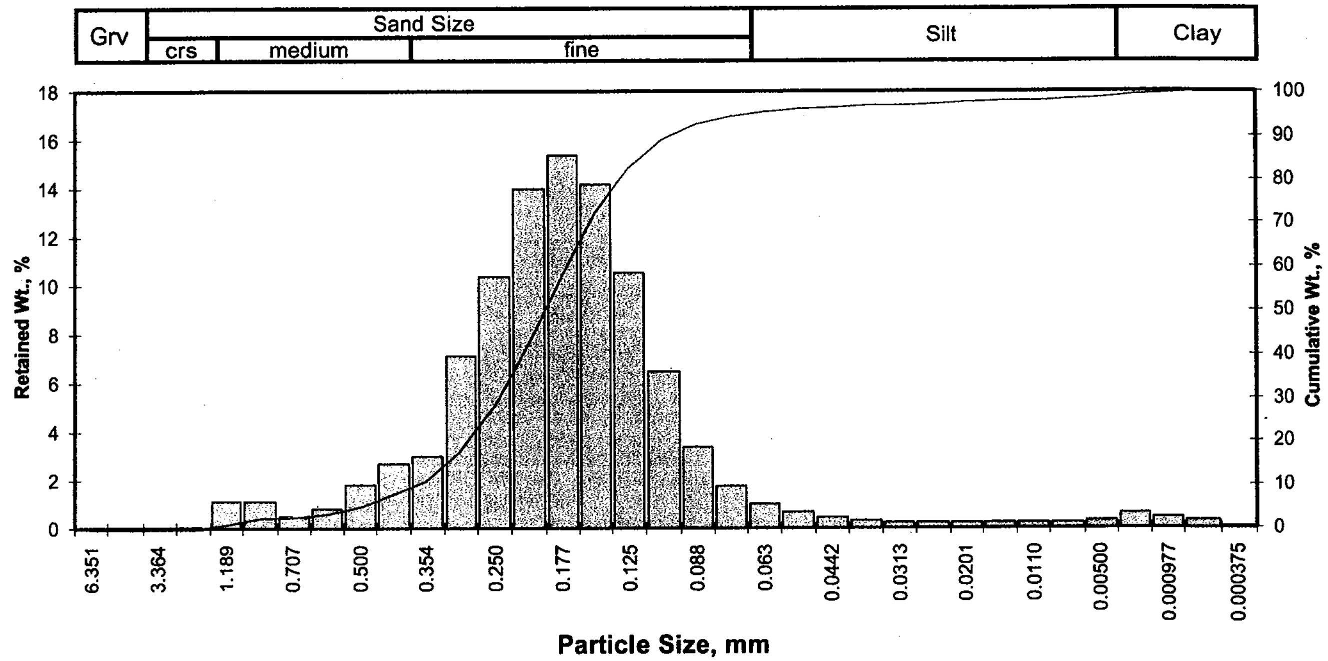
| Description | Retained on Sieve # | Weight Percent |
|---|---|---|
| Gravel | 4 | 0.00 |
| Coarse Sand | 10 | 0.00 |
| Medium Sand | 40 | 48.49 |
| Fine Sand | 200 | 49.12 |
| Silt | >0.005 mm | 1.84 |
| Clay | <0.005 mm | 0.56 |
| | **Total** | **100** |



Phone: (562) 907-3607 Fax: (562) 907-3610

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

| | | | |
|---|---|---|---|
| **Client:** | Calscience | **PTS File No:** | 37791 |
| **Project:** | N/A | **Sample ID:** | MGS B2 |
| **Project No:** | 07-09-1308 | **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 | 1.15 | 1.15 | 1.15 |
| 0.0331 | 0.841 | 0.25 | 20 | 1.11 | 1.11 | 2.26 |
| 0.0278 | 0.707 | 0.50 | 25 | 0.47 | 0.47 | 2.73 |
| 0.0234 | 0.595 | 0.75 | 30 | 0.80 | 0.80 | 3.53 |
| 0.0197 | 0.500 | 1.00 | 35 | 1.83 | 1.83 | 5.36 |
| 0.0166 | 0.420 | 1.25 | 40 | 2.66 | 2.66 | 8.01 |
| 0.0139 | 0.354 | 1.50 | 45 | 3.00 | 3.00 | 11.01 |
| 0.0117 | 0.297 | 1.75 | 50 | 7.13 | 7.13 | 18.14 |
| 0.0098 | 0.250 | 2.00 | 60 | 10.40 | 10.39 | 28.53 |
| 0.0083 | 0.210 | 2.25 | 70 | 14.00 | 13.99 | 42.52 |
| 0.0070 | 0.177 | 2.50 | 80 | 15.40 | 15.39 | 57.91 |
| 0.0059 | 0.149 | 2.75 | 100 | 14.20 | 14.19 | 72.10 |
| 0.0049 | 0.125 | 3.00 | 120 | 10.60 | 10.59 | 82.70 |
| 0.0041 | 0.105 | 3.25 | 140 | 6.51 | 6.51 | 89.20 |
| 0.0035 | 0.088 | 3.50 | 170 | 3.40 | 3.40 | 92.60 |
| 0.0029 | 0.074 | 3.75 | 200 | 1.74 | 1.74 | 94.34 |
| 0.0025 | 0.063 | 4.00 | 230 | 1.02 | 1.02 | 95.36 |
| 0.0021 | 0.053 | 4.25 | 270 | 0.66 | 0.66 | 96.02 |
| 0.00174 | 0.0442 | 4.50 | 325 | 0.43 | 0.43 | 96.45 |
| 0.00146 | 0.0372 | 4.75 | 400 | 0.31 | 0.31 | 96.76 |
| 0.00123 | 0.0313 | 5.00 | 450 | 0.25 | 0.25 | 97.01 |
| 0.000986 | 0.0250 | 5.32 | 500 | 0.27 | 0.27 | 97.28 |
| 0.000790 | 0.0201 | 5.64 | 635 | 0.24 | 0.24 | 97.52 |
| 0.000615 | 0.0156 | 6.00 | | 0.23 | 0.23 | 97.75 |
| 0.000435 | 0.0110 | 6.50 | | 0.28 | 0.28 | 98.03 |
| 0.000308 | 0.00781 | 7.00 | | 0.26 | 0.26 | 98.29 |
| 0.000197 | 0.00500 | 7.65 | | 0.32 | 0.32 | 98.61 |
| 0.000077 | 0.00195 | 9.00 | | 0.60 | 0.60 | 99.21 |
| 0.000038 | 0.000977 | 10.00 | | 0.43 | 0.43 | 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** | | | | **100.10** | **100.00** | **100.00** |

| Cumulative Weight Percent greater than | | | |
|---|---|---|---|
| **Weight percent** | **Phi Value** | **Particle Size Inches** | **Particle Size Millimeters** |
| 5 | 0.95 | 0.0204 | 0.517 |
| 10 | 1.42 | 0.0148 | 0.375 |
| 16 | 1.67 | 0.0123 | 0.313 |
| 25 | 1.92 | 0.0104 | 0.265 |
| 40 | 2.20 | 0.0085 | 0.217 |
| 50 | 2.37 | 0.0076 | 0.193 |
| 60 | 2.54 | 0.0068 | 0.172 |
| 75 | 2.82 | 0.0056 | 0.142 |
| 84 | 3.05 | 0.0048 | 0.121 |
| 90 | 3.31 | 0.0040 | 0.101 |
| 95 | 3.91 | 0.0026 | 0.066 |

| Measure | Trask | Inman | Folk-Ward |
|---|---|---|---|
| Median, phi | 2.37 | 2.37 | 2.37 |
| Median, in. | 0.0076 | 0.0076 | 0.0076 |
| Median, mm | 0.193 | 0.193 | 0.193 |
| Mean, phi | 2.30 | 2.36 | 2.37 |
| Mean, in. | 0.0080 | 0.0077 | 0.0076 |
| Mean, mm | 0.203 | 0.194 | 0.194 |
| Sorting | 1.368 | 0.688 | 0.792 |
| Skewness | 1.003 | -0.013 | 0.014 |
| Kurtosis | 0.225 | 1.153 | 1.343 |

| 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 | 8.01 |
| Fine Sand | 200 | 86.32 |
| Silt | >0.005 mm | 4.27 |
| Clay | <0.005 mm | 1.39 |
| | Total | 100 |

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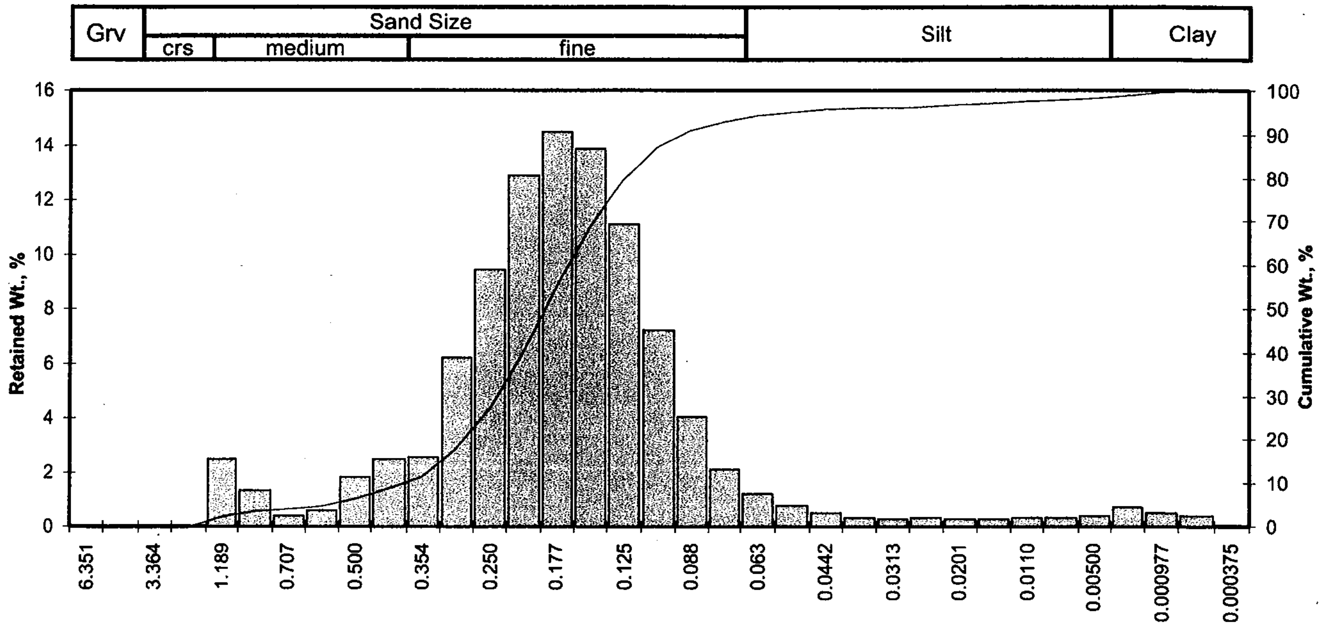
**PTS** Laboratories, Inc.

**Particle Size Analysis - ASTM D4464M**

| | | | |
|---|---|---|---|
| **Client:** | Calscience | **PTS File No:** | 37791 |
| **Project:** | N/A | **Sample ID:** | MGS B3 |
| **Project No:** | 07-09-1308 | **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 | 2.50 | 2.50 | 2.50 |
| 0.0331 | 0.841 | 0.25 | 20 | 1.32 | 1.32 | 3.82 |
| 0.0278 | 0.707 | 0.50 | 25 | 0.41 | 0.41 | 4.23 |
| 0.0234 | 0.595 | 0.75 | 30 | 0.61 | 0.61 | 4.84 |
| 0.0197 | 0.500 | 1.00 | 35 | 1.83 | 1.83 | 6.66 |
| 0.0166 | 0.420 | 1.25 | 40 | 2.51 | 2.51 | 9.17 |
| 0.0139 | 0.354 | 1.50 | 45 | 2.54 | 2.54 | 11.71 |
| 0.0117 | 0.297 | 1.75 | 50 | 6.24 | 6.23 | 17.94 |
| 0.0098 | 0.250 | 2.00 | 60 | 9.48 | 9.47 | 27.42 |
| 0.0083 | 0.210 | 2.25 | 70 | 12.90 | 12.89 | 40.30 |
| 0.0070 | 0.177 | 2.50 | 80 | 14.50 | 14.49 | 54.79 |
| 0.0059 | 0.149 | 2.75 | 100 | 13.90 | 13.89 | 68.68 |
| 0.0049 | 0.125 | 3.00 | 120 | 11.10 | 11.09 | 79.77 |
| 0.0041 | 0.105 | 3.25 | 140 | 7.24 | 7.23 | 87.00 |
| 0.0035 | 0.088 | 3.50 | 170 | 4.04 | 4.04 | 91.04 |
| 0.0029 | 0.074 | 3.75 | 200 | 2.14 | 2.14 | 93.18 |
| 0.0025 | 0.063 | 4.00 | 230 | 1.23 | 1.23 | 94.40 |
| 0.0021 | 0.053 | 4.25 | 270 | 0.79 | 0.79 | 95.19 |
| 0.00174 | 0.0442 | 4.50 | 325 | 0.51 | 0.51 | 95.70 |
| 0.00146 | 0.0372 | 4.75 | 400 | 0.36 | 0.36 | 96.06 |
| 0.00123 | 0.0313 | 5.00 | 450 | 0.29 | 0.29 | 96.35 |
| 0.000986 | 0.0250 | 5.32 | 500 | 0.31 | 0.31 | 96.66 |
| 0.000790 | 0.0201 | 5.64 | 635 | 0.28 | 0.28 | 96.94 |
| 0.000615 | 0.0156 | 6.00 | | 0.28 | 0.28 | 97.22 |
| 0.000435 | 0.0110 | 6.50 | | 0.36 | 0.36 | 97.58 |
| 0.000308 | 0.00781 | 7.00 | | 0.34 | 0.34 | 97.92 |
| 0.000197 | 0.00500 | 7.65 | | 0.41 | 0.41 | 98.33 |
| 0.000077 | 0.00195 | 9.00 | | 0.75 | 0.75 | 99.08 |
| 0.000038 | 0.000977 | 10.00 | | 0.50 | 0.50 | 99.58 |
| 0.000019 | 0.000488 | 11.00 | | 0.38 | 0.38 | 99.96 |
| 0.000015 | 0.000375 | 11.38 | | 0.04 | 0.04 | 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 | 0.77 | 0.0230 | 0.585 |
| 10 | 1.33 | 0.0156 | 0.397 |
| 16 | 1.67 | 0.0124 | 0.314 |
| 25 | 1.94 | 0.0103 | 0.261 |
| 40 | 2.24 | 0.0083 | 0.211 |
| 50 | 2.42 | 0.0074 | 0.187 |
| 60 | 2.59 | 0.0065 | 0.166 |
| 75 | 2.89 | 0.0053 | 0.135 |
| 84 | 3.15 | 0.0044 | 0.113 |
| 90 | 3.44 | 0.0036 | 0.092 |
| 95 | 4.19 | 0.0022 | 0.055 |

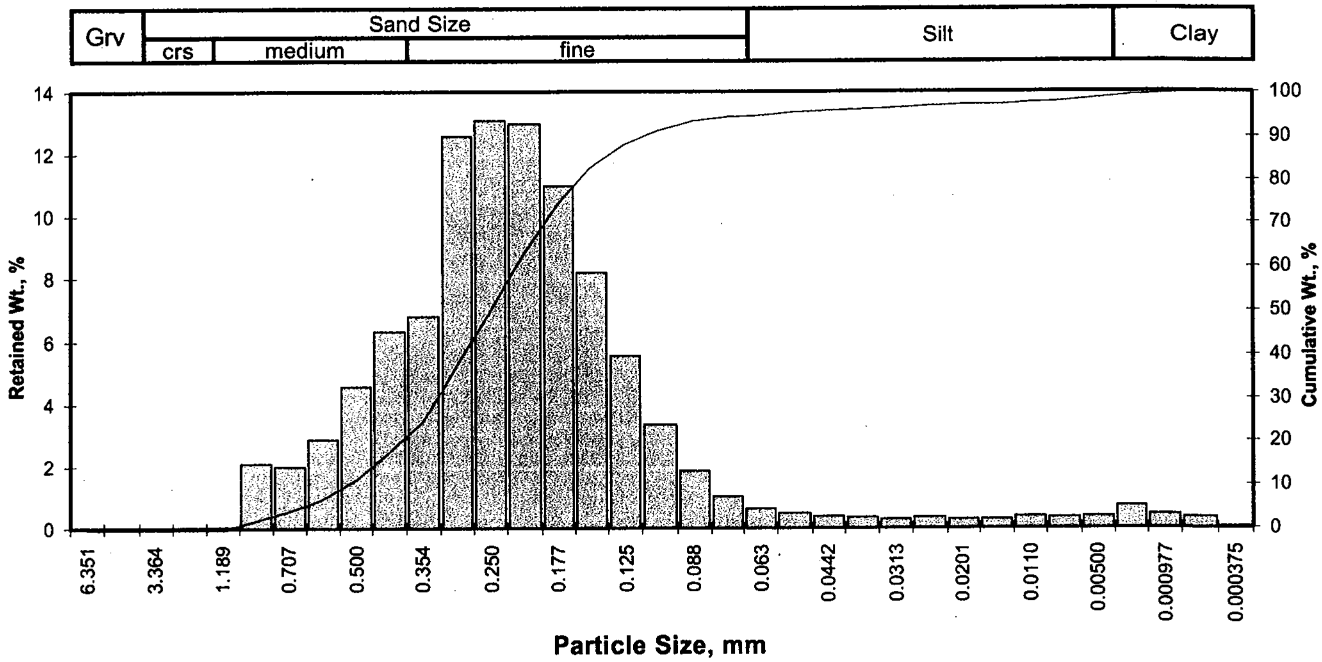
| Measure | Trask | Inman | Folk-Ward |
|---|---|---|---|
| Median, phi | 2.42 | 2.42 | 2.42 |
| Median, in. | 0.0074 | 0.0074 | 0.0074 |
| Median, mm | 0.187 | 0.187 | 0.187 |
| Mean, phi | 2.34 | 2.41 | 2.41 |
| Mean, in. | 0.0078 | 0.0074 | 0.0074 |
| Mean, mm | 0.198 | 0.188 | 0.188 |
| Sorting | 1.393 | 0.737 | 0.886 |
| Skewness | 1.002 | -0.011 | 0.013 |
| Kurtosis | 0.208 | 1.317 | 1.464 |
| 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 | 9.17 |
| Fine Sand | 200 | 84.00 |
| Silt | >0.005 mm | 5.16 |
| Clay | <0.005 mm | 1.67 |
| | **Total** | **100** |

**PTS** Laboratories, Inc.

## Particle Size Analysis - ASTM D4464M

| | | | |
|---|---|---|---|
| **Client:** | Calscience | **PTS File No:** | 37791 |
| **Project:** | N/A | **Sample ID:** | MGS B4 |
| **Project No:** | 07-09-1308 | **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 | 0.04 | 0.04 | 0.04 |
| 0.0331 | 0.841 | 0.25 | 20 | 2.07 | 2.07 | 2.10 |
| 0.0278 | 0.707 | 0.50 | 25 | 1.98 | 1.98 | 4.08 |
| 0.0234 | 0.595 | 0.75 | 30 | 2.85 | 2.85 | 6.93 |
| 0.0197 | 0.500 | 1.00 | 35 | 4.59 | 4.59 | 11.52 |
| 0.0166 | 0.420 | 1.25 | 40 | 6.33 | 6.33 | 17.85 |
| 0.0139 | 0.354 | 1.50 | 45 | 6.81 | 6.81 | 24.65 |
| 0.0117 | 0.297 | 1.75 | 50 | 12.60 | 12.59 | 37.24 |
| 0.0098 | 0.250 | 2.00 | 60 | 13.10 | 13.09 | 50.34 |
| 0.0083 | 0.210 | 2.25 | 70 | 13.00 | 12.99 | 63.33 |
| 0.0070 | 0.177 | 2.50 | 80 | 11.00 | 10.99 | 74.32 |
| 0.0059 | 0.149 | 2.75 | 100 | 8.20 | 8.20 | 82.52 |
| 0.0049 | 0.125 | 3.00 | 120 | 5.55 | 5.55 | 88.06 |
| 0.0041 | 0.105 | 3.25 | 140 | 3.36 | 3.36 | 91.42 |
| 0.0035 | 0.088 | 3.50 | 170 | 1.85 | 1.85 | 93.27 |
| 0.0029 | 0.074 | 3.75 | 200 | 1.01 | 1.01 | 94.28 |
| 0.0025 | 0.063 | 4.00 | 230 | 0.64 | 0.64 | 94.92 |
| 0.0021 | 0.053 | 4.25 | 270 | 0.48 | 0.48 | 95.40 |
| 0.00174 | 0.0442 | 4.50 | 325 | 0.40 | 0.40 | 95.80 |
| 0.00146 | 0.0372 | 4.75 | 400 | 0.34 | 0.34 | 96.14 |
| 0.00123 | 0.0313 | 5.00 | 450 | 0.29 | 0.29 | 96.43 |
| 0.000986 | 0.0250 | 5.32 | 500 | 0.33 | 0.33 | 96.76 |
| 0.000790 | 0.0201 | 5.64 | 635 | 0.30 | 0.30 | 97.06 |
| 0.000615 | 0.0156 | 6.00 | | 0.30 | 0.30 | 97.36 |
| 0.000435 | 0.0110 | 6.50 | | 0.37 | 0.37 | 97.73 |
| 0.000308 | 0.00781 | 7.00 | | 0.34 | 0.34 | 98.07 |
| 0.000197 | 0.00500 | 7.65 | | 0.41 | 0.41 | 98.48 |
| 0.000077 | 0.00195 | 9.00 | | 0.72 | 0.72 | 99.20 |
| 0.000038 | 0.000977 | 10.00 | | 0.45 | 0.45 | 99.65 |
| 0.000019 | 0.000488 | 11.00 | | 0.32 | 0.32 | 99.97 |
| 0.000015 | 0.000375 | 11.38 | | 0.04 | 0.03 | 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 | 0.58 | 0.0263 | 0.669 |
| 10 | 0.92 | 0.0208 | 0.530 |
| 16 | 1.18 | 0.0174 | 0.442 |
| 25 | 1.51 | 0.0139 | 0.352 |
| 40 | 1.80 | 0.0113 | 0.287 |
| 50 | 1.99 | 0.0099 | 0.251 |
| 60 | 2.19 | 0.0087 | 0.220 |
| 75 | 2.52 | 0.0069 | 0.174 |
| 84 | 2.82 | 0.0056 | 0.142 |
| 90 | 3.14 | 0.0045 | 0.113 |
| 95 | 4.04 | 0.0024 | 0.061 |

| Measure | Trask | Inman | Folk-Ward |
|---|---|---|---|
| Median, phi | 1.99 | 1.99 | 1.99 |
| Median, in. | 0.0099 | 0.0099 | 0.0099 |
| Median, mm | 0.251 | 0.251 | 0.251 |
| Mean, phi | 1.93 | 2.00 | 2.00 |
| Mean, in. | 0.0104 | 0.0099 | 0.0099 |
| Mean, mm | 0.263 | 0.251 | 0.251 |
| Sorting | 1.421 | 0.820 | 0.935 |
| Skewness | 0.986 | 0.004 | 0.094 |
| Kurtosis | 0.213 | 1.111 | 1.400 |
| 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 | 17.85 |
| Fine Sand | 200 | 76.43 |
| Silt | >0.005 mm | 4.20 |
| Clay | <0.005 mm | 1.52 |
| | **Total** | **100** |



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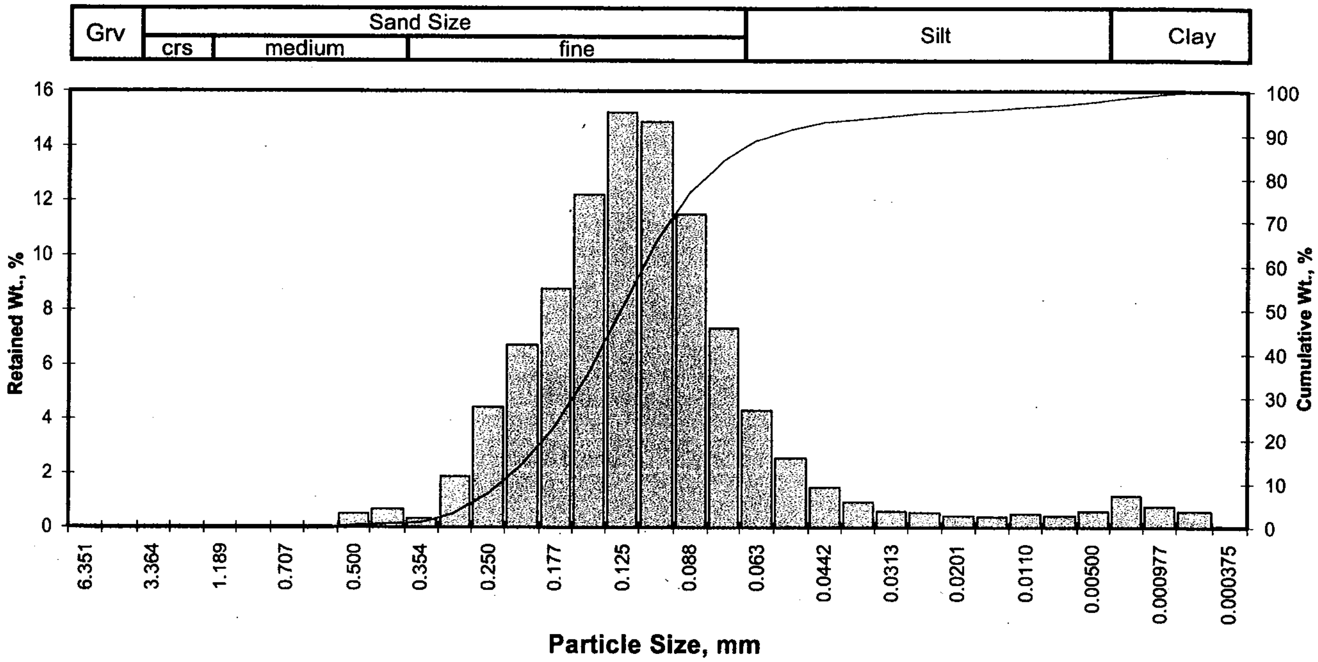
Appendix C-2. (Cont.).

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

| | | | |
|---|---|---|---|
| **Client:** | Calscience | **PTS File No:** | 37791 |
| **Project:** | N/A | **Sample ID:** | MGS B5 |
| **Project No:** | 07-09-1308 | **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 | 0.01 | 0.01 | 0.01 |
| 0.0197 | 0.500 | 1.00 | 35 | 0.51 | 0.51 | 0.52 |
| 0.0166 | 0.420 | 1.25 | 40 | 0.66 | 0.66 | 1.18 |
| 0.0139 | 0.354 | 1.50 | 45 | 0.32 | 0.32 | 1.50 |
| 0.0117 | 0.297 | 1.75 | 50 | 1.90 | 1.90 | 3.40 |
| 0.0098 | 0.250 | 2.00 | 60 | 4.46 | 4.46 | 7.86 |
| 0.0083 | 0.210 | 2.25 | 70 | 6.70 | 6.70 | 14.56 |
| 0.0070 | 0.177 | 2.50 | 80 | 8.79 | 8.79 | 23.35 |
| 0.0059 | 0.149 | 2.75 | 100 | 12.20 | 12.20 | 35.55 |
| 0.0049 | 0.125 | 3.00 | 120 | 15.20 | 15.20 | 50.75 |
| 0.0041 | 0.105 | 3.25 | 140 | 14.90 | 14.90 | 65.65 |
| 0.0035 | 0.088 | 3.50 | 170 | 11.50 | 11.50 | 77.15 |
| 0.0029 | 0.074 | 3.75 | 200 | 7.36 | 7.36 | 84.51 |
| 0.0025 | 0.063 | 4.00 | 230 | 4.34 | 4.34 | 88.85 |
| 0.0021 | 0.053 | 4.25 | 270 | 2.56 | 2.56 | 91.41 |
| 0.00174 | 0.0442 | 4.50 | 325 | 1.52 | 1.52 | 92.93 |
| 0.00146 | 0.0372 | 4.75 | 400 | 0.94 | 0.94 | 93.87 |
| 0.00123 | 0.0313 | 5.00 | 450 | 0.62 | 0.62 | 94.49 |
| 0.000986 | 0.0250 | 5.32 | 500 | 0.56 | 0.56 | 95.05 |
| 0.000790 | 0.0201 | 5.64 | 635 | 0.43 | 0.43 | 95.48 |
| 0.000615 | 0.0156 | 6.00 | | 0.40 | 0.40 | 95.88 |
| 0.000435 | 0.0110 | 6.50 | | 0.48 | 0.48 | 96.36 |
| 0.000308 | 0.00781 | 7.00 | | 0.47 | 0.47 | 96.83 |
| 0.000197 | 0.00500 | 7.65 | | 0.59 | 0.59 | 97.42 |
| 0.000077 | 0.00195 | 9.00 | | 1.14 | 1.14 | 98.56 |
| 0.000038 | 0.000977 | 10.00 | | 0.78 | 0.78 | 99.34 |
| 0.000019 | 0.000488 | 11.00 | | 0.60 | 0.60 | 99.94 |
| 0.000015 | 0.000375 | 11.38 | | 0.07 | 0.06 | 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 | 1.84 | 0.0110 | 0.279 |
| 10 | 2.08 | 0.0093 | 0.237 |
| 16 | 2.29 | 0.0080 | 0.204 |
| 25 | 2.53 | 0.0068 | 0.173 |
| 40 | 2.82 | 0.0056 | 0.141 |
| 50 | 2.99 | 0.0050 | 0.126 |
| 60 | 3.16 | 0.0044 | 0.112 |
| 75 | 3.45 | 0.0036 | 0.091 |
| 84 | 3.73 | 0.0030 | 0.075 |
| 90 | 4.11 | 0.0023 | 0.058 |
| 95 | 5.29 | 0.0010 | 0.025 |

| Measure | Trask | Inman | Folk-Ward |
|---|---|---|---|
| Median, phi | 2.99 | 2.99 | 2.99 |
| Median, in. | 0.0050 | 0.0050 | 0.0050 |
| Median, mm | 0.126 | 0.126 | 0.126 |
| Mean, phi | 2.92 | 3.01 | 3.00 |
| Mean, in. | 0.0052 | 0.0049 | 0.0049 |
| Mean, mm | 0.132 | 0.124 | 0.125 |
| Sorting | 1.375 | 0.721 | 0.884 |
| Skewness | 0.996 | 0.034 | 0.184 |
| Kurtosis | 0.228 | 1.396 | 1.540 |
| **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 | 1.18 |
| Fine Sand | 200 | 83.32 |
| Silt | >0.005 mm | 12.91 |
| Clay | <0.005 mm | 2.58 |
| | **Total** | **100** |

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**Appendix C-3. Yearly grain size values, 1990 - 2007. Mandalay Generating Station NPDES, 2007.**

| | | | | | | Mean grain size | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | Station | Gravel (%) | Sand (%) | Silt (%) | Clay (%) | phi | µm | Sorting* | Skewness | Kurtosis |
| 2007 | B1 | 0.00 | 97.89 | 1.55 | 0.56 | 1.25 | 421 | 0.902 | -0.031 | 1.099 |
| | B2 | 0.00 | 95.36 | 3.25 | 1.39 | 2.37 | 194 | 0.792 | 0.014 | 1.343 |
| | B3 | 0.00 | 94.40 | 3.93 | 1.67 | 2.41 | 188 | 0.886 | 0.013 | 1.464 |
| | B4 | 0.00 | 94.92 | 3.56 | 1.52 | 2.00 | 251 | 0.935 | 0.094 | 1.400 |
| | B5 | 0.00 | 88.85 | 8.57 | 2.58 | 3.00 | 125 | 0.884 | 0.184 | 1.540 |
| 2006 | B1 | 0.00 | 93.64 | 4.67 | 1.69 | 2.59 | 166 | 0.740 | 0.179 | 1.518 |
| | B2 | 0.00 | 92.99 | 5.17 | 1.84 | 2.94 | 130 | 0.654 | 0.150 | 1.439 |
| | B3 | 0.00 | 94.30 | 4.06 | 1.64 | 2.71 | 153 | 0.665 | 0.143 | 1.272 |
| | B4 | 0.00 | 83.58 | 11.8 | 4.62 | 3.09 | 117 | 1.286 | 0.482 | 2.502 |
| | B5 | 0.00 | 65.64 | 29.73 | 4.63 | 3.79 | 72 | 1.158 | 0.356 | 1.972 |
| 2005 | B1 | 0.00 | 88.15 | 10.27 | 1.58 | 3.24 | 106 | 0.651 | 0.130 | 1.166 |
| | B2 | 0.00 | 89.87 | 8.54 | 1.59 | 3.15 | 113 | 0.734 | -0.001 | 1.350 |
| | B3 | 0.00 | 91.09 | 7.04 | 1.87 | 3.06 | 120 | 0.714 | 0.112 | 1.371 |
| | B4 | 0.00 | 94.18 | 5.02 | 0.80 | 2.65 | 159 | 0.810 | 0.041 | 1.079 |
| | B5 | 0.00 | 83.27 | 14.12 | 2.61 | 3.40 | 94 | 0.754 | 0.237 | 1.555 |
| 2004 | B1 | 1.22 | 95.73 | 2.15 | 0.90 | 2.16 | 224 | 0.74 | -0.08 | 1.28 |
| | B2 | 0.00 | 97.09 | 2.16 | 0.75 | 2.27 | 207 | 0.59 | 0.08 | 1.06 |
| | B3 | 0.71 | 95.89 | 2.48 | 0.92 | 2.14 | 226 | 0.74 | 0.06 | 1.15 |
| | B4 | 1.48 | 94.91 | 2.61 | 1.00 | 2.18 | 221 | 0.80 | -0.12 | 1.51 |
| | B5 | 0.00 | 92.76 | 5.38 | 1.86 | 2.82 | 142 | 0.77 | 0.08 | 1.39 |
| 2003 | B1 | 0.00 | 95.01 | 3.53 | 1.46 | 2.28 | 207 | 0.81 | 0.09 | 1.32 |
| | B2 | 0.00 | 96.63 | 2.48 | 0.89 | 2.19 | 220 | 0.75 | 0.04 | 1.22 |
| | B3 | 0.00 | 93.67 | 4.66 | 1.67 | 2.58 | 168 | 0.84 | 0.10 | 1.28 |
| | B4 | 0.00 | 96.02 | 2.89 | 1.09 | 1.94 | 260 | 0.89 | 0.06 | 1.28 |
| | B5 | - | - | - | - | - | - | - | - | - |
| 2002 | B1 | 0.00 | 96.73 | 2.58 | 0.69 | 2.46 | 182 | 0.63 | -0.01 | 1.20 |
| | B2 | 0.00 | 94.97 | 4.08 | 0.95 | 2.64 | 161 | 0.71 | -0.02 | 1.33 |
| | B3 | 0.00 | 84.43 | 12.83 | 2.74 | 3.07 | 119 | 1.23 | 0.14 | 2.17 |
| | B4 | 0.00 | 94.60 | 4.40 | 1.00 | 2.62 | 162 | 0.76 | -0.03 | 1.35 |
| | B5 | 0.00 | 75.25 | 22.21 | 2.54 | 3.54 | 86 | 0.97 | 0.34 | 1.47 |
| 2001 | B1 | 0.00 | 94.78 | 4.52 | 0.70 | 2.47 | 180 | 0.71 | 0.18 | 1.23 |
| | B2 | 0.00 | 95.96 | 3.44 | 0.60 | 2.61 | 163 | 0.61 | 0.10 | 1.18 |
| | B3 | 0.00 | 96.21 | 2.90 | 0.89 | 2.64 | 161 | 0.61 | 0.00 | 1.13 |
| | B4 | 0.00 | 96.92 | 2.41 | 0.67 | 2.63 | 162 | 0.57 | 0.02 | 1.13 |
| | B5 | 0.00 | 85.18 | 13.15 | 1.67 | 3.28 | 103 | 0.79 | 0.11 | 1.46 |
| 2000 | B1 | 0.00 | 92.10 | 6.40 | 1.50 | 2.55 | 171 | 0.93 | 0.16 | 1.24 |
| | B2 | 0.00 | 93.42 | 4.97 | 1.61 | 2.71 | 153 | 0.73 | 0.16 | 1.36 |
| | B3 | 0.00 | 90.14 | 7.69 | 2.17 | 2.70 | 154 | 0.98 | 0.23 | 1.72 |
| | B4 | 0.00 | 94.23 | 4.09 | 1.68 | 2.65 | 160 | 0.65 | 0.23 | 1.26 |
| | B5 | 0.00 | 83.51 | 14.01 | 2.48 | 3.34 | 99 | 0.86 | 0.28 | 1.68 |
| 1999 | B1 | 0.00 | 94.55 | 4.41 | 1.04 | 2.67 | 158 | 0.72 | 0.01 | 1.31 |
| | B2 | 0.00 | 94.21 | 4.89 | 0.90 | 2.41 | 188 | 0.87 | 0.13 | 1.14 |
| | B3 | 0.00 | 95.60 | 3.57 | 0.83 | 2.56 | 169 | 0.75 | 0.00 | 1.06 |
| | B4 | 0.00 | 96.79 | 2.53 | 0.68 | 2.27 | 207 | 0.75 | 0.02 | 1.16 |
| | B5 | 0.00 | 76.32 | 21.05 | 2.63 | 3.55 | 85 | 0.84 | 0.28 | 1.48 |
| 1998 | B1 | 0.12 | 93.37 | 5.33 | 1.17 | 3.01 | 124 | 65.30 | 0.16 | 1.23 |
| | B2 | 0.01 | 98.14 | 1.82 | 0.02 | 2.59 | 166 | 71.18 | -0.12 | 1.09 |
| | B3 | 0.25 | 92.88 | 5.70 | 1.17 | 2.89 | 135 | 58.93 | 0.10 | 1.14 |
| | B4 | - | - | - | - | - | - | - | - | - |
| | B5 | - | - | - | - | - | - | - | - | - |
| 1997 | B1 | 2.14 | 85.05 | 10.34 | 2.47 | 3.31 | 101 | 60.14 | 0.10 | 1.30 |
| | B2 | 1.82 | 93.66 | 3.06 | 1.45 | 2.79 | 145 | 61.12 | -0.10 | 1.11 |
| | B3 | 0.16 | 69.54 | 28.49 | 1.82 | 3.80 | 72 | 60.25 | 0.14 | 1.15 |
| | B4 | 0.28 | 93.28 | 5.68 | 0.76 | 3.08 | 119 | 65.17 | 0.08 | 1.12 |
| | B5 | 0.12 | 96.07 | 3.34 | 0.47 | 2.62 | 163 | 59.24 | -0.03 | 0.98 |

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

| Year | Station | Gravel (%) | Sand (%) | Silt (%) | Clay (%) | Mean grain size phi | Mean grain size µm | Sorting* | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|---|---|---|
| 1994 | B1 | 1.37 | 91.74 | 6.89 | 0.00 | 3.05 | 121 | 65.76 | -0.01 | 1.16 |
| | B2 | 48.53 | 46.64 | 4.45 | 0.38 | 0.12 | 920 | 39.76 | -0.37 | 0.50 |
| | B3 | 0.20 | 65.31 | 33.34 | 1.15 | 3.93 | 66 | 61.17 | 0.25 | 1.17 |
| | B4 | 5.04 | 89.57 | 5.40 | 0.00 | 2.61 | 164 | 55.63 | -0.25 | 1.96 |
| | B5 | 0.21 | 97.43 | 2.23 | 0.13 | 2.48 | 179 | 66.01 | 0.02 | 1.11 |
| 1993 | B1 | 20.44 | 78.30 | 0.84 | 0.42 | 1.07 | 480 | N.A. | N.A. | N.A. |
| | B2 | 0.23 | 98.66 | 0.74 | 0.37 | 2.47 | 180 | N.A. | N.A. | N.A. |
| | B3 | 0.80 | 93.69 | 5.09 | 0.42 | 2.48 | 179 | N.A. | N.A. | N.A. |
| | B4 | 0.59 | 98.95 | 0.00 | 0.46 | 2.23 | 213 | N.A. | N.A. | N.A. |
| | B5 | 0.05 | 90.83 | 8.72 | 0.40 | 2.50 | 177 | N.A. | N.A. | N.A. |
| 1992 | B1 | 1.37 | 97.68 | 0.71 | 0.24 | 2.45 | 183 | N.A. | N.A. | N.A. |
| | B2 | 0.00 | 98.80 | 0.60 | 0.60 | 2.48 | 179 | N.A. | N.A. | N.A. |
| | B3 | 5.05 | 93.59 | 0.91 | 0.45 | 2.37 | 193 | N.A. | N.A. | N.A. |
| | B4 | 8.84 | 89.79 | 0.69 | 0.69 | 2.58 | 167 | N.A. | N.A. | N.A. |
| | B5 | 0.54 | 91.55 | 7.01 | 0.90 | 2.57 | 168 | N.A. | N.A. | N.A. |
| 1991 | B1 | 0.33 | 93.39 | 5.23 | 1.05 | 2.58 | 167 | N.A. | N.A. | N.A. |
| | B2 | 0.24 | 95.14 | 3.60 | 1.03 | 2.42 | 186 | N.A. | N.A. | N.A. |
| | B3 | 1.11 | 89.44 | 8.40 | 1.05 | 2.40 | 190 | N.A. | N.A. | N.A. |
| | B4 | 0.20 | 95.54 | 3.20 | 1.07 | 2.38 | 192 | N.A. | N.A. | N.A. |
| | B5 | 0.00 | 83.57 | 14.73 | 1.70 | 3.13 | 114 | N.A. | N.A. | N.A. |
| 1990 | B1 | 1.84 | 96.28 | 1.88 | 0.00 | 2.35 | 196 | 68.62 | -0.04 | 1.33 |
| | B2 | 0.60 | 98.86 | 2.53 | 0.01 | 2.68 | 156 | 72.52 | -0.07 | 1.48 |
| | B3 | 1.11 | 95.87 | 3.01 | 0.01 | 2.54 | 173 | 74.10 | -0.07 | 1.47 |
| | B4 | 4.88 | 92.48 | 2.64 | 0.01 | 2.37 | 193 | 66.20 | -0.31 | 2.95 |
| | B5 | 0.15 | 90.52 | 9.33 | 0.00 | 3.38 | 96 | 76.64 | 0.11 | 1.34 |
| 1988 | B1 | 4.56 | 87.93 | 6.86 | 0.64 | 2.57 | 168 | 58.77 | -0.18 | 2.22 |
| | B2 | 1.46 | 95.19 | 3.05 | 0.29 | 2.53 | 174 | 71.58 | 0.17 | 1.57 |
| | B3 | 3.50 | 92.18 | 4.16 | 0.16 | 2.32 | 200 | 66.75 | -0.09 | 2.44 |
| | B4 | 0.71 | 92.82 | 5.10 | 1.37 | 3.16 | 111 | 66.85 | 0.32 | 1.63 |
| | B5 | 4.34 | 90.91 | 2.95 | 1.81 | 2.80 | 144 | 64.47 | -0.13 | 2.05 |
| 1986 | B1 | 0.09 | 85.65 | 14.23 | 0.00 | 3.26 | 104 | 42.05 | 0.38 | 1.22 |
| | B2 | 0.00 | 94.40 | 4.94 | 0.66 | 3.16 | 111 | 58.88 | 0.31 | 1.57 |
| | B3 | 0.00 | 91.15 | 8.22 | 0.00 | 3.09 | 118 | 30.23 | 0.14 | 1.43 |
| | B4 | 0.11 | 89.76 | 9.88 | 0.26 | 3.18 | 110 | 49.68 | 0.38 | 1.55 |
| | B5 | 0.38 | 80.31 | 18.93 | 0.38 | 3.40 | 95 | 47.90 | 0.11 | 1.59 |
| 1980 | B1 | 0.00 | 67.77 | 25.78 | 6.03 | 3.77 | 73 | 0.80 | 0.37 | 3.32 |
| | B2 | 0.00 | 86.09 | 10.95 | 2.95 | 3.11 | 116 | 0.58 | 0.35 | 2.71 |
| | B3 | 0.00 | 74.46 | 22.80 | 2.74 | 3.61 | 82 | 0.60 | 0.40 | 2.00 |
| | B4 | 6.00 | 81.23 | 10.36 | 2.36 | 3.10 | 117 | 0.53 | 0.13 | 5.71 |
| | B5 | 0.00 | 68.28 | 29.51 | 2.18 | 3.69 | 78 | 0.73 | 0.42 | 1.32 |
| 1978 | B1 | 0.52 | 96.44 | 3.04 | 0.00 | 2.46 | 182 | 0.57 | 0.10 | NA |
| | B2 | 0.08 | 97.77 | 2.15 | 0.00 | 2.64 | 161 | 0.46 | -0.04 | NA |
| | B3 | 0.10 | 80.00 | 19.90 | 0.00 | 3.39 | 95 | 0.61 | 0.05 | NA |
| | B4 | 0.21 | 99.42 | 0.37 | 0.00 | 2.37 | 193 | 0.54 | -0.20 | NA |
| | B5 | 0.03 | 80.46 | 19.51 | 0.00 | 3.45 | 92 | 0.56 | 0.00 | NA |

N.A. = Not Available
- = not required
*Sorting values: % 1986-1998; phi 1978 & 1980, 1999-present

# 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 07202A

| | |
|---|---|
| Date Received: | 08/31/07 |
| Work Order No: | 07-08-2233 |
| Preparation: | EPA 3050B |
| Method: | EPA 6020 |
| Units: | mg/kg |

Page 1 of 1

| Client Sample Number | Lab Sample Number | Date Collected | Matrix | Instrument | Date Prepared | Date Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **MGS-B1 (I, II, III)** | **07-08-2233-16** | **08/29/07** | **Solid** | **ICP/MS A** | **09/04/07** | **09/05/07** | **070904L03** |

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

| Parameter | Result | RL | DF | Qual | Parameter | Result | RL | DF | Qual |
|---|---|---|---|---|---|---|---|---|---|
| Chromium | 4.75 | 0.125 | 1 | | Nickel | 6.34 | 0.125 | 1 | |
| Copper | 3.03 | 0.125 | 1 | | Zinc | 17.7 | 1.25 | 1 | |

| Client Sample Number | Lab Sample Number | Date Collected | Matrix | Instrument | Date Prepared | Date Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **MGS-B2 (I, II, III)** | **07-08-2233-17** | **08/29/07** | **Solid** | **ICP/MS A** | **09/04/07** | **09/05/07** | **070904L03** |

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

| Parameter | Result | RL | DF | Qual | Parameter | Result | RL | DF | Qual |
|---|---|---|---|---|---|---|---|---|---|
| Chromium | 7.06 | 0.131 | 1 | | Nickel | 7.84 | 0.131 | 1 | |
| Copper | 3.70 | 0.131 | 1 | | Zinc | 25.0 | 1.31 | 1 | |

| Client Sample Number | Lab Sample Number | Date Collected | Matrix | Instrument | Date Prepared | Date Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **MGS-B3 (I, II, III)** | **07-08-2233-18** | **08/29/07** | **Solid** | **ICP/MS A** | **09/04/07** | **09/05/07** | **070904L03** |

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

| Parameter | Result | RL | DF | Qual | Parameter | Result | RL | DF | Qual |
|---|---|---|---|---|---|---|---|---|---|
| Chromium | 5.96 | 0.131 | 1 | | Nickel | 6.81 | 0.131 | 1 | |
| Copper | 3.71 | 0.131 | 1 | | Zinc | 19.7 | 1.31 | 1 | |

| Client Sample Number | Lab Sample Number | Date Collected | Matrix | Instrument | Date Prepared | Date Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **MGS-B4 (I, II, III)** | **07-08-2233-19** | **08/29/07** | **Solid** | **ICP/MS A** | **09/04/07** | **09/05/07** | **070904L03** |

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

| Parameter | Result | RL | DF | Qual | Parameter | Result | RL | DF | Qual |
|---|---|---|---|---|---|---|---|---|---|
| Chromium | 4.09 | 0.128 | 1 | | Nickel | 6.03 | 0.128 | 1 | |
| Copper | 3.40 | 0.128 | 1 | | Zinc | 19.0 | 1.28 | 1 | |

| Client Sample Number | Lab Sample Number | Date Collected | Matrix | Instrument | Date Prepared | Date Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **MGS-B5 (I, II, III)** | **07-08-2233-20** | **08/29/07** | **Solid** | **ICP/MS A** | **09/04/07** | **09/05/07** | **070904L03** |

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

| Parameter | Result | RL | DF | Qual | Parameter | Result | RL | DF | Qual |
|---|---|---|---|---|---|---|---|---|---|
| Chromium | 6.80 | 0.137 | 1 | | Nickel | 10.1 | 0.137 | 1 | |
| Copper | 7.25 | 0.137 | 1 | | Zinc | 31.9 | 1.37 | 1 | |

| Client Sample Number | Lab Sample Number | Date Collected | Matrix | Instrument | Date Prepared | Date Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **Method Blank** | **096-10-002-933** | **N/A** | **Solid** | **ICP/MS A** | **09/04/07** | **09/05/07** | **070904L03** |

| 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

**Calscience Environmental Laboratories, Inc.**

# Analytical Report

| | | | |
|---|---|---|---|
| MBC Applied Environmental Sciences | | Date Received: | 08/31/07 |
| 3000 Redhill Avenue | | Work Order No: | 07-08-2233 |
| Costa Mesa, CA 92626-4524 | | Preparation: | N/A |
| | | Method: | SM 2540 B |

Project: MGS 07202A



| Client Sample Number | Lab Sample Number | Date Collected | Matrix | Instrument | Date Prepared | Date Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **MGS-B1 (I, II, III)** | **07-08-2233-16** | **08/29/07** | **Solid** | **N/A** | **N/A** | **09/04/07** | **70904TSD1** |

| Parameter | Result | RL | DF | Qual | Units |
|---|---|---|---|---|---|
| Solids, Total | 79.8 | 0.100 | 1 | | % |

| Client Sample Number | Lab Sample Number | Date Collected | Matrix | Instrument | Date Prepared | Date Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **MGS-B2 (I, II, III)** | **07-08-2233-17** | **08/29/07** | **Solid** | **N/A** | **N/A** | **09/04/07** | **70904TSD1** |

| Parameter | Result | RL | DF | Qual | Units |
|---|---|---|---|---|---|
| Solids, Total | 76.5 | 0.100 | 1 | | % |

| Client Sample Number | Lab Sample Number | Date Collected | Matrix | Instrument | Date Prepared | Date Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **MGS-B3 (I, II, III)** | **07-08-2233-18** | **08/29/07** | **Solid** | **N/A** | **N/A** | **09/04/07** | **70904TSD1** |

| Parameter | Result | RL | DF | Qual | Units |
|---|---|---|---|---|---|
| Solids, Total | 76.5 | 0.100 | 1 | | % |

| Client Sample Number | Lab Sample Number | Date Collected | Matrix | Instrument | Date Prepared | Date Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **MGS-B4 (I, II, III)** | **07-08-2233-19** | **08/29/07** | **Solid** | **N/A** | **N/A** | **09/04/07** | **70904TSD1** |

| Parameter | Result | RL | DF | Qual | Units |
|---|---|---|---|---|---|
| Solids, Total | 78.2 | 0.100 | 1 | | % |

| Client Sample Number | Lab Sample Number | Date Collected | Matrix | Instrument | Date Prepared | Date Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **MGS-B5 (I, II, III)** | **07-08-2233-20** | **08/29/07** | **Solid** | **N/A** | **N/A** | **09/04/07** | **70904TSD1** |

| Parameter | Result | RL | DF | Qual | Units |
|---|---|---|---|---|---|
| Solids, Total | 72.8 | 0.100 | 1 | | % |

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

**Calscience Environmental Laboratories, Inc.**

## Quality Control - Spike/Spike Duplicate

| | | | |
|---|---|---|---|
| MBC Applied Environmental Sciences | | Date Received: | 08/31/07 |
| 3000 Redhill Avenue | | Work Order No: | 07-08-2233 |
| Costa Mesa, CA 92626-4524 | | Preparation: | EPA 3050B |
| | | Method: | EPA 6020 |

Project MGS 07202A

| Quality Control Sample ID | Matrix | Instrument | Date Prepared | Date Analyzed | MS/MSD Batch Number |
|---|---|---|---|---|---|
| **07-08-2232-19** | **Solid** | **ICP/MS A** | **09/04/07** | **09/05/07** | **070904S03** |

| Parameter | MS %REC | MSD %REC | %REC CL | RPD | RPD CL | Qualifiers |
|---|---|---|---|---|---|---|
| Chromium | 109 | 97 | 80-120 | 10 | 0-20 | |
| Copper | 101 | 95 | 80-120 | 5 | 0-20 | |
| Nickel | 112 | 96 | 80-120 | 13 | 0-20 | |
| Zinc | 111 | 90 | 80-120 | 12 | 0-20 | |

RPD - Relative Percent Difference , CL - Control Limit

Calscience Environmental Laboratories, Inc.

## Quality Control - PDS / PDSD

| | | | |
|---|---|---|---|
| MBC Applied Environmental Sciences | | Date Received | 08/31/07 |
| 3000 Redhill Avenue | | Work Order N | 07-08-2233 |
| Costa Mesa, CA 92626-4524 | | Preparation: | EPA 3050B |
| | | Method: | EPA 6020 |

Project: MGS 07202A

| Quality Control Sample ID | Matrix | Instrument | Date Prepared | Date Analyzed | PDS/PDSD Batch Number |
|---|---|---|---|---|---|
| **07-08-2232-19** | **Solid** | **ICP/MS A** | **09/04/07** | **09/05/07** | **070904S03** |

| Parameter | PDS %REC | PDSD %REC | %REC CL | RPD | RPD CL | Qualifiers |
|---|---|---|---|---|---|---|
| Chromium | 92 | 96 | 75-125 | 4 | 0-20 | |
| Copper | 95 | 93 | 75-125 | 3 | 0-20 | |
| Nickel | 97 | 97 | 75-125 | 0 | 0-20 | |
| Zinc | 105 | 88 | 75-125 | 10 | 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: 08/31/07
Work Order No: 07-08-2233
Preparation: N/A
Method: SM 2540 B

Project: MGS 07202A

| Quality Control Sample ID | Matrix | Instrument | Date Prepared: | Date Analyzed: | Duplicate Batch Number |
|---|---|---|---|---|---|
| **07-08-2232-19** | **Solid** | **N/A** | **N/A** | **09/04/07** | **70904TSD1** |

| Parameter | Sample Conc | DUP Conc | RPD | RPD CL | Qualifiers |
|---|---|---|---|---|---|
| Solids, Total | 75.7 | 75.7 | 0 | 0-25 | |

RPD - Relative Percent Difference , CL - Control Limit

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: | 07-08-2233 |
| Preparation: | EPA 3050B |
| Method: | EPA 6020 |

Project: MGS 07202A

| Quality Control Sample ID | Matrix | Instrument | Date Prepared | Date Analyzed | LCS/LCSD Batch Number |
|---|---|---|---|---|---|
| **096-10-002-933** | **Solid** | **ICP/MS A** | **09/04/07** | **09/05/07** | **070904L03** |

| Parameter | LCS %REC | LCSD %REC | %REC CL | RPD | RPD CL | Qualifiers |
|---|---|---|---|---|---|---|
| Chromium | 111 | 111 | 80-120 | 0 | 0-20 | |
| Copper | 108 | 106 | 80-120 | 2 | 0-20 | |
| Nickel | 111 | 114 | 80-120 | 2 | 0-20 | |
| Zinc | 106 | 105 | 80-120 | 1 | 0-20 | |

RPD - Relative Percent Difference , CL - Control Limit

**Calscience Environmental Laboratories, Inc.**

## Glossary of Terms and Qualifiers

Work Order Number: 07-08-2233

| 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. |
| 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. |

**Appendix D-2. Yearly sediment metal concentrations, 1990 - 2007. Mandalay Generating Station NPDES, 2007.**

| | | Year | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Metal | Station | 1990 | 1991 | 1992 | 1993 | 1994 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | Mean |
| Chromium | B1 | 9.7 | 25.3 | 7.2 | 8.9 | 9.6 | 8.8 | 7.0 | 11 | 11 | 11 | 12 | 8.7 | 8.3 | 7.23 | 2.06 | 4.75 | 10 |
| ERL = 81 | B2 | 15.6 | 37.2 | 7.8 | 7.4 | 9.6 | 8.7 | 7.2 | 7.5 | 10 | 8.9 | 12 | 9.6 | 8.6 | 6.31 | 2.98 | 7.06 | 10 |
| | B3 | 8.7 | 23.4 | 10.1 | 9.3 | 12 | 11 | 7.2 | 9.1 | 9.9 | 11 | 13 | 7.7 | 8.6 | 7.17 | 2.25 | 5.96 | 10 |
| | B4 | 9.3 | 14.3 | 10.0 | 8.1 | 12 | 9.2 | - | 7.9 | 9.6 | 13 | 11 | 7.0 | 7.5 | 7.78 | 3.39 | 4.09 | 9 |
| | B5 | 11.3 | 24.6 | 8.8 | 8.4 | 8.4 | 9.2 | - | 13 | 13 | 8.3 | 13 | - | 10 | 8.15 | 3.25 | 6.80 | 10 |
| Copper | B1 | 4.4 | 20.0 | 4.0 | 5.3 | 5.6 | 3.7 | 6.1 | 7.0 | 4.6 | 2.5 | 4.5 | 2.8 | 2.9 | 6.49 | 1.48 | 3.03 | 5.3 |
| ERL = 34 | B2 | 5.8 | 24.4 | 3.6 | 4.1 | 7.1 | 2.7 | 4.1 | 3.8 | 4.3 | 2.3 | 4.7 | 3.7 | 3.3 | 5.54 | 2.18 | 3.70 | 5.3 |
| | B3 | 2.6 | 14.8 | 5.1 | 9.0 | 8.4 | 5.3 | 4.2 | 5.3 | 5.3 | 2.6 | 5.5 | 3.1 | 2.9 | 6.91 | 1.81 | 3.71 | 5.4 |
| | B4 | 2.3 | 8.2 | 4.2 | 3.9 | 4.9 | 3.3 | - | 3.7 | 3.7 | 2.8 | 4.5 | ND | 2.8 | 5.31 | 1.73 | 3.40 | 3.6 |
| | B5 | 4.3 | 15.9 | 4.6 | 5.1 | 3.0 | 1.7 | - | 8.5 | 6.4 | 2.6 | 6.4 | - | 6.0 | 6.77 | 2.53 | 7.25 | 5.8 |
| Nickel | B1 | 6.6 | 14.7 | 6.0 | 7.9 | 7.1 | 7.8 | 4.3 | 9.7 | 8.5 | 6.7 | 8.9 | 6.2 | 6.5 | 8.53 | 2.23 | 6.34 | 7.4 |
| ERL = 20.9 | B2 | 10.3 | 16.7 | 6.2 | 5.9 | 8.2 | 6.6 | 4.2 | 6.3 | 7.8 | 6.3 | 9.0 | 6.2 | 6.8 | 7.32 | 3.03 | 7.84 | 7.4 |
| | B3 | 6.2 | 9.5 | 8.1 | 9.3 | 9.2 | 10 | 4.1 | 8.8 | 8.7 | 6.7 | 10.0 | 6.2 | 6.8 | 8.34 | 2.21 | 6.81 | 7.6 |
| | B4 | 6.3 | 9.1 | 6.7 | 6.3 | 6.5 | 7.1 | - | 6.5 | 7.0 | 8.0 | 8.9 | 5.1 | 6.3 | 7.53 | 2.85 | 6.03 | 6.7 |
| | B5 | 6.7 | 13.8 | 6.4 | 7.2 | 6.5 | 6.3 | - | 12.0 | 8.5 | 6.0 | 9.2 | - | 8.1 | 8.51 | 3.16 | 10.1 | 8.0 |
| Zinc | B1 | 17 | 14.7 | 15.4 | 18 | 22 | 27 | 19 | 6.4 | 23 | 21 | 21 | 15 | 14 | 24.6 | 7.76 | 17.7 | 18 |
| ERL = 150 | B2 | 27 | 15.4 | 16.2 | 16 | 25 | 23 | 14 | 16 | 22 | 18 | 19 | 15 | 16 | 22.0 | 10.1 | 25.0 | 19 |
| | B3 | 17 | 17.2 | 20.0 | 29 | 31 | 34 | 14 | 24 | 24 | 20 | 23 | 15 | 13 | 25.4 | 7.30 | 19.7 | 21 |
| | B4 | 17 | 16.4 | 19.0 | 18 | 20 | 24 | - | 17 | 20 | 23 | 19 | 13 | 13 | 21.1 | 9.30 | 19.0 | 18 |
| | B5 | 23 | 24.6 | 17.3 | 20 | 13 | 18 | - | 34 | 28 | 18 | 26 | - | 25 | 26.3 | 10.6 | 31.9 | 23 |
| Percent | B1 | 1.9 | 6.3 | 1.0 | 1.3 | 6.9 | 12.8 | 6.5 | 5.5 | 7.9 | 5.2 | 3.3 | 5.0 | 3.1 | 11.85 | 6.36 | 2.11 | 5.4 |
| Fines | B2 | 2.5 | 4.6 | 1.2 | 1.1 | 4.8 | 4.5 | 1.8 | 5.8 | 6.6 | 4.0 | 5.0 | 3.4 | 2.9 | 10.13 | 7.01 | 4.64 | 4.4 |
| | B3 | 3.0 | 9.5 | 1.4 | 5.5 | 34.5 | 30.3 | 6.9 | 4.4 | 9.9 | 3.8 | 15.6 | 6.3 | 3.4 | 8.91 | 5.70 | 5.60 | 9.7 |
| | B4 | 2.7 | 4.3 | 1.4 | 0.5 | 5.4 | 6.4 | - | 3.2 | 5.8 | 3.1 | 5.4 | 4.0 | 3.6 | 5.82 | 16.42 | 5.08 | 4.9 |
| | B5 | 9.3 | 16.4 | 7.9 | 9.1 | 2.4 | 3.8 | - | 23.7 | 16.5 | 14.8 | 24.8 | - | 7.2 | 16.73 | 34.36 | 11.15 | 14.2 |

ERL = Effects Range Low
- = not required
ND = below the detection limit (for calcuations ND = 0)

# APPENDIX E

## Mussel tissue chemistry by station

Calscience Environmental Laboratories, Inc.

## Analytical Report

| | |
|---|---|
| MBC Applied Environmental Sciences | Date Received: 09/10/07 |
| 3000 Redhill Avenue | Work Order No: 07-09-0466 |
| Costa Mesa, CA 92626-4524 | Preparation: EPA 3050B |
| | Method: EPA 6020 |
| | Units: mg/kg |
| Project: MGS 07202A | Page 1 of 1 |

| Client Sample Number | Lab Sample Number | Date Collected | Matrix | Instrument | Date Prepared | Date Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **MGS-I** | **07-09-0466-1** | **08/29/07** | **Tissue** | **ICP/MS A** | **09/25/07** | **09/26/07** | **070926L02** |

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

| Parameter | Result | RL | DF | Qual | Parameter | Result | RL | DF | Qual |
|---|---|---|---|---|---|---|---|---|---|
| Chromium | 2.10 | 0.855 | 0.667 | | Nickel | 4.28 | 0.427 | 0.667 | |
| Copper | 5.83 | 1.28 | 0.667 | | Zinc | 148 | 8.55 | 0.667 | |

| Client Sample Number | Lab Sample Number | Date Collected | Matrix | Instrument | Date Prepared | Date Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **Method Blank** | **099-12-411-5** | **N/A** | **Tissue** | **ICP/MS A** | **09/25/07** | **09/26/07** | **070926L02** |

| 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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# Analytical Report

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

| | |
|---|---|
| Date Received: | 09/10/07 |
| Work Order No: | 07-09-0466 |
| Preparation: | N/A |
| Method: | SM 2540 B |

Project: MGS 07202A

Page 1 of 1

| Client Sample Number | Lab Sample Number | Date Collected | Matrix | Instrument | Date Prepared | Date Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **MGS-I** | **07-09-0466-1** | **08/29/07** | **Tissue** | **N/A** | **N/A** | **09/19/07** | **70919TSD1** |

| Parameter | Result | RL | DF | Qual | Units |
|---|---|---|---|---|---|
| Solids, Total | 15.6 | 0.100 | 1 | | % |

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

Calscience Environmental Laboratories, Inc.

## Quality Control - PDS / PDSD

| | | | |
|---|---|---|---|
| MBC Applied Environmental Sciences | | Date Received | 09/10/07 |
| 3000 Redhill Avenue | | Work Order N | 07-09-0466 |
| Costa Mesa, CA 92626-4524 | | Preparation: | EPA 3050B |
| | | Method: | EPA 6020 |

Project: MGS 07202A

| Quality Control Sample ID | Matrix | Instrument | Date Prepared | Date Analyzed | PDS/PDSD Batch Number |
|---|---|---|---|---|---|
| **MGS-I** | **Tissue** | **ICP/MS A** | **09/25/07** | **09/26/07** | **070926P02** |

| Parameter | PDS %REC | PDSD %REC | %REC CL | RPD | RPD CL | Qualifiers |
|---|---|---|---|---|---|---|
| Chromium | 109 | 110 | 75-125 | 1 | 0-20 | |
| Copper | 100 | 101 | 75-125 | 1 | 0-20 | |
| Nickel | 102 | 102 | 75-125 | 0 | 0-20 | |
| Zinc | 111 | 116 | 75-125 | 2 | 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: | 09/10/07 |
| Work Order No: | 07-09-0466 |
| Preparation: | N/A |
| Method: | SM 2540 B |

Project: MGS 07202A

| Quality Control Sample ID | Matrix | Instrument | Date Prepared: | Date Analyzed: | Duplicate Batch Number |
|---|---|---|---|---|---|
| **07-09-1086-3** | **Tissue** | **N/A** | **N/A** | **09/19/07** | **70919TSD1** |

| Parameter | Sample Conc | DUP Conc | RPD | RPD CL | Qualifiers |
|---|---|---|---|---|---|
| Solids, Total | 18.0 | 17.6 | 2 | 0-25 | |

RPD - Relative Percent Difference , CL - Control Limit

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: 07-09-0466
Preparation: EPA 3050B
Method: EPA 6020

Project: MGS 07202A

| Quality Control Sample ID | Matrix | Instrument | Date Prepared | Date Analyzed | LCS/LCSD Batch Number |
|---|---|---|---|---|---|
| **099-12-411-5** | **Tissue** | **ICP/MS A** | **09/25/07** | **09/26/07** | **070926L02** |

| Parameter | LCS %REC | LCSD %REC | %REC CL | RPD | RPD CL | Qualifiers |
|---|---|---|---|---|---|---|
| Chromium | 108 | 106 | 80-120 | 2 | 0-20 | |
| Copper | 103 | 102 | 80-120 | 2 | 0-20 | |
| Nickel | 105 | 103 | 80-120 | 2 | 0-20 | |
| Zinc | 111 | 107 | 80-120 | 3 | 0-20 | |

RPD - Relative Percent Difference , CL - Control Limit

Calscience Environmental Laboratories, Inc.

## Glossary of Terms and Qualifiers

Work Order Number: 07-09-0466

| 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. |
| 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. |

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## Analytical Report

| | |
|---|---|
| MBC Applied Environmental Sciences | Date Received: 09/17/07 |
| 3000 Redhill Avenue | Work Order No: 07-09-1083 |
| Costa Mesa, CA 92626-4524 | Preparation: EPA 3050B |
| | Method: EPA 6020 |
| | Units: mg/kg |
| Project: RGS 07205A | Page 1 of 1 |

| Client Sample Number | Lab Sample Number | Date Collected | Matrix | Instrument | Date Prepared | Date Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **RGS MBP - I** | **07-09-1083-1** | **07/25/07** | **Tissue** | **ICP/MS A** | **09/20/07** | **09/20/07** | **070920L01** |

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

| Parameter | Result | RL | DF | Qual | Parameter | Result | RL | DF | Qual |
|---|---|---|---|---|---|---|---|---|---|
| Chromium | 4.37 | 0.469 | 0.5 | | Nickel | 2.46 | 0.235 | 0.5 | |
| Copper | 8.49 | 0.704 | 0.5 | | Zinc | 94.5 | 4.69 | 0.5 | |

| Client Sample Number | Lab Sample Number | Date Collected | Matrix | Instrument | Date Prepared | Date Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **RGS MBP - II** | **07-09-1083-2** | **07/25/07** | **Tissue** | **ICP/MS A** | **09/20/07** | **09/20/07** | **070920L01** |

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

| Parameter | Result | RL | DF | Qual | Parameter | Result | RL | DF | Qual |
|---|---|---|---|---|---|---|---|---|---|
| Chromium | 3.78 | 0.446 | 0.5 | | Nickel | 1.24 | 0.223 | 0.5 | |
| Copper | 7.56 | 0.670 | 0.5 | | Zinc | 73.9 | 4.46 | 0.5 | |

| Client Sample Number | Lab Sample Number | Date Collected | Matrix | Instrument | Date Prepared | Date Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **RGS MBP - III** | **07-09-1083-3** | **07/25/07** | **Tissue** | **ICP/MS A** | **09/20/07** | **09/20/07** | **070920L01** |

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

| Parameter | Result | RL | DF | Qual | Parameter | Result | RL | DF | Qual |
|---|---|---|---|---|---|---|---|---|---|
| Chromium | 5.81 | 0.526 | 0.5 | | Nickel | 1.74 | 0.263 | 0.5 | |
| Copper | 9.48 | 0.789 | 0.5 | | Zinc | 94.2 | 5.26 | 0.5 | |

| Client Sample Number | Lab Sample Number | Date Collected | Matrix | Instrument | Date Prepared | Date Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **Method Blank** | **099-12-411-3** | **N/A** | **Tissue** | **ICP/MS A** | **09/20/07** | **09/20/07** | **070920L01** |

| 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: 09/17/07
Work Order No: 07-09-1083
Preparation: N/A
Method: SM 2540 B

Project: RGS 07205A

Page 1 of 1

| Client Sample Number | Lab Sample Number | Date Collected | Matrix | Instrument | Date Prepared | Date Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **RGS MBP - I** | **07-09-1083-1** | **07/25/07** | **Tissue** | **N/A** | **N/A** | **09/18/07** | **70918TSD1** |

| Parameter | Result | RL | DF | Qual | Units |
|---|---|---|---|---|---|
| Solids, Total | 21.3 | 0.100 | 1 | | % |

| Client Sample Number | Lab Sample Number | Date Collected | Matrix | Instrument | Date Prepared | Date Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **RGS MBP - II** | **07-09-1083-2** | **07/25/07** | **Tissue** | **N/A** | **N/A** | **09/18/07** | **70918TSD1** |

| Parameter | Result | RL | DF | Qual | Units |
|---|---|---|---|---|---|
| Solids, Total | 22.4 | 0.100 | 1 | | % |

| Client Sample Number | Lab Sample Number | Date Collected | Matrix | Instrument | Date Prepared | Date Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **RGS MBP - III** | **07-09-1083-3** | **07/25/07** | **Tissue** | **N/A** | **N/A** | **09/18/07** | **70918TSD1** |

| Parameter | Result | RL | DF | Qual | Units |
|---|---|---|---|---|---|
| Solids, Total | 19.0 | 0.100 | 1 | | % |

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: 09/17/07
Work Order No: 07-09-1083
Preparation: EPA 3050B
Method: EPA 6020

Project RGS 07205A

| Quality Control Sample ID | Matrix | Instrument | Date Prepared | Date Analyzed | MS/MSD Batch Number |
|---|---|---|---|---|---|
| **RGS MBP - I** | **Tissue** | **ICP/MS A** | **09/20/07** | **09/20/07** | **070920S01** |

| Parameter | MS %REC | MSD %REC | %REC CL | RPD | RPD CL | Qualifiers |
|---|---|---|---|---|---|---|
| Chromium | 111 | 112 | 80-120 | 1 | 0-20 | |
| Copper | 103 | 105 | 80-120 | 2 | 0-20 | |
| Nickel | 107 | 108 | 80-120 | 1 | 0-20 | |
| Zinc | 135 | 113 | 80-120 | 8 | 0-20 | 3 |

RPD - Relative Percent Difference , CL - Control Limit

Calscience Environmental Laboratories, Inc.

# Quality Control - Duplicate

| | | | |
|---|---|---|---|
| MBC Applied Environmental Sciences | | Date Received: | 09/17/07 |
| 3000 Redhill Avenue | | Work Order No: | 07-09-1083 |
| Costa Mesa, CA 92626-4524 | | Preparation: | N/A |
| | | Method: | SM 2540 B |

Project: RGS 07205A

| Quality Control Sample ID | Matrix | Instrument | Date Prepared: | Date Analyzed: | Duplicate Batch Number |
|---|---|---|---|---|---|
| **07-09-1039-1** | **Solid** | **N/A** | **N/A** | **09/18/07** | **70918TSD1** |

| Parameter | Sample Conc | DUP Conc | RPD | RPD CL | Qualifiers |
|---|---|---|---|---|---|
| Solids, Total | 44.8 | 48.6 | 8 | 0-25 | |

RPD - Relative Percent Difference , CL - Control Limit

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: | 07-09-1083 |
| Preparation: | EPA 3050B |
| Method: | EPA 6020 |

Project: RGS 07205A

| Quality Control Sample ID | Matrix | Instrument | Date Prepared | Date Analyzed | LCS/LCSD Batch Number |
|---|---|---|---|---|---|
| **099-12-411-3** | **Tissue** | **ICP/MS A** | **09/20/07** | **09/20/07** | **070920L01** |

| Parameter | LCS %REC | LCSD %REC | %REC CL | RPD | RPD CL | Qualifiers |
|---|---|---|---|---|---|---|
| Chromium | 107 | 108 | 80-120 | 1 | 0-20 | |
| Copper | 100 | 100 | 80-120 | 0 | 0-20 | |
| Nickel | 102 | 103 | 80-120 | 1 | 0-20 | |
| Zinc | 100 | 104 | 80-120 | 4 | 0-20 | |

RPD - Relative Percent Difference , CL - Control Limit

Calscience Environmental Laboratories, Inc.

## Analytical Report

| | | | |
|---|---|---|---|
| MBC Applied Environmental Sciences | | Date Received: | 09/10/07 |
| 3000 Redhill Avenue | | Work Order No: | 07-09-0465 |
| Costa Mesa, CA 92626-4524 | | Preparation: | EPA 3050B |
| | | Method: | EPA 6020 |
| | | Units: | mg/kg |
| Project: MGS / OBGS 07202/3 | | | Page 1 of 1 |

| Client Sample Number | Lab Sample Number | Date Collected | Matrix | Instrument | Date Prepared | Date Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **Donor Site - I** | **07-09-0465-1** | **03/29/07** | **Tissue** | **ICP/MS A** | **09/20/07** | **09/20/07** | **070920L01** |

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

| Parameter | Result | RL | DF | Qual | Parameter | Result | RL | DF | Qual |
|---|---|---|---|---|---|---|---|---|---|
| Chromium | 5.78 | 0.885 | 0.5 | | Nickel | 3.26 | 0.442 | 0.5 | |
| Copper | 12.1 | 1.33 | 0.5 | | Zinc | 144 | 8.85 | 0.5 | |

| Client Sample Number | Lab Sample Number | Date Collected | Matrix | Instrument | Date Prepared | Date Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **Donor Site - II** | **07-09-0465-2** | **03/29/07** | **Tissue** | **ICP/MS A** | **09/20/07** | **09/20/07** | **070920L01** |

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

| Parameter | Result | RL | DF | Qual | Parameter | Result | RL | DF | Qual |
|---|---|---|---|---|---|---|---|---|---|
| Chromium | 6.52 | 1.20 | 0.5 | | Nickel | 2.20 | 0.602 | 0.5 | |
| Copper | 10.3 | 1.81 | 0.5 | | Zinc | 168 | 12.0 | 0.5 | |

| Client Sample Number | Lab Sample Number | Date Collected | Matrix | Instrument | Date Prepared | Date Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **Donor Site - III** | **07-09-0465-3** | **03/29/07** | **Tissue** | **ICP/MS A** | **09/20/07** | **09/20/07** | **070920L01** |

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

| Parameter | Result | RL | DF | Qual | Parameter | Result | RL | DF | Qual |
|---|---|---|---|---|---|---|---|---|---|
| Chromium | 6.42 | 1.27 | 0.5 | | Nickel | 2.36 | 0.633 | 0.5 | |
| Copper | 9.75 | 1.90 | 0.5 | | Zinc | 179 | 12.7 | 0.5 | |

| Client Sample Number | Lab Sample Number | Date Collected | Matrix | Instrument | Date Prepared | Date Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **Method Blank** | **099-12-411-3** | **N/A** | **Tissue** | **ICP/MS A** | **09/20/07** | **09/20/07** | **070920L01** |

| 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 | Date Received: 09/10/07 |
| 3000 Redhill Avenue | Work Order No: 07-09-0465 |
| Costa Mesa, CA 92626-4524 | Preparation: N/A |
| | Method: SM 2540 B |

Project: MGS / OBGS 07202/3

Page 1 of 1

| Client Sample Number | Lab Sample Number | Date Collected | Matrix | Instrument | Date Prepared | Date Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **Donor Site - I** | **07-09-0465-1** | **03/29/07** | **Tissue** | **N/A** | **N/A** | **09/19/07** | **70919TSD1** |

| Parameter | Result | RL | DF | Qual | Units |
|---|---|---|---|---|---|
| Solids, Total | 11.3 | 0.100 | 1 | | % |

| Client Sample Number | Lab Sample Number | Date Collected | Matrix | Instrument | Date Prepared | Date Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **Donor Site - II** | **07-09-0465-2** | **03/29/07** | **Tissue** | **N/A** | **N/A** | **09/19/07** | **70919TSD1** |

| Parameter | Result | RL | DF | Qual | Units |
|---|---|---|---|---|---|
| Solids, Total | 8.30 | 0.100 | 1 | | % |

| Client Sample Number | Lab Sample Number | Date Collected | Matrix | Instrument | Date Prepared | Date Analyzed | QC Batch ID |
|---|---|---|---|---|---|---|---|
| **Donor Site - III** | **07-09-0465-3** | **03/29/07** | **Tissue** | **N/A** | **N/A** | **09/19/07** | **70919TSD1** |

| Parameter | Result | RL | DF | Qual | Units |
|---|---|---|---|---|---|
| Solids, Total | 7.90 | 0.100 | 1 | | % |

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

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## Quality Control - Spike/Spike Duplicate

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

| | |
|---|---|
| Date Received: | 09/10/07 |
| Work Order No: | 07-09-0465 |
| Preparation: | EPA 3050B |
| Method: | EPA 6020 |

Project MGS / OBGS 07202/3

| Quality Control Sample ID | Matrix | Instrument | Date Prepared | Date Analyzed | MS/MSD Batch Number |
|---|---|---|---|---|---|
| **07-09-1083-1** | **Solid** | **ICP/MS A** | **09/20/07** | **09/20/07** | **070920S01** |

| Parameter | MS %REC | MSD %REC | %REC CL | RPD | RPD CL | Qualifiers |
|---|---|---|---|---|---|---|
| Chromium | 111 | 112 | 80-120 | 1 | 0-20 | |
| Copper | 103 | 105 | 80-120 | 2 | 0-20 | |
| Nickel | 107 | 108 | 80-120 | 1 | 0-20 | |
| Zinc | 135 | 113 | 80-120 | 8 | 0-20 | 3 |

RPD - Relative Percent Difference , CL - Control Limit

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## Quality Control - Duplicate

| | | | |
|---|---|---|---|
| MBC Applied Environmental Sciences | | Date Received: | 09/10/07 |
| 3000 Redhill Avenue | | Work Order No: | 07-09-0465 |
| Costa Mesa, CA 92626-4524 | | Preparation: | N/A |
| | | Method: | SM 2540 B |

Project: MGS / OBGS 07202/3

| Quality Control Sample ID | Matrix | Instrument | Date Prepared: | Date Analyzed: | Duplicate Batch Number |
|---|---|---|---|---|---|
| **07-09-1086-3** | **Solid** | **N/A** | **N/A** | **09/19/07** | **70919TSD1** |

| Parameter | Sample Conc | DUP Conc | RPD | RPD CL | Qualifiers |
|---|---|---|---|---|---|
| Solids, Total | 18.0 | 17.6 | 2 | 0-25 | |

RPD - Relative Percent Difference , CL - Control Limit

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# Quality Control - LCS/LCS Duplicate

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

| | |
|---|---|
| Date Received: | N/A |
| Work Order No: | 07-09-0465 |
| Preparation: | EPA 3050B |
| Method: | EPA 6020 |

Project: MGS / OBGS 07202/3

| Quality Control Sample ID | Matrix | Instrument | Date Prepared | Date Analyzed | LCS/LCSD Batch Number |
|---|---|---|---|---|---|
| **099-12-411-3** | **Tissue** | **ICP/MS A** | **09/20/07** | **09/20/07** | **070920L01** |

| Parameter | LCS %REC | LCSD %REC | %REC CL | RPD | RPD CL | Qualifiers |
|---|---|---|---|---|---|---|
| Chromium | 107 | 108 | 80-120 | 1 | 0-20 | |
| Copper | 100 | 100 | 80-120 | 0 | 0-20 | |
| Nickel | 102 | 103 | 80-120 | 1 | 0-20 | |
| Zinc | 100 | 104 | 80-120 | 4 | 0-20 | |

RPD - Relative Percent Difference , CL - Control Limit

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**Appendix E-2. Yearly mussel tissue metal concentrations (mg/dry kg). Mandalay Generating Station NPDES, 2007.**

| | Chromium | | | | | Copper | | | | | Nickel | | | | | Zinc | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Rep 1 | Rep 2 | Rep 3 | Mean | SD | Rep 1 | Rep 2 | Rep 3 | Mean | SD | Rep 1 | Rep 2 | Rep 3 | Mean | SD | Rep 1 | Rep 2 | Rep 3 | Mean | SD |
| **Mussel Mooring** | | | | | | | | | | | | | | | | | | | | |
| 2007[1] | 2.10 | NA | NA | 2.10 | - | 5.83 | NA | NA | 5.83 | - | 4.28 | NA | NA | 4.28 | - | 148 | NA | NA | 148 | - |
| 2006[2] | 9.48 | 6.03 | 5.86 | 7.12 | 2.04 | 6.63 | 8.671 | 5.387 | 6.90 | 1.66 | 1.461 | 2.322 | 1.216 | 1.666 | 0.581 | 159.354 | 100.454 | 82.324 | 114.044 | 40.273 |
| 2005[2] | 4.6 | 2.91 | 2.46 | 3.3 | 1.1 | 13.6 | 6.02 | 4.93 | 8.2 | 4.7 | 2.98 | 1.39 | 0.93 | 1.77 | 1.08 | 83.1 | 64.8 | 37 | 62 | 23.2 |
| 2004[1] | ND | ND | ND | - | - | 4.9 | 6.3 | 6.0 | 5.7 | 0.7 | ND | ND | ND | - | - | 54 | 58 | 55 | 56 | 2.1 |
| 2003[2] | ND | ND | ND | - | - | 1.1 | 1.2 | 1.0 | 1.1 | 0.1 | ND | ND | ND | - | - | 13 | 18 | 13 | 15 | 2.9 |
| 2002[2] | ND | ND | ND | - | - | 6.6 | 6.4 | 7.1 | 6.7 | 0.4 | ND | ND | ND | - | - | 100 | 97 | 110 | 102 | 6.8 |
| 2001[2] | ND | ND | ND | - | - | 12 | 13 | 7.0 | 10.7 | 3.2 | ND | ND | ND | - | - | 130 | 260 | 140 | 177 | 72.3 |
| **Donor Site** | | | | | | | | | | | | | | | | | | | | |
| 2007* | NS | NS | NS | - | - | NS | NS | NS | - | - | NS | NS | NS | - | - | NS | NS | NS | - | - |
| 2006[2] | 6.47 | 7.34 | 9.92 | 7.91 | 1.79 | 4.69 | 4.79 | 9.19 | 6.22 | 2.6 | 0.48 | 0.50 | 0.86 | 0.61 | 0.21 | 90.19 | 89.06 | 105.95 | 95.07 | 9.44 |
| 2005 | 3.23 | 3.23 | 5.06 | 3.8 | 1.1 | 8.54 | 12.8 | 12.4 | 11.2 | 2.4 | 7.55 | 3.49 | 10.6 | 7.2 | 3.6 | 65 | 95.6 | 86.1 | 82 | 15.7 |
| 2004* | NS | NS | NS | - | - | NS | NS | NS | - | - | NS | NS | NS | - | - | NS | NS | NS | - | - |
| 2003 | ND | ND | ND | - | - | 1.3 | 1.2 | 1.1 | 1.2 | 0.1 | ND | ND | ND | - | - | 11 | 11 | 10 | 11 | 0.6 |
| 2002 | ND | ND | ND | - | - | 16 | 20 | 40 | 25 | 12.9 | ND | ND | ND | - | - | 87 | 92 | 120 | 100 | 17.8 |
| 2001 | ND | ND | ND | - | - | 13 | 16 | 16 | 15 | 1.7 | ND | ND | ND | - | - | 270 | 170 | 250 | 230 | 52.9 |

ND = Below the detection limit (for calculations ND = 0)
NS = Not required
1 = Resident mussels
2 = Transplanated mussels
* = Transplant mussel source not required
NA = Not available

# APPENDIX F

## Infauna data by station

## Appendix F-1. Infaunal master species list. Mandalay Generating Station NPDES, 2007.

PHYLUM (Phy)
- Subphylum or Class
  - Species

CNIDARIA (CN)
- Anthozoa
  - *Zaolutus actius*

NEMERTEA (NE)
- Anopla
  - *Carinoma mutabilis*
  - Lineidae
- Enopla
  - Hoplonemertea sp A Paquette 1988
  - Nemertea sp B Paquette 2005
  - *Tetrastemma candidum*
- Uncertain
  - Nemertea

NEMATODA (NT)
- Nematoda

MOLLUSCA (MO)
- Gastropoda
  - *Cyclostremella dalli*
  - *Odostomia columbiana*
- Bivalvia
  - *Cooperella subdiaphana*
  - *Donax gouldii*
  - *Macoma secta*
  - *Mactromeris catilliformis*[1]
  - *Siliqua lucida*
  - *Solen sicarius*
  - *Tellina modesta*
  - *Tellina nuculoides*
  - *Yoldia cooperii*

ANNELIDA (AN)
- Polychaeta
  - *Ampharete labrops*
  - *Apoprionospio pygmaea*[2]
  - *Aricidea (Acmira) catherinae*[3]
  - *Aricidea (Aedicira) pacifica*
  - *Armandia brevis*[4]
  - *Chone minuta*
  - *Chone* sp SD1 Pt. Loma 1997
  - *Dispio uncinata*
  - *Exogone lourei*
  - *Glycera macrobranchia*[5]
  - *Goniadia littorea*
  - *Hesionella mccullochae*
  - *Mediomastus acutus*
  - *Mediomastus ambiseta*[6]

PHYLUM
- Subphylum or Class
  - Species

ANNELIDA (AN) Cont
- Polychaeta (cont)
  - *Nephtys caecoides*
  - *Notomastus* sp A SCAMIT 2001
  - Onuphidae
  - *Onuphis eremita*
  - *Onuphis* sp 1 Pt Loma 1983
  - *Owenia collaris*[7]
  - *Pectinaria californiensis*
  - *Spiochaetopterus costarum*
  - *Spiophanes bombyx*
  - *Sthenelais tertiaglabra*
  - *Syllis (Typosyllis) farallonensis*

ARTHROPODA (AR)
- Pycnogonida
  - *Anoropallene palpida*
- Ostracoda
  - *Euphilomedes longiseta*
- Copepoda
  - Harpacticoida
- Malacostraca
  - *Acuminodeutopus heteruropus*
  - *Americhelidium shoemakeri*[8]
  - *Ampelisca agassizi*
  - *Anchicolurus occidentalis*
  - *Campylaspis* sp C Myers & Benedict 1974
  - *Cancer* sp
  - *Caprella verrucosa*
  - *Diastylopsis tenuis*
  - *Edotia sublittoralis*
  - *Ericthonius brasiliensis*
  - *Gammaropsis thompsoni*
  - *Jassa slatteryi*[9]
  - *Laticorophium baconi*
  - *Leptocuma forsmani*
  - *Mandibulophoxus gilesi*
  - *Photis macinerneyi*
  - *Podocerus brasiliensis*
  - *Rhepoxynius menziesi*[10]
  - *Stenothoe estacola*
  - *Uromunna ubiquita*[11]

ECHINODERMATA (EC)
- Echinoidea
  - *Dendraster excentricus*

PHORONA (PR)
- *Phoronis* sp

The following footnotes indicate names used in previous surveys:

1 *Spisula catilliformis*
2 *Apoprionospio pygmaeus*
3 *Acesta catherinae, Acmira catherinae*
4 *Armandia bioculata*
5 *Glycera convoluta*
6 *Mediomastus* spp (in part)
7 *Owenia fusiformis*
8 *Synchelidium shoemakeri*
9 *Jassa falcata* (in part)
10 *Paraphoxus epistomus, Rhepoxynius epistomus*
11 *Munna ubiquita*

**Appendix F-2. Infauna results by station. Mandalay Generating Station NPDES, 2007.**

| | | Station | | | | | | Percent |
|---|---|---|---|---|---|---|---|---|
| Phylum | Species | B1 | B2 | B3 | B4 | B5 | Total | Total |
| EC | *Dendraster excentricus* | 14 | 504 | 218 | 31 | 21 | 788 | 49.40 |
| AN | *Apoprionospio pygmaea* | 2 | 11 | 30 | 4 | 39 | 86 | 5.39 |
| MO | *Tellina modesta* | 1 | 17 | 4 | 1 | 34 | 57 | 3.57 |
| AR | *Rhepoxynius menziesi* | - | 25 | 13 | 9 | 8 | 55 | 3.45 |
| AN | *Armandia brevis* | - | 19 | 7 | - | 24 | 50 | 3.13 |
| AN | *Chone* sp SD1 Pt. Loma 1997 | 2 | 25 | 13 | 1 | 8 | 49 | 3.07 |
| MO | *Siliqua lucida* | 1 | 19 | 7 | - | 15 | 42 | 2.63 |
| CN | *Zaolutus actius* | - | 34 | 2 | - | 3 | 39 | 2.45 |
| AN | *Mediomastus acutus* | 1 | 4 | 2 | 1 | 30 | 38 | 2.38 |
| AR | *Americhelidium shoemakeri* | 19 | 3 | 1 | 11 | - | 34 | 2.13 |
| AR | *Diastylopsis tenuis* | 1 | 4 | 3 | - | 24 | 32 | 2.01 |
| NT | Nematoda | 4 | 4 | 1 | 21 | 2 | 32 | 2.01 |
| AN | *Owenia collaris* | - | 24 | 5 | - | 2 | 31 | 1.94 |
| AR | *Euphilomedes longiseta* | 1 | 19 | 4 | 6 | 1 | 31 | 1.94 |
| NE | *Carinoma mutabilis* | - | 9 | 3 | 4 | 7 | 23 | 1.44 |
| AR | *Photis macinerneyi* | 3 | 3 | 4 | - | 4 | 14 | 0.88 |
| AN | *Nephtys caecoides* | 1 | 4 | 3 | 4 | - | 12 | 0.75 |
| AR | *Ericthonius brasiliensis* | 5 | - | 4 | 2 | - | 11 | 0.69 |
| AR | *Mandibulophoxus gilesi* | 10 | - | 1 | - | - | 11 | 0.69 |
| AN | *Ampharete labrops* | - | - | 1 | - | 7 | 8 | 0.50 |
| AN | *Onuphis eremita* | - | 1 | 7 | - | - | 8 | 0.50 |
| AN | *Pectinaria californiensis* | - | - | - | - | 8 | 8 | 0.50 |
| AN | *Sthenelais tertiaglabra* | - | 5 | 2 | - | 1 | 8 | 0.50 |
| AN | *Glycera macrobranchia* | 1 | 1 | 2 | - | 3 | 7 | 0.44 |
| MO | *Solen sicarius* | - | 6 | 1 | - | - | 7 | 0.44 |
| NE | *Tetrastemma candidum* | - | 2 | 3 | 2 | - | 7 | 0.44 |
| AN | *Mediomastus ambiseta* | - | 1 | - | - | 5 | 6 | 0.38 |
| AN | Onuphidae | - | 4 | - | - | 2 | 6 | 0.38 |
| AN | *Spiochaetopterus costarum* | - | 5 | 1 | - | - | 6 | 0.38 |
| AR | *Jassa slatteryi* | 1 | 2 | - | 3 | - | 6 | 0.38 |
| MO | *Cooperella subdiaphana* | - | 2 | - | - | 4 | 6 | 0.38 |
| AR | Harpacticoida | - | - | - | - | 5 | 5 | 0.31 |
| NE | Lineidae | - | 1 | 1 | - | 3 | 5 | 0.31 |
| AN | *Goniada littorea* | - | 1 | 1 | - | 2 | 4 | 0.25 |
| AN | *Onuphis* sp 1 Pt. Loma 1983 | - | - | - | - | 4 | 4 | 0.25 |
| AN | *Spiophanes bombyx* | - | 2 | 1 | - | 1 | 4 | 0.25 |
| AR | *Edotia sublittoralis* | - | 4 | - | - | - | 4 | 0.25 |
| AR | *Podocerus brasiliensis* | - | 1 | - | 2 | 1 | 4 | 0.25 |
| AN | *Aricidea (Aedicira) pacifica* | - | 1 | - | - | 2 | 3 | 0.19 |
| AN | *Syllis (Typosyllis) farallonensis* | - | 3 | - | - | - | 3 | 0.19 |
| AR | *Acuminodeutopus heteruropus* | 1 | - | - | 2 | - | 3 | 0.19 |
| MO | *Donax gouldii* | - | - | 2 | - | 1 | 3 | 0.19 |
| MO | *Yoldia cooperii* | - | - | - | - | 3 | 3 | 0.19 |
| AN | *Aricidea (Acmira) catherinae* | - | 1 | - | - | 1 | 2 | 0.13 |
| AN | *Dispio uncinata* | - | - | 2 | - | - | 2 | 0.13 |
| AR | *Anchicolurus occidentalis* | - | 1 | 1 | - | - | 2 | 0.13 |
| AR | *Uromunna ubiquita* | - | 1 | 1 | - | - | 2 | 0.13 |
| MO | *Mactromeris catilliformis* | - | 1 | - | - | 1 | 2 | 0.13 |
| NE | Nemertea | - | - | - | 2 | - | 2 | 0.13 |
| AN | *Chone minuta* | 1 | - | - | - | - | 1 | 0.06 |
| AN | *Exogone lourei* | - | - | - | 1 | - | 1 | 0.06 |
| AN | *Hesionella mccullochae* | - | - | 1 | - | - | 1 | 0.06 |
| AN | *Notomastus* sp A SCAMIT 2001 | - | - | - | - | 1 | 1 | 0.06 |
| AR | *Ampelisca agassizi* | - | - | 1 | - | - | 1 | 0.06 |
| AR | *Anoropallene palpida* | - | 1 | - | - | - | 1 | 0.06 |
| AR | *Campylaspis* sp C M & B 1974 | - | - | - | - | 1 | 1 | 0.06 |
| AR | *Cancer* sp | - | - | - | 1 | - | 1 | 0.06 |
| AR | *Caprella verrucosa* | - | - | - | 1 | - | 1 | 0.06 |
| AR | *Gammaropsis thompsoni* | - | - | 1 | - | - | 1 | 0.06 |
| AR | *Laticorophium baconi* | - | - | 1 | - | - | 1 | 0.06 |
| AR | *Leptocuma forsmani* | 1 | - | - | - | - | 1 | 0.06 |
| AR | *Stenothoe estacola* | - | - | - | 1 | - | 1 | 0.06 |
| MO | *Cyclostremella dalli* | - | 1 | - | - | - | 1 | 0.06 |
| MO | *Macoma secta* | - | - | 1 | - | - | 1 | 0.06 |
| MO | *Odostomia columbiana* | - | - | - | - | 1 | 1 | 0.06 |

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

| Phylum | Species | Station B1 | B2 | B3 | B4 | B5 | Total | Percent Total |
|---|---|---|---|---|---|---|---|---|
| MO | *Tellina nuculoides* | - | - | 1 | - | - | 1 | 0.06 |
| NE | Hoplonemertea sp A Paquette 1988 | - | 1 | - | - | - | 1 | 0.06 |
| NE | Nemertea sp B Paquette 2005 | 1 | - | - | - | - | 1 | 0.06 |
| PR | *Phoronis* sp | - | - | - | - | 1 | 1 | 0.06 |
| | Number of individuals | 71 | 777 | 357 | 110 | 280 | 1595 | |
| | Number of species | 20 | 41 | 39 | 21 | 37 | 69 | |
| | Diversity (H') | 2.35 | 1.72 | 1.86 | 2.39 | 2.95 | 2.43 | |

**Appendix F-3. Infaunal data by station and replicate. Mandalay Generating Station NPDES, 2007.**

**Station B1**

| Phylum | Species | Replicate B1-I | B1-II | B1-III | B1-IV | Total | Percent Composition | Density No./m² |
|---|---|---|---|---|---|---|---|---|
| AR | *Americhelidium shoemakeri* | 16 | - | 2 | 1 | 19 | 26.76 | 475.0 |
| EC | *Dendraster excentricus* | 4 | 1 | 4 | 5 | 14 | 19.72 | 350.0 |
| AR | *Mandibulophoxus gilesi* | 7 | 1 | 1 | 1 | 10 | 14.08 | 250.0 |
| AR | *Ericthonius brasiliensis* | 4 | - | 1 | - | 5 | 7.04 | 125.0 |
| NT | Nematoda | - | - | 4 | - | 4 | 5.63 | 100.0 |
| AR | *Photis macinerneyi* | 2 | 1 | - | - | 3 | 4.23 | 75.0 |
| AN | *Apoprionospio pygmaea* | 1 | - | 1 | - | 2 | 2.82 | 50.0 |
| AN | *Chone* sp SD1 Pt. Loma 1997 | 1 | - | - | 1 | 2 | 2.82 | 50.0 |
| AN | *Chone minuta* | 1 | - | - | - | 1 | 1.41 | 25.0 |
| AN | *Glycera macrobranchia* | - | - | 1 | - | 1 | 1.41 | 25.0 |
| AN | *Mediomastus acutus* | - | - | 1 | - | 1 | 1.41 | 25.0 |
| AN | *Nephtys caecoides* | 1 | - | - | - | 1 | 1.41 | 25.0 |
| AR | *Acuminodeutopus heteruropus* | - | - | - | 1 | 1 | 1.41 | 25.0 |
| AR | *Diastylopsis tenuis* | - | - | 1 | - | 1 | 1.41 | 25.0 |
| AR | *Euphilomedes longiseta* | - | - | - | 1 | 1 | 1.41 | 25.0 |
| AR | *Jassa slatteryi* | - | - | - | 1 | 1 | 1.41 | 25.0 |
| AR | *Leptocuma forsmani* | 1 | - | - | - | 1 | 1.41 | 25.0 |
| MO | *Siliqua lucida* | - | - | - | 1 | 1 | 1.41 | 25.0 |
| MO | *Tellina modesta* | - | - | - | 1 | 1 | 1.41 | 25.0 |
| NE | Nemertea sp B Paquette 2005 | 1 | - | - | - | 1 | 1.41 | 25.0 |

**Summary**

| Parameter | Replicate B1-I | B1-II | B1-III | B1-IV | Station Total | Replicate Mean | S.D. |
|---|---|---|---|---|---|---|---|
| Number of individuals | 39 | 3 | 16 | 13 | 71 | 17.8 | 15.2 |
| Number of species | 11 | 3 | 9 | 9 | 20 | 8.0 | 3.5 |
| Diversity (H') | 1.86 | 1.10 | 1.99 | 1.95 | 2.35 | 1.72 | 0.42 |

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

**Station B2**

| Phylum | Species | Replicate B2-I | B2-II | B2-III | B2-IV | Total | Percent Composition | Density No./m² |
|---|---|---|---|---|---|---|---|---|
| EC | *Dendraster excentricus* | 106 | 30 | 244 | 124 | 504 | 64.86 | 12600.0 |
| CN | *Zaolutus actius* | 4 | 16 | 3 | 11 | 34 | 4.38 | 850.0 |
| AN | *Chone* sp SD1 Pt. Loma 1997 | 7 | 3 | 6 | 9 | 25 | 3.22 | 625.0 |
| AR | *Rhepoxynius menziesi* | 2 | 6 | 10 | 7 | 25 | 3.22 | 625.0 |
| AN | *Owenia collaris* | 1 | 11 | 3 | 9 | 24 | 3.09 | 600.0 |
| AN | *Armandia brevis* | 6 | 9 | 2 | 2 | 19 | 2.45 | 475.0 |
| AR | *Euphilomedes longiseta* | 5 | 2 | 9 | 3 | 19 | 2.45 | 475.0 |
| MO | *Siliqua lucida* | 5 | 4 | 6 | 4 | 19 | 2.45 | 475.0 |
| MO | *Tellina modesta* | 3 | 6 | 2 | 6 | 17 | 2.19 | 425.0 |
| AN | *Apoprionospio pygmaea* | 1 | 5 | 2 | 3 | 11 | 1.42 | 275.0 |
| NE | *Carinoma mutabilis* | 2 | 3 | 2 | 2 | 9 | 1.16 | 225.0 |
| MO | *Solen sicarius* | - | 1 | 3 | 2 | 6 | 0.77 | 150.0 |
| AN | *Spiochaetopterus costarum* | 3 | 2 | - | - | 5 | 0.64 | 125.0 |
| AN | *Sthenelais tertiaglabra* | - | 1 | 3 | 1 | 5 | 0.64 | 125.0 |
| AN | *Mediomastus acutus* | 2 | 1 | - | 1 | 4 | 0.51 | 100.0 |
| AN | *Nephtys caecoides* | - | 2 | 1 | 1 | 4 | 0.51 | 100.0 |
| AN | Onuphidae | - | - | 4 | - | 4 | 0.51 | 100.0 |
| AR | *Diastylopsis tenuis* | 2 | - | - | 2 | 4 | 0.51 | 100.0 |
| AR | *Edotia sublittoralis* | - | - | - | 4 | 4 | 0.51 | 100.0 |
| NT | Nematoda | 2 | 1 | - | 1 | 4 | 0.51 | 100.0 |
| AN | *Syllis (Typosyllis) farallonensis* | - | 2 | 1 | - | 3 | 0.39 | 75.0 |
| AR | *Americhelidium shoemakeri* | - | 1 | 2 | - | 3 | 0.39 | 75.0 |
| AR | *Photis macinerneyi* | 1 | - | 1 | 1 | 3 | 0.39 | 75.0 |
| AN | *Spiophanes bombyx* | 1 | - | - | 1 | 2 | 0.26 | 50.0 |
| AR | *Jassa slatteryi* | 1 | - | 1 | - | 2 | 0.26 | 50.0 |
| MO | *Cooperella subdiaphana* | - | - | 1 | 1 | 2 | 0.26 | 50.0 |
| NE | *Tetrastemma candidum* | - | 2 | - | - | 2 | 0.26 | 50.0 |
| AN | *Aricidea (Acmira) catherinae* | - | - | 1 | - | 1 | 0.13 | 25.0 |
| AN | *Aricidea (Aedicira) pacifica* | 1 | - | - | - | 1 | 0.13 | 25.0 |
| AN | *Glycera macrobranchia* | - | - | - | 1 | 1 | 0.13 | 25.0 |
| AN | *Goniada littorea* | - | 1 | - | - | 1 | 0.13 | 25.0 |
| AN | *Mediomastus ambiseta* | 1 | - | - | - | 1 | 0.13 | 25.0 |
| AN | *Onuphis eremita* | - | - | - | 1 | 1 | 0.13 | 25.0 |
| AR | *Anchicolurus occidentalis* | 1 | - | - | - | 1 | 0.13 | 25.0 |
| AR | *Anoropallene palpida* | - | - | 1 | - | 1 | 0.13 | 25.0 |
| AR | *Podocerus brasiliensis* | 1 | - | - | - | 1 | 0.13 | 25.0 |
| AR | *Uromunna ubiquita* | - | - | - | 1 | 1 | 0.13 | 25.0 |
| MO | *Cyclostremella dalli* | - | - | - | 1 | 1 | 0.13 | 25.0 |
| MO | *Mactromeris catilliformis* | 1 | - | - | - | 1 | 0.13 | 25.0 |
| NE | Hoplonemertea sp A Paquette 1988 | - | - | - | 1 | 1 | 0.13 | 25.0 |
| NE | Lineidae | - | - | - | 1 | 1 | 0.13 | 25.0 |

**Summary**

| Parameter | Replicate B2-I | B2-II | B2-III | B2-IV | Station Total | Replicate Mean | S.D. |
|---|---|---|---|---|---|---|---|
| Number of individuals | 159 | 109 | 308 | 201 | 777 | 194.3 | 84.6 |
| Number of species | 23 | 21 | 22 | 27 | 41 | 23.3 | 2.6 |
| Diversity (H') | 1.59 | 2.48 | 1.08 | 1.76 | 1.72 | 1.73 | 0.58 |

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

**Station B3**

| Phylum | Species | Replicate B3-I | B3-II | B3-III | B3-IV | Total | Percent Composition | Density No./m² |
|---|---|---|---|---|---|---|---|---|
| EC | *Dendraster excentricus* | 26 | 38 | 110 | 44 | 218 | 61.06 | 5450.0 |
| AN | *Apoprionospio pygmaea* | 13 | 10 | 1 | 6 | 30 | 8.40 | 750.0 |
| AN | *Chone* sp SD1 Pt. Loma 1997 | - | 6 | 3 | 4 | 13 | 3.64 | 325.0 |
| AR | *Rhepoxynius menziesi* | 12 | 1 | - | - | 13 | 3.64 | 325.0 |
| AN | *Armandia brevis* | 4 | - | 1 | 2 | 7 | 1.96 | 175.0 |
| AN | *Onuphis eremita* | 1 | 4 | 1 | 1 | 7 | 1.96 | 175.0 |
| MO | *Siliqua lucida* | 3 | - | 2 | 2 | 7 | 1.96 | 175.0 |
| AN | *Owenia collaris* | 4 | - | - | 1 | 5 | 1.40 | 125.0 |
| AR | *Ericthonius brasiliensis* | 2 | - | - | 2 | 4 | 1.12 | 100.0 |
| AR | *Euphilomedes longiseta* | 1 | - | 2 | 1 | 4 | 1.12 | 100.0 |
| AR | *Photis macinerneyi* | 3 | - | - | 1 | 4 | 1.12 | 100.0 |
| MO | *Tellina modesta* | 2 | - | 1 | 1 | 4 | 1.12 | 100.0 |
| AN | *Nephtys caecoides* | 1 | - | 2 | - | 3 | 0.84 | 75.0 |
| AR | *Diastylopsis tenuis* | - | 1 | 1 | 1 | 3 | 0.84 | 75.0 |
| NE | *Carinoma mutabilis* | - | 1 | 2 | - | 3 | 0.84 | 75.0 |
| NE | *Tetrastemma candidum* | - | 2 | - | 1 | 3 | 0.84 | 75.0 |
| AN | *Dispio uncinata* | 1 | - | 1 | - | 2 | 0.56 | 50.0 |
| AN | *Glycera macrobranchia* | 1 | - | - | 1 | 2 | 0.56 | 50.0 |
| AN | *Mediomastus acutus* | - | - | 2 | - | 2 | 0.56 | 50.0 |
| AN | *Sthenelais tertiaglabra* | 1 | - | 1 | - | 2 | 0.56 | 50.0 |
| CN | *Zaolutus actius* | 2 | - | - | - | 2 | 0.56 | 50.0 |
| MO | *Donax gouldii* | 2 | - | - | - | 2 | 0.56 | 50.0 |
| AN | *Ampharete labrops* | - | - | - | 1 | 1 | 0.28 | 25.0 |
| AN | *Goniada littorea* | - | 1 | - | - | 1 | 0.28 | 25.0 |
| AN | *Hesionella mccullochae* | - | - | 1 | - | 1 | 0.28 | 25.0 |
| AN | *Spiochaetopterus costarum* | - | - | - | 1 | 1 | 0.28 | 25.0 |
| AN | *Spiophanes bombyx* | - | 1 | - | - | 1 | 0.28 | 25.0 |
| AR | *Americhelidium shoemakeri* | - | - | - | 1 | 1 | 0.28 | 25.0 |
| AR | *Ampelisca agassizi* | - | - | - | 1 | 1 | 0.28 | 25.0 |
| AR | *Anchicolurus occidentalis* | - | 1 | - | - | 1 | 0.28 | 25.0 |
| AR | *Gammaropsis thompsoni* | 1 | - | - | - | 1 | 0.28 | 25.0 |
| AR | *Laticorophium baconi* | - | - | 1 | - | 1 | 0.28 | 25.0 |
| AR | *Mandibulophoxus gilesi* | 1 | - | - | - | 1 | 0.28 | 25.0 |
| AR | *Uromunna ubiquita* | 1 | - | - | - | 1 | 0.28 | 25.0 |
| MO | *Macoma secta* | 1 | - | - | - | 1 | 0.28 | 25.0 |
| MO | *Solen sicarius* | - | - | 1 | - | 1 | 0.28 | 25.0 |
| MO | *Tellina nuculoides* | - | - | 1 | - | 1 | 0.28 | 25.0 |
| NE | Lineidae | - | 1 | - | - | 1 | 0.28 | 25.0 |
| NT | Nematoda | - | - | - | 1 | 1 | 0.28 | 25.0 |

**Summary**

| Parameter | Replicate B3-I | B3-II | B3-III | B3-IV | Station Total | Replicate Mean | S.D. |
|---|---|---|---|---|---|---|---|
| Number of individuals | 83 | 67 | 134 | 73 | 357 | 89.3 | 30.6 |
| Number of species | 21 | 12 | 18 | 19 | 39 | 17.5 | 3.9 |
| Diversity (H') | 2.36 | 1.53 | 0.96 | 1.73 | 1.86 | 1.65 | 0.58 |

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

**Station B4**

| Phylum | Species | Replicate B4-I | B4-II | B4-III | B4-IV | Total | Percent Composition | Density No./m² |
|---|---|---|---|---|---|---|---|---|
| EC | *Dendraster excentricus* | 10 | 3 | 10 | 8 | 31 | 28.18 | 775.0 |
| NT | Nematoda | 2 | 6 | 11 | 2 | 21 | 19.09 | 525.0 |
| AR | *Americhelidium shoemakeri* | 1 | 2 | 1 | 7 | 11 | 10.00 | 275.0 |
| AR | *Rhepoxynius menziesi* | 6 | - | 2 | 1 | 9 | 8.18 | 225.0 |
| AR | *Euphilomedes longiseta* | 3 | 2 | - | 1 | 6 | 5.45 | 150.0 |
| AN | *Apoprionospio pygmaea* | 4 | - | - | - | 4 | 3.64 | 100.0 |
| AN | *Nephtys caecoides* | 1 | - | - | 3 | 4 | 3.64 | 100.0 |
| NE | *Carinoma mutabilis* | - | 1 | 2 | 1 | 4 | 3.64 | 100.0 |
| AR | *Jassa slatteryi* | 1 | 2 | - | - | 3 | 2.73 | 75.0 |
| AR | *Acuminodeutopus heteruropus* | 2 | - | - | - | 2 | 1.82 | 50.0 |
| AR | *Ericthonius brasiliensis* | 1 | - | 1 | - | 2 | 1.82 | 50.0 |
| AR | *Podocerus brasiliensis* | 1 | 1 | - | - | 2 | 1.82 | 50.0 |
| NE | Nemertea | 1 | 1 | - | - | 2 | 1.82 | 50.0 |
| NE | *Tetrastemma candidum* | - | 1 | 1 | - | 2 | 1.82 | 50.0 |
| AN | *Chone* sp SD1 Pt. Loma 1997 | - | - | - | 1 | 1 | 0.91 | 25.0 |
| AN | *Exogone lourei* | - | - | - | 1 | 1 | 0.91 | 25.0 |
| AN | *Mediomastus acutus* | - | 1 | - | - | 1 | 0.91 | 25.0 |
| AR | *Cancer* sp | - | - | 1 | - | 1 | 0.91 | 25.0 |
| AR | *Caprella verrucosa* | - | - | - | 1 | 1 | 0.91 | 25.0 |
| AR | *Stenothoe estacola* | 1 | - | - | - | 1 | 0.91 | 25.0 |
| MO | *Tellina modesta* | 1 | - | - | - | 1 | 0.91 | 25.0 |

**Summary**

| Parameter | Replicate B4-I | B4-II | B4-III | B4-IV | Station Total | Replicate Mean | S.D. |
|---|---|---|---|---|---|---|---|
| Number of individuals | 35 | 20 | 29 | 26 | 110 | 27.5 | 6.2 |
| Number of species | 14 | 10 | 8 | 10 | 21 | 10.5 | 2.5 |
| Diversity (H') | 2.26 | 2.09 | 1.57 | 1.91 | 2.39 | 1.96 | 0.29 |

**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* | 7 | 10 | 14 | 8 | 39 | 13.93 | 975.0 |
| MO | *Tellina modesta* | 3 | 13 | 13 | 5 | 34 | 12.14 | 850.0 |
| AN | *Mediomastus acutus* | 9 | 4 | 15 | 2 | 30 | 10.71 | 750.0 |
| AN | *Armandia brevis* | 1 | 21 | - | 2 | 24 | 8.57 | 600.0 |
| AR | *Diastylopsis tenuis* | 12 | - | 11 | 1 | 24 | 8.57 | 600.0 |
| EC | *Dendraster excentricus* | 8 | 4 | 4 | 5 | 21 | 7.50 | 525.0 |
| MO | *Siliqua lucida* | 4 | 2 | 3 | 6 | 15 | 5.36 | 375.0 |
| AN | *Chone* sp SD1 Pt. Loma 1997 | - | 1 | 6 | 1 | 8 | 2.86 | 200.0 |
| AN | *Pectinaria californiensis* | 2 | - | 6 | - | 8 | 2.86 | 200.0 |
| AR | *Rhepoxynius menziesi* | 1 | 3 | - | 4 | 8 | 2.86 | 200.0 |
| AN | *Ampharete labrops* | 1 | 5 | 1 | - | 7 | 2.50 | 175.0 |
| NE | *Carinoma mutabilis* | 1 | 1 | 5 | - | 7 | 2.50 | 175.0 |
| AN | *Mediomastus ambiseta* | - | - | 4 | 1 | 5 | 1.79 | 125.0 |
| AR | Harpacticoida | 2 | 1 | 2 | - | 5 | 1.79 | 125.0 |
| AN | *Onuphis* sp 1 Pt. Loma 1983 | 1 | - | 1 | 2 | 4 | 1.43 | 100.0 |
| AR | *Photis macinerneyi* | 2 | 1 | 1 | - | 4 | 1.43 | 100.0 |
| MO | *Cooperella subdiaphana* | - | 2 | 1 | 1 | 4 | 1.43 | 100.0 |
| AN | *Glycera macrobranchia* | 1 | - | 2 | - | 3 | 1.07 | 75.0 |
| CN | *Zaolutus actius* | - | - | 1 | 2 | 3 | 1.07 | 75.0 |
| MO | *Yoldia cooperii* | 1 | - | 2 | - | 3 | 1.07 | 75.0 |
| NE | Lineidae | - | 1 | 2 | - | 3 | 1.07 | 75.0 |
| AN | *Aricidea (Aedicira) pacifica* | - | - | 1 | 1 | 2 | 0.71 | 50.0 |
| AN | *Goniada littorea* | 1 | - | - | 1 | 2 | 0.71 | 50.0 |
| AN | Onuphidae | - | - | 1 | 1 | 2 | 0.71 | 50.0 |
| AN | *Owenia collaris* | - | - | 1 | 1 | 2 | 0.71 | 50.0 |
| NT | Nematoda | 1 | - | - | 1 | 2 | 0.71 | 50.0 |
| AN | *Aricidea (Acmira) catherinae* | 1 | - | - | - | 1 | 0.36 | 25.0 |
| AN | *Notomastus* sp A SCAMIT 2001 | - | - | - | 1 | 1 | 0.36 | 25.0 |
| AN | *Spiophanes bombyx* | - | - | - | 1 | 1 | 0.36 | 25.0 |
| AN | *Sthenelais tertiaglabra* | 1 | - | - | - | 1 | 0.36 | 25.0 |
| AR | *Campylaspis* sp C M & B 1974 | - | 1 | - | - | 1 | 0.36 | 25.0 |
| AR | *Euphilomedes longiseta* | - | 1 | - | - | 1 | 0.36 | 25.0 |
| AR | *Podocerus brasiliensis* | 1 | - | - | - | 1 | 0.36 | 25.0 |
| MO | *Donax gouldii* | 1 | - | - | - | 1 | 0.36 | 25.0 |
| MO | *Mactromeris catilliformis* | - | - | 1 | - | 1 | 0.36 | 25.0 |
| MO | *Odostomia columbiana* | - | 1 | - | - | 1 | 0.36 | 25.0 |
| PR | *Phoronis* sp | - | 1 | - | - | 1 | 0.36 | 25.0 |

**Summary**

| Parameter | Replicate B5-I | B5-II | B5-III | B5-IV | Station Total | Replicate Mean | S.D. |
|---|---|---|---|---|---|---|---|
| Number of individuals | 62 | 73 | 98 | 47 | 280 | 70.0 | 21.5 |
| Number of species | 22 | 18 | 23 | 20 | 37 | 20.8 | 2.2 |
| Diversity (H') | 2.63 | 2.30 | 2.68 | 2.69 | 2.95 | 2.57 | 0.19 |

**Appendix F-4. Infaunal wet weight biomass data (g). Mandalay Generating Station NPDES, 2007.**

| Sta-Rep | Annelida | Arthropoda | Mollusca | Echinodermata | Misc. | Total |
|---|---|---|---|---|---|---|
| B1-I | 0.0258 | 0.0675 | - | 0.0030 | 0.0515 | 0.1478 |
| B1-II | - | <0.0001 | - | <0.0001 | - | - |
| B1-III | <0.0001 | 0.0643 | - | <0.0001 | <0.0001 | 0.0643 |
| B1-IV | 0.0265 | 0.0353 | 0.0179 | <0.0001 | - | 0.0797 |
| Total | 0.0523 | 0.1671 | 0.0179 | 0.0030 | 0.0515 | 0.2918 |
| B2-I | 0.1625 | 0.0766 | <0.0001 | 0.0164 | 0.0124 | 0.2679 |
| B2-II | 0.6182 | 0.0050 | 0.0541 | <0.0001 | 0.1190 | 0.7963 |
| B2-III | 0.0674 | 0.0504 | 0.0430 | <0.0001 | 0.0318 | 0.1926 |
| B2-IV | 0.3491 | 0.0467 | 0.0741 | 0.0037 | 0.0411 | 0.5147 |
| Total | 1.1972 | 0.1787 | 0.1712 | 0.0201 | 0.2043 | 1.7715 |
| B3-I | 0.4523 | 0.0326 | <0.0001 | 0.3783 | 0.0296 | 0.8928 |
| B3-II | 0.0166 | 0.0159 | - | <0.0001 | 0.0772 | 0.1097 |
| B3-III | 0.0104 | <0.0001 | 0.0221 | 0.0148 | 0.0316 | 0.0789 |
| B3-IV | 0.0906 | <0.0001 | <0.0001 | <0.0001 | 0.0122 | 0.1028 |
| Total | 0.5699 | 0.0485 | 0.0221 | 0.3931 | 0.1506 | 1.1842 |
| B4-I | 0.0946 | 0.0225 | 0.0071 | 45.1587 [a] | <0.0001 | 45.2829 |
| B4-II | <0.0001 | 0.0368 | - | 11.3864 [b] | <0.0001 | 11.4232 |
| B4-III | - | <0.0001 | - | 34.9290 [c] | 0.0250 | 34.9540 |
| B4-IV | 0.1109 | 0.0871 | - | 38.2617 [d] | <0.0001 | 38.4597 |
| Total | 0.2055 | 0.1464 | 0.0071 | 129.7358 | 0.0250 | 130.1198 |
| B5-I | 0.8599 | 0.0383 | <0.0001 | <0.0001 | 0.0371 | 0.9353 |
| B5-II | 0.1412 | <0.0001 | 0.1884 | 1.6399 | <0.0001 | 1.9695 |
| B5-III | 0.0586 | <0.0001 | 0.0206 | 0.7556 | 0.0823 | 0.9171 |
| B5-IV | 0.3396 | <0.0001 | 0.0984 | <0.0001 | 0.0542 | 0.4922 |
| Total | 1.3993 | 0.0383 | 0.3074 | 2.3955 | 0.1736 | 4.3141 |
| Grand Total | 3.4242 | 0.5790 | 0.5257 | 132.5475 | 0.6050 | 137.6814 |

Notes:

- = no animals

a = 10 medium sized *Dendraster excentricus*

b = 3 medium sized *Dendraster excentricus*

c = 10 medium sized *Dendraster excentricus*

d = 7 medium sized and 1 large *Dendraster excentricus*

## Appendix F-5. Yearly infaunal abundance, 1978 - 2007. Mandalay Generating Station NPDES, 2007.

| | | Year | | | | | | | | | | | | | | | | | | | | | Percent |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Phy | Species | 1978 | 1980 | 1986 | 1988 | 1990 | 1991 | 1992 | 1993 | 1994 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 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 | 5134 | 21.42 |
| MO | *Donax gouldii* | - | - | - | - | - | - | - | - | - | - | 3064 | - | 2 | - | - | 6 | - | 1 | 1 | 3 | 3077 | 12.84 |
| AN | *Mediomastus acutus* | 5 | 1 | - | - | - | - | - | 1 | 58 | 35 | 1026 | 28 | 12 | 103 | 83 | 3 | 40 | 6 | 22 | 38 | 1461 | 6.09 |
| EC | *Dendraster excentricus* | 12 | 1 | 43 | 17 | 87 | 14 | 14 | - | 10 | 103 | 52 | 75 | 34 | 41 | 15 | 7 | 4 | 3 | 27 | 788 | 1347 | 5.62 |
| AR | *Diastylopsis tenuis* | 123 | 163 | 75 | 33 | 12 | 9 | 5 | 11 | 88 | 45 | 2 | 51 | 56 | 7 | 19 | - | 4 | 424 | 74 | 32 | 1233 | 5.14 |
| AR | *Rhepoxynius menziesi* | 17 | 25 | 20 | 61 | 43 | 14 | 18 | 14 | 34 | - | 35 | 270 | 84 | 67 | 71 | 64 | 85 | 36 | 30 | 55 | 1043 | 4.35 |
| AN | *Scoloplos armiger* Cmplx | 61 | 28 | 20 | 111 | 187 | 149 | 55 | 69 | 43 | 71 | 16 | 10 | 10 | 20 | 12 | 18 | 33 | 4 | - | - | 917 | 3.83 |
| AN | *Chone* sp SD1 Pt. Loma 1997 | - | - | - | - | - | - | - | - | - | - | 14 | 1 | 20 | 7 | 25 | 5 | 290 | 10 | 242 | 49 | 663 | 2.77 |
| AN | *Spiophanes bombyx* | 14 | 51 | 92 | 46 | 17 | 2 | 3 | 154 | 60 | 15 | 13 | 8 | 43 | 4 | 2 | - | 12 | 76 | 6 | 4 | 622 | 2.59 |
| AN | *Owenia collaris* | 5 | 40 | - | 2 | 10 | 88 | 9 | 44 | 2 | 130 | 8 | 31 | 111 | 5 | 29 | 1 | 1 | - | 10 | 31 | 557 | 2.32 |
| MO | *Siliqua lucida* | - | 17 | 9 | 112 | - | 4 | - | - | 82 | 62 | 22 | 31 | 6 | 17 | 11 | - | 1 | 12 | 12 | 42 | 440 | 1.84 |
| NE | *Carinoma mutabilis* | - | 3 | 16 | 18 | 7 | 18 | 28 | 19 | 25 | 24 | 78 | 17 | 18 | 29 | 28 | 7 | 14 | 11 | 52 | 23 | 435 | 1.81 |
| AR | *Euphilomedes carcharodonta* | - | 1 | 1 | 3 | - | - | - | - | 47 | 333 | - | - | - | - | 2 | - | - | - | - | - | 387 | 1.61 |
| MO | *Tellina modesta* | 2 | 18 | 29 | 2 | 4 | - | - | 1 | 11 | 101 | 2 | 19 | 46 | 20 | 8 | 1 | 23 | 3 | 25 | 57 | 372 | 1.55 |
| AN | *Magelona pitelkai* | 9 | 131 | - | 38 | 13 | 21 | 14 | 24 | 20 | 5 | - | 1 | - | 8 | 6 | 5 | 1 | 3 | - | - | 299 | 1.25 |
| AN | *Goniada littorea* | 21 | 26 | 6 | - | 6 | 2 | - | 3 | 6 | 11 | 36 | 74 | 37 | 5 | 9 | - | 4 | 11 | 12 | 4 | 273 | 1.14 |
| AR | *Americhelidium shoemakeri* | 4 | - | - | 1 | 7 | - | - | - | 8 | 3 | - | 5 | 23 | 68 | 25 | 13 | 18 | 2 | 5 | 34 | 216 | 0.90 |
| CN | *Zaolutus actius* | - | 4 | - | - | - | - | - | - | - | 99 | 4 | 7 | 40 | 4 | 17 | - | - | - | - | 39 | 214 | 0.89 |
| AN | *Pectinaria californiensis* | - | 1 | 9 | 60 | 3 | - | - | - | 4 | 112 | - | 1 | 6 | - | 2 | - | 1 | - | - | 8 | 207 | 0.86 |
| AN | *Nephtys caecoides* | 6 | 4 | 8 | 5 | 9 | 24 | 8 | 11 | 14 | 3 | 3 | 6 | 11 | 9 | 19 | 21 | 8 | 2 | 10 | 12 | 193 | 0.81 |
| AR | *Euphilomedes longiseta* | - | - | - | 2 | 10 | 22 | - | - | - | - | 3 | - | 3 | 5 | 54 | 12 | 12 | 6 | 28 | 31 | 188 | 0.78 |
| AR | *Photis macinerneyi* | - | - | 13 | 45 | - | - | - | - | 4 | 20 | 2 | 5 | 10 | 6 | 1 | - | - | 58 | 3 | 14 | 181 | 0.76 |
| AR | *Rhepoxynius* sp A SCAMIT 1987 | 2 | 5 | 9 | 12 | 26 | 11 | - | - | 23 | 37 | - | 4 | 11 | 12 | 12 | - | 2 | 4 | 3 | - | 173 | 0.72 |
| MO | *Mactromeris catilliformis* | - | - | - | - | - | - | - | - | - | 12 | - | - | - | 14 | 120 | - | 1 | 1 | 12 | 2 | 162 | 0.68 |
| AN | *Mediomastus* spp | - | 9 | 16 | 17 | 12 | 7 | 4 | - | - | - | 91 | 2 | 1 | 2 | - | - | - | - | - | - | 161 | 0.67 |
| AN | *Armandia brevis* | - | 7 | - | 5 | - | 1 | - | - | 7 | 3 | 6 | 9 | - | 6 | 3 | - | 11 | 46 | 3 | 50 | 157 | 0.65 |
| AR | *Mandibulophoxus gilesi* | 14 | - | - | - | - | 36 | 15 | - | 4 | 15 | - | - | 3 | - | - | 4 | 23 | - | - | 11 | 125 | 0.52 |
| AN | *Magelona sacculata* | 2 | 23 | 47 | 22 | 16 | 4 | - | - | - | - | - | - | - | 2 | 6 | - | - | - | - | - | 122 | 0.51 |
| MO | *Solen sicarius* | 2 | - | 9 | 16 | 3 | 5 | 2 | 5 | 3 | 20 | 20 | 3 | 6 | - | - | 1 | - | - | 16 | 7 | 118 | 0.49 |
| AN | *Spiophanes duplex* | 4 | 17 | - | 11 | - | - | - | 4 | 3 | 1 | 1 | - | 5 | 1 | - | - | - | 70 | - | - | 117 | 0.49 |
| AN | *Onuphis eremita* | - | - | - | - | 11 | 9 | - | 45 | 1 | 1 | 17 | - | 1 | - | 1 | 19 | - | - | - | 8 | 113 | 0.47 |
| NE | Lineidae | - | - | - | 1 | - | - | - | - | - | 9 | 22 | 13 | 5 | 4 | 2 | 1 | 24 | 10 | 14 | 5 | 110 | 0.46 |
| AN | *Mediomastus ambiseta* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 13 | - | 61 | 5 | 20 | 6 | 105 | 0.44 |
| AN | *Chone albocincta* | - | - | - | - | 5 | 14 | - | 5 | 9 | 62 | - | - | - | - | 1 | - | - | - | - | - | 96 | 0.40 |
| AR | *Anchicolurus occidentalis* | - | - | - | 2 | - | 3 | - | 1 | 2 | 4 | - | 19 | 4 | 1 | 1 | 1 | 4 | 35 | 15 | 2 | 94 | 0.39 |
| AR | *Isocheles pilosus* | 12 | 1 | - | 75 | 1 | - | - | - | - | 1 | - | - | 2 | 1 | - | - | - | - | - | - | 93 | 0.39 |
| AN | *Dispio uncinata* | 9 | 20 | 10 | 6 | 2 | - | - | - | 1 | 4 | - | 4 | 9 | 7 | - | 1 | - | 12 | - | 2 | 87 | 0.36 |
| AR | *Edotia sublittoralis* | 1 | 7 | - | 1 | - | - | - | - | 1 | 35 | 1 | - | 2 | - | 3 | - | - | 18 | 9 | 4 | 82 | 0.34 |
| AN | *Glycera macrobranchia* | 1 | 1 | - | 1 | 13 | 3 | 4 | 3 | 3 | 6 | 4 | 1 | 1 | 4 | 8 | 2 | 6 | 6 | 6 | 7 | 80 | 0.33 |
| AR | *Eohaustorius barnardi* | 17 | 12 | 9 | 4 | 1 | - | - | - | 5 | 11 | 1 | 1 | 4 | 7 | 2 | - | - | - | 1 | - | 75 | 0.31 |
| AN | *Ampharete labrops* | 1 | - | 3 | 5 | - | 4 | - | - | 6 | - | 5 | 3 | 6 | 5 | 24 | - | 2 | 1 | 1 | 8 | 74 | 0.31 |
| NT | Nematoda | - | - | - | - | 1 | - | 1 | - | 2 | 4 | - | 2 | - | 1 | - | 6 | 15 | 6 | 2 | 32 | 72 | 0.30 |
| AN | *Spiochaetopterus costarum* | - | 1 | 1 | 5 | 7 | 2 | - | 12 | 7 | 4 | - | - | 10 | 5 | - | - | 1 | 1 | - | 6 | 62 | 0.26 |
| NE | Nemertea | 3 | 4 | 3 | 4 | 4 | 1 | - | 10 | 2 | 4 | 16 | - | 1 | - | - | 3 | 2 | - | - | 2 | 59 | 0.25 |
| AR | *Uromunna ubiquita* | - | - | - | 1 | - | - | - | - | - | 33 | 2 | 4 | 1 | 3 | 6 | 1 | 3 | 1 | - | 2 | 57 | 0.24 |
| NE | *Paranemertes californica* | - | 4 | 1 | 6 | 2 | - | - | - | 4 | 11 | 1 | 1 | 3 | - | 1 | 2 | 1 | 10 | 5 | - | 52 | 0.22 |
| AN | Onuphidae | 1 | - | - | - | 1 | - | 1 | - | 1 | 1 | - | - | 3 | - | 35 | - | - | - | - | 6 | 49 | 0.20 |
| AR | *Jassa slatteryi* | - | - | - | - | - | - | - | - | - | - | - | 38 | - | - | - | 3 | 2 | - | - | 6 | 49 | 0.20 |
| AN | *Onuphis* sp 1 Pt. Loma 1983 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 6 | - | 3 | 24 | 11 | 4 | 48 | 0.20 |
| AR | *Photis* sp | 17 | 30 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | 48 | 0.20 |
| AR | *Eohaustorius sawyeri* | - | - | - | - | 8 | - | - | - | - | - | - | 4 | - | - | 28 | 5 | 1 | - | - | - | 46 | 0.19 |
| MO | *Cooperella subdiaphana* | - | 1 | 1 | 6 | - | - | - | - | - | 7 | 2 | 3 | 2 | 6 | 2 | 1 | 2 | - | 4 | 6 | 43 | 0.18 |
| MO | *Macoma nasuta* | - | - | 8 | - | 35 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 43 | 0.18 |
| AN | *Aricidea (Acmira) catherinae* | - | 7 | 9 | 1 | 5 | 2 | - | - | 3 | 2 | - | - | - | 1 | 3 | - | 3 | - | 2 | 2 | 40 | 0.17 |
| AR | *Leptocuma forsmani* | 1 | - | - | - | - | - | 14 | 3 | 1 | 5 | 1 | 2 | 2 | 2 | - | - | 4 | 2 | - | 1 | 38 | 0.16 |
| AN | *Amastigos acutus* | - | 35 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 35 | 0.15 |
| AN | *Syllis (Typosyllis) farallonensis* | - | - | 1 | - | - | - | - | - | 6 | - | - | - | - | - | - | - | - | 18 | 7 | 3 | 35 | 0.15 |
| AN | *Amaeana occidentalis* | 1 | - | - | - | - | - | 1 | - | - | - | 28 | 1 | - | - | - | - | - | - | 2 | - | 33 | 0.14 |
| AN | *Onuphis* sp | - | - | - | 1 | - | - | - | - | - | 11 | - | - | 15 | 5 | - | - | - | - | - | - | 32 | 0.13 |
| AR | *Gibberosus myersi* | 2 | - | 1 | 1 | - | - | - | - | 2 | 8 | - | 3 | 4 | 5 | - | 2 | - | 2 | 2 | - | 32 | 0.13 |
| AR | *Campylaspis* sp C M & B 1974 | - | - | - | - | - | - | - | 1 | 1 | 1 | - | 8 | 12 | 1 | 2 | - | 1 | 1 | 2 | 1 | 31 | 0.13 |
| MO | *Mysella pedroana* | - | 1 | - | 27 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 28 | 0.12 |
| PR | Phoronidae | - | 2 | - | - | 1 | 1 | - | 2 | 3 | 7 | 1 | - | 5 | 2 | 1 | - | 3 | - | - | - | 28 | 0.12 |
| AN | *Neosabellaria cementarium* | - | - | - | - | - | - | - | - | - | - | - | 27 | - | - | - | - | - | - | - | - | 27 | 0.11 |
| MO | *Tellina bodegensis* | - | - | 1 | 2 | 2 | - | - | - | 13 | 1 | - | 3 | 1 | 2 | 2 | - | - | - | - | - | 27 | 0.11 |
| AN | *Polydora limicola* | - | - | - | - | - | - | - | - | 26 | - | - | - | - | - | - | - | - | - | - | - | 26 | 0.11 |
| AN | *Polydora* sp | 1 | 1 | 1 | 14 | 1 | 2 | - | 1 | - | - | - | - | - | 3 | - | - | - | - | - | - | 24 | 0.10 |
| AR | *Anoropallene palpida* | - | - | - | - | - | - | - | - | - | 17 | - | 3 | - | - | - | - | - | - | 3 | 1 | 24 | 0.10 |
| AN | *Hesionella mccullochae* | - | - | - | - | - | - | - | - | - | 1 | 3 | 1 | 5 | 1 | - | - | 1 | 3 | 7 | 1 | 23 | 0.10 |
| AN | *Prionospio (Minuspio) lighti* | 1 | 1 | 1 | - | 4 | - | - | - | 5 | 7 | - | - | - | - | - | - | 3 | 1 | - | - | 23 | 0.10 |

## Appendix F-5. (Cont.).

| Phy | Species | 1978 | 1980 | 1986 | 1988 | 1990 | 1991 | 1992 | 1993 | 1994 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | Total | Percent Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AN | *Syllis* spp | - | - | - | 3 | 13 | 5 | 1 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | 23 | 0.10 |
| AR | Phoxocephalidae | - | - | - | - | - | 16 | 7 | - | - | - | - | - | - | - | - | - | - | - | - | - | 23 | 0.10 |
| MO | *Macoma* sp | - | - | 6 | - | - | - | - | 1 | 2 | - | - | 2 | 7 | - | 1 | 2 | 1 | 1 | - | - | 23 | 0.10 |
| AR | *Lepidopa californica* | 2 | 1 | 5 | 3 | - | - | 4 | 3 | - | - | - | 1 | - | - | - | - | 3 | - | - | - | 22 | 0.09 |
| AR | *Photis macrotica* | 13 | 9 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 22 | 0.09 |
| AN | *Notomastus tenuis* | - | - | - | 1 | - | - | - | - | 2 | - | 10 | 6 | 1 | - | - | - | - | - | - | - | 20 | 0.08 |
| AN | *Sthenelais tertiaglabra* | - | - | - | - | - | - | - | - | 2 | 6 | - | 4 | - | - | - | - | - | - | - | 8 | 20 | 0.08 |
| MO | Mactridae | 1 | 5 | 14 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 20 | 0.08 |
| AR | *Hemilamprops californica* | - | - | - | - | - | - | - | - | - | 17 | - | 2 | - | - | - | - | - | - | - | - | 19 | 0.08 |
| EC | Amphiuridae | - | - | - | - | 2 | - | - | - | 6 | - | - | 3 | 2 | 3 | - | - | 1 | 1 | 1 | - | 19 | 0.08 |
| AN | *Polydora cornuta* | - | - | 16 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | 17 | 0.07 |
| AN | *Sthenelais verruculosa* | - | 1 | 2 | - | - | 1 | 1 | 2 | - | - | 2 | - | 5 | 2 | 1 | - | - | - | - | - | 17 | 0.07 |
| AR | *Lamprops carinatus* | - | - | - | - | - | - | - | - | - | - | - | - | 5 | - | 2 | - | 1 | 9 | - | - | 17 | 0.07 |
| MO | *Macoma secta* | - | 2 | - | 1 | - | 3 | - | - | - | 1 | - | - | 1 | - | - | - | 8 | - | - | 1 | 17 | 0.07 |
| PL | *Stylochoplana* sp | - | - | - | 3 | 2 | - | - | - | - | 7 | 2 | - | 1 | - | - | - | - | - | 2 | - | 17 | 0.07 |
| AR | *Cyclaspis nubila* | - | - | - | - | - | - | - | - | 5 | 7 | - | - | 1 | - | 1 | - | - | - | 1 | - | 15 | 0.06 |
| MO | *Mactrotoma californica* | - | - | - | - | - | - | - | - | - | - | 1 | 1 | 13 | - | - | - | - | - | - | - | 15 | 0.06 |
| MO | *Rochefortia coani* | - | - | - | - | - | - | - | - | - | 11 | - | - | 4 | - | - | - | - | - | - | - | 15 | 0.06 |
| PR | *Phoronis* sp | - | 3 | - | 8 | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 | 1 | 1 | 15 | 0.06 |
| AN | *Chaetozone setosa* Cmplx | - | - | - | - | 13 | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | 14 | 0.06 |
| AN | *Nephtys cornuta* | - | 8 | - | - | - | - | - | - | - | - | 2 | - | - | 1 | - | - | 1 | 1 | 1 | - | 14 | 0.06 |
| AR | *Rhepoxynius* sp | 10 | - | - | - | - | - | 4 | - | - | - | - | - | - | - | - | - | - | - | - | - | 14 | 0.06 |
| MO | *Crepidula naticarum* | - | 4 | 9 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 13 | 0.05 |
| MO | *Cyclostremella dalli* | - | - | - | - | - | - | - | - | - | 12 | - | - | - | - | - | - | - | - | - | 1 | 13 | 0.05 |
| NE | *Tetrastemma candidum* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 | - | 4 | - | 7 | 13 | 0.05 |
| AN | *Aricidea (Aedicira) pacifica* | - | - | - | 1 | - | - | - | - | - | - | 7 | - | - | - | - | - | - | 1 | - | 3 | 12 | 0.05 |
| AN | *Aricidea (Allia) hartleyi* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 12 | - | - | - | 12 | 0.05 |
| AN | *Onuphis iridescens* | - | 5 | - | 7 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 12 | 0.05 |
| AN | *Spiophanes berkeleyorum* | 2 | - | - | 7 | - | - | - | - | - | - | - | - | - | - | - | - | - | 3 | - | - | 12 | 0.05 |
| AR | *Balanus pacificus* | - | 4 | 2 | - | - | - | - | - | - | - | - | 2 | - | 4 | - | - | - | - | - | - | 12 | 0.05 |
| CN | Actiniaria sp A Paquette 2005 | - | - | - | - | 5 | - | - | - | - | 1 | 1 | 1 | - | - | 1 | - | - | - | 3 | - | 12 | 0.05 |
| MO | *Olivella baetica* | 1 | 1 | 1 | 2 | - | - | - | - | - | - | 1 | 1 | - | 2 | 2 | - | 1 | - | - | - | 12 | 0.05 |
| NE | *Tetrastemma* sp | - | - | - | - | - | - | - | - | 3 | 4 | - | 2 | - | - | 2 | - | - | - | 1 | - | 12 | 0.05 |
| NE | *Tubulanus polymorphus* | - | - | 2 | - | - | - | - | - | 4 | - | 1 | - | 1 | 2 | 1 | - | 1 | - | - | - | 12 | 0.05 |
| AN | *Carraziella* sp A SCAMIT 1995 | - | - | - | - | - | - | - | - | - | - | - | - | - | 11 | - | - | - | - | - | - | 11 | 0.05 |
| AN | *Cirriformia spirabrancha* | - | - | 2 | - | - | - | - | - | 1 | 5 | - | 2 | - | 1 | - | - | - | - | - | - | 11 | 0.05 |
| AN | *Dipolydora socialis* | - | - | - | - | - | - | - | - | 11 | - | - | - | - | - | - | - | - | - | - | - | 11 | 0.05 |
| AN | *Scolelepis squamata* | - | - | - | - | - | 4 | - | 6 | - | 1 | - | - | - | - | - | - | - | - | - | - | 11 | 0.05 |
| AR | *Aoroides* sp | - | - | - | - | - | - | - | - | 4 | - | 1 | 1 | 2 | - | 3 | - | - | - | - | - | 11 | 0.05 |
| AR | *Ericthonius brasiliensis* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 11 | 11 | 0.05 |
| CN | Actiniaria | - | - | - | - | 6 | - | - | - | 5 | - | - | - | - | - | - | - | - | - | - | - | 11 | 0.05 |
| MO | *Rictaxis punctocaelatus* | - | - | 4 | - | - | - | - | - | - | - | 2 | - | 4 | 1 | - | - | - | - | - | - | 11 | 0.05 |
| AN | *Glycinde armigera* | 3 | 1 | - | - | - | - | - | - | - | - | - | - | - | 3 | - | - | 1 | 2 | - | - | 10 | 0.04 |
| AN | *Phyllodoce hartmanae* | - | - | 3 | 3 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | 3 | - | - | 10 | 0.04 |
| AR | Harpacticoida | - | - | - | - | - | - | - | - | - | - | 3 | - | 1 | - | - | - | - | 1 | - | 5 | 10 | 0.04 |
| AR | *Neotrypaea* sp | 1 | - | 7 | 1 | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | 10 | 0.04 |
| AR | *Ogyrides* sp A Roney 1978 | 1 | - | 3 | 1 | - | - | - | - | 1 | 1 | - | 2 | 1 | - | - | - | - | - | - | - | 10 | 0.04 |
| CN | Anthozoa | - | 2 | 2 | 1 | - | 3 | - | 2 | - | - | - | - | - | - | - | - | - | - | - | - | 10 | 0.04 |
| AN | *Mooreonuphis stigmatis* | - | - | - | - | - | - | - | - | - | - | - | 9 | - | - | - | - | - | - | - | - | 9 | 0.04 |
| AN | *Sigalion spinosus* | - | - | 2 | 2 | - | 1 | - | - | 3 | - | - | - | - | 1 | - | - | - | - | - | - | 9 | 0.04 |
| MO | *Macoma indentata* | - | - | - | - | - | - | - | - | 3 | 2 | - | - | - | 2 | 2 | - | - | - | - | - | 9 | 0.04 |
| NE | *Tetrastemma nigrifrons* | - | - | - | - | - | - | - | - | - | 3 | - | - | - | - | 2 | - | 4 | - | - | - | 9 | 0.04 |
| AN | *Glycinde polygnatha* | - | 8 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 8 | 0.03 |
| AN | *Polydora cirrosa* | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | 7 | - | - | - | - | - | 8 | 0.03 |
| AR | *Aoroides inermis* | - | - | - | - | - | - | - | - | - | - | - | 3 | - | 5 | - | - | - | - | - | - | 8 | 0.03 |
| AR | *Metamysidopsis elongata* | 1 | - | 1 | - | 2 | - | - | - | 1 | - | - | - | - | - | - | - | 1 | - | 2 | - | 8 | 0.03 |
| EC | *Leptosynapta* sp | - | 1 | 1 | 2 | - | 1 | - | 3 | - | - | - | - | - | - | - | - | - | - | - | - | 8 | 0.03 |
| MO | *Nassarius perpinguis* | - | 1 | - | - | - | - | - | - | 1 | 2 | - | - | - | 1 | 1 | 1 | - | - | 1 | - | 8 | 0.03 |
| PL | *Pseudoceros* sp | - | - | - | - | - | - | - | - | 1 | 2 | 1 | - | 1 | - | - | 3 | - | - | - | - | 8 | 0.03 |
| NE | *Cerebratulus californiensis* | - | 2 | - | 1 | 1 | 1 | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | 7 | 0.03 |
| AN | *Chone* sp | 1 | - | 1 | 1 | - | - | - | - | - | - | - | - | - | - | 2 | - | - | 1 | - | - | 6 | 0.03 |
| AN | *Lumbrineris californiensis* | - | - | 1 | - | - | - | - | - | 1 | - | - | 2 | 2 | - | - | - | - | - | - | - | 6 | 0.03 |
| AN | *Magelona californica* | - | - | - | - | - | - | - | - | - | - | - | - | 6 | - | - | - | - | - | - | - | 6 | 0.03 |
| AN | *Phyllodoce* sp | - | 6 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 6 | 0.03 |
| AN | *Scoletoma tetraura* Cmplx | - | - | - | - | 1 | - | - | - | 2 | 1 | - | - | - | - | - | - | 1 | - | 1 | - | 6 | 0.03 |
| AR | *Eohaustorius sencillus* | - | - | - | - | - | 5 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | 6 | 0.03 |
| AR | *Pollicipes polymerus* | - | - | 6 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 6 | 0.03 |
| AR | *Rhepoxynius abronius* | - | - | - | - | - | - | - | - | 1 | - | - | - | 3 | - | - | - | - | 1 | 1 | - | 6 | 0.03 |
| CO | Enteropneusta | 1 | - | - | - | - | - | - | - | - | 1 | - | 1 | - | - | - | - | 3 | - | - | - | 6 | 0.03 |
| EC | *Amphiodia urtica* | - | - | - | - | 1 | 1 | 3 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | 6 | 0.03 |

## Appendix F-5. (Cont.).

| Phy | Species | 1978 | 1980 | 1986 | 1988 | 1990 | 1991 | 1992 | 1993 | 1994 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | Total | Percent Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NE | *Zygonemertes virescens* | - | - | - | - | - | - | - | - | - | - | - | - | - | 5 | - | - | - | 1 | - | - | 6 | 0.03 |
| AN | *Heteromastus* sp | - | - | 5 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 5 | 0.02 |
| AN | *Nephtys* sp | - | - | - | 2 | 1 | 1 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | 5 | 0.02 |
| AN | *Spiophanes* sp | - | 1 | - | - | - | - | 1 | 3 | - | - | - | - | - | - | - | - | - | - | - | - | 5 | 0.02 |
| AN | *Syllis (Typosyllis)* sp | - | - | - | - | - | - | - | - | - | 5 | - | - | - | - | - | - | - | - | - | - | 5 | 0.02 |
| AR | *Blepharipoda occidentalis* | - | - | - | - | - | - | 2 | 2 | 1 | - | - | - | - | - | - | - | - | - | - | - | 5 | 0.02 |
| AR | *Cumella californica* | - | 1 | - | - | 1 | - | - | - | - | 3 | - | - | - | - | - | - | - | - | - | - | 5 | 0.02 |
| AR | *Cyclaspis* sp C SCAMIT 1986 | - | - | - | - | - | 5 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 5 | 0.02 |
| AR | Gammaridea | 1 | 1 | - | - | - | - | 1 | - | - | - | - | - | 1 | - | - | - | - | 1 | - | - | 5 | 0.02 |
| AR | *Hartmanodes hartmanae* | - | - | 1 | - | 1 | - | 1 | - | - | 1 | - | - | - | 1 | - | - | - | - | - | - | 5 | 0.02 |
| AR | *Jassa marmorata* | | | - | - | - | - | - | - | - | - | - | - | - | - | - | 5 | - | - | - | - | 5 | 0.02 |
| CN | *Renilla kollikeri* | - | - | 1 | 1 | - | - | - | - | - | - | - | 1 | - | - | - | 2 | - | - | - | - | 5 | 0.02 |
| EC | *Amphiodia* sp | - | - | - | - | - | - | - | - | - | 3 | - | 1 | - | - | - | - | 1 | - | - | - | 5 | 0.02 |
| MO | *Modiolus* sp | - | - | - | - | - | - | - | - | - | - | 1 | - | 1 | 1 | 2 | - | - | - | - | - | 5 | 0.02 |
| MO | *Rochefortia tumida* | - | - | - | - | - | - | - | - | - | 1 | - | 1 | - | - | 1 | - | 2 | - | - | - | 5 | 0.02 |
| NE | *Tetrastemma* sp A SCAMIT 1995 | - | - | - | - | - | - | - | - | - | - | 3 | 1 | - | - | - | - | 1 | - | - | - | 5 | 0.02 |
| AN | *Notomastus* sp A SCAMIT 2001 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 3 | - | - | 1 | 4 | 0.02 |
| AN | *Onuphis eremita parva* | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 2 | 1 | - | - | - | - | - | 4 | 0.02 |
| AN | Phyllodocidae | - | - | - | - | - | - | - | - | - | 4 | - | - | - | - | - | - | - | - | - | - | 4 | 0.02 |
| AN | *Podarkeopsis glabra* | - | - | - | 1 | 1 | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 4 | 0.02 |
| AN | *Typosyllis aciculata* | 1 | 3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 4 | 0.02 |
| AR | *Balanus* sp | - | - | - | - | - | - | - | - | 4 | - | - | - | - | - | - | - | - | - | - | - | 4 | 0.02 |
| AR | *Cancer gracilis* | - | 2 | 1 | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | 4 | 0.02 |
| AR | *Cancer* sp | - | - | - | 1 | - | - | - | - | 1 | - | - | - | - | - | 1 | - | - | - | - | 1 | 4 | 0.02 |
| AR | *Lamprops quadriplicatus* | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | 3 | - | - | - | 4 | 0.02 |
| AR | Mysidacea | 1 | 2 | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 4 | 0.02 |
| AR | *Podocerus brasiliensis* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 4 | 4 | 0.02 |
| AR | *Zeuxo normani* | - | - | - | - | 2 | - | - | - | - | - | - | - | - | - | 2 | - | - | - | - | - | 4 | 0.02 |
| MO | *Chione* sp | - | - | 4 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 4 | 0.02 |
| MO | *Crepidula norrisiarum* | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 3 | - | - | - | - | - | 4 | 0.02 |
| MO | *Macoma yoldiformis* | - | - | 4 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 4 | 0.02 |
| MO | *Modiolus neglectus* | - | 2 | - | - | - | - | - | - | - | - | - | - | - | 2 | - | - | - | - | - | - | 4 | 0.02 |
| MO | *Pandora bilirata* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | 3 | - | - | - | 4 | 0.02 |
| MO | *Yoldia cooperii* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | 3 | 4 | 0.02 |
| MO | *Yoldia seminuda* | - | - | 4 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 4 | 0.02 |
| AN | *Diopatra ornata* | - | - | - | - | - | - | - | - | - | - | - | 3 | - | - | - | - | - | - | - | - | 3 | 0.01 |
| AN | *Eteone fauchaldi* | - | - | - | - | - | - | - | - | 1 | - | - | - | - | 1 | 1 | - | - | - | - | - | 3 | 0.01 |
| AN | *Goniada maculata* | - | - | - | - | - | - | - | - | 2 | - | - | - | - | - | - | - | - | 1 | - | - | 3 | 0.01 |
| AN | Lumbrineridae | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 2 | - | - | - | - | - | - | 3 | 0.01 |
| AN | *Nereis procera* | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | 2 | - | - | - | 3 | 0.01 |
| AN | *Polycirrus* sp A SCAMIT 1995 | - | - | - | - | - | - | - | - | - | - | 3 | - | - | - | - | - | - | - | - | - | 3 | 0.01 |
| AN | *Postasterope barnesi* | - | - | - | - | - | - | - | - | - | 3 | - | - | - | - | - | - | - | - | - | - | 3 | 0.01 |
| AN | *Sabellaria nanella* | - | 3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 3 | 0.01 |
| AN | *Syllides* sp | - | - | - | - | - | - | - | - | 3 | - | - | - | - | - | - | - | - | - | - | - | 3 | 0.01 |
| AR | *Acuminodeutopus heteruropus* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 3 | 3 | 0.01 |
| AR | *Americhelidium* sp | 2 | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | 3 | 0.01 |
| AR | *Anoplodactylus oculospinus* | - | - | 3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 3 | 0.01 |
| AR | *Caprella californica* | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | 2 | - | 3 | 0.01 |
| AR | *Ischyrocerus anguipes* | - | - | - | - | - | - | - | - | - | - | - | 2 | - | 1 | - | - | - | - | - | - | 3 | 0.01 |
| AR | *Ischyrocerus pelagops* | - | - | - | - | - | - | - | - | 3 | - | - | - | - | - | - | - | - | - | - | - | 3 | 0.01 |
| AR | *Parasterope hulingsi* | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | 1 | - | 1 | - | - | - | 3 | 0.01 |
| AR | *Photis brevipes* | - | - | - | - | - | - | - | - | - | - | - | - | - | 3 | - | - | - | - | - | - | 3 | 0.01 |
| MO | *Leptopecten latiauratus* | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | 2 | - | 3 | 0.01 |
| MO | *Neverita reclusiana* | - | - | - | 1 | 1 | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | 3 | 0.01 |
| MO | *Nuculana taphria* | - | - | 3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 3 | 0.01 |
| MO | *Odostomia* sp D MBC 1975 | - | - | 1 | 1 | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | 3 | 0.01 |
| MO | *Protothaca staminea* | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | 1 | - | 1 | - | - | - | 3 | 0.01 |
| NE | *Carinomella lactea* | - | 1 | - | - | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 3 | 0.01 |
| NE | *Enopla* sp A SCAMIT 1995 | - | - | - | - | - | - | - | - | - | - | 3 | - | - | - | - | - | - | - | - | - | 3 | 0.01 |
| NE | Nemertea sp B MBC 2004 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 3 | - | - | - | 3 | 0.01 |
| PL | Platyhelminthes | 1 | - | - | 1 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 3 | 0.01 |
| AN | *Aricidea (Acmira) horikoshii* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | - | - | - | - | 2 | 0.01 |
| AN | *Eteone balboensis* | - | - | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 | 0.01 |
| AN | *Exogone lourei* | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | 1 | 2 | 0.01 |
| AN | *Glycera nana* | - | - | - | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 | 0.01 |
| AN | *Heteropodarke heteromorpha* | - | - | - | - | - | - | - | - | 1 | 1 | - | - | - | - | - | - | - | - | - | - | 2 | 0.01 |
| AN | *Leitoscoloplos pugettensis* | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | 1 | - | - | - | 2 | 0.01 |
| AN | *Lumbrineris* sp | - | - | 1 | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 | 0.01 |
| AN | *Magelona* sp | - | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 | 0.01 |
| AN | *Pholoides asperus* | - | - | - | - | - | - | - | - | - | - | - | - | 2 | - | - | - | - | - | - | - | 2 | 0.01 |

## Appendix F-5. (Cont.).

| Phy | Species | Year 1978 | 1980 | 1986 | 1988 | 1990 | 1991 | 1992 | 1993 | 1994 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | Total | Percent Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AN | *Phyllochaetopterus prolifica* | - | - | - | - | - | - | - | - | - | - | 2 | - | - | - | - | - | - | - | - | - | 2 | 0.01 |
| AN | *Phyllodoce pettiboneae* | - | - | - | - | - | - | - | - | 1 | 1 | - | - | - | - | - | - | - | - | - | - | 2 | 0.01 |
| AN | Spionidae | - | 1 | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | 2 | 0.01 |
| AN | *Tenonia priops* | - | 1 | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | 2 | 0.01 |
| AR | *Caprella verrucosa* | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | 1 | 2 | 0.01 |
| AR | *Cerapus tubularis* Cmplx | - | - | - | - | - | - | - | - | 1 | - | - | - | - | 1 | - | - | - | - | - | - | 2 | 0.01 |
| AR | *Monocorophium acherusicum* | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | 1 | - | - | - | - | 2 | 0.01 |
| AR | Paguridae | - | - | - | - | - | 1 | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | 2 | 0.01 |
| AR | *Pinnixa franciscana* | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 | 0.01 |
| AR | *Rhepoxynius stenodes* | - | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 | 0.01 |
| AR | *Rhepoxynius variatus* | - | - | - | - | 1 | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | 2 | 0.01 |
| AR | *Stenothoe estacola* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | 1 | 2 | 0.01 |
| EC | *Caudina arenicola* | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | 2 | 0.01 |
| EC | Holothuroidea | - | - | - | - | - | 1 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 | 0.01 |
| MO | Bivalvia | - | - | - | - | 1 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 | 0.01 |
| MO | *Crepidula* sp | - | - | - | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 | 0.01 |
| MO | Gastropoda | - | - | - | - | - | - | - | - | - | - | - | 1 | - | 1 | - | - | - | - | - | - | 2 | 0.01 |
| MO | *Nassarius fossatus* | - | - | - | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 | 0.01 |
| MO | *Polygireulima rutila* | - | - | - | - | 1 | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | 2 | 0.01 |
| NE | *Micrura alaskensis* | - | 1 | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 | 0.01 |
| NE | *Micrura* sp | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 | - | - | - | 2 | 0.01 |
| PR | *Phoronopsis* sp | - | - | - | - | - | - | - | - | - | - | - | - | 2 | - | - | - | - | - | - | - | 2 | 0.01 |
| AN | *Aricidea* sp | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | 1 | 0.00 |
| AN | *Axiothella rubrocincta* | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 0.00 |
| AN | Capitellidae | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 0.00 |
| AN | *Chaetozone* sp | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 0.00 |
| AN | *Chone minuta* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | 0.00 |
| AN | *Chone* sp C Harris 1984 | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | 1 | 0.00 |
| AN | *Cirriformia moorei* | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | 1 | 0.00 |
| AN | *Cirriformia* sp | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | 1 | 0.00 |
| AN | *Cirriformia tentaculata* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | 1 | 0.00 |
| AN | *Diopatra* sp | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | 1 | 0.00 |
| AN | *Diopatra splendidissima* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | 1 | 0.00 |
| AN | *Eteone brigitteae* | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | 1 | 0.00 |
| AN | Euclymeninae sp A SCAMIT 1987 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | 1 | 0.00 |
| AN | *Glycera* sp | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 0.00 |
| AN | *Harmothoe hirsuta* | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | 1 | 0.00 |
| AN | *Lumbrineris japonica* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | 1 | 0.00 |
| AN | Maldanidae | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | 1 | 0.00 |
| AN | *Malmgreniella* sp | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | 1 | 0.00 |
| AN | Oligochaeta | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | 1 | 0.00 |
| AN | *Parandalia ocularis* | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | 1 | 0.00 |
| AN | *Paraonella platybranchia* | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 0.00 |
| AN | *Paraprionospio pinnata* | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | 1 | 0.00 |
| AN | *Pholoe glabra* | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | 1 | 0.00 |
| AN | *Phylo felix* | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 0.00 |
| AN | *Pista disjuncta* | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 0.00 |
| AN | *Polyophthalmus pictus* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | 1 | 0.00 |
| AN | Sigalionidae | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | 1 | 0.00 |
| AN | *Sphaerephesia similisetis* | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | 1 | 0.00 |
| AN | Syllidae | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | 1 | 0.00 |
| AN | *Timarete luxuriosa* | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 0.00 |
| AR | *Alienacanthomysis macropsis* | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 0.00 |
| AR | *Ampelisca agassizi* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | 0.00 |
| AR | *Amphideutopus oculatus* | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | 1 | 0.00 |
| AR | *Cancer antennarius* | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | 1 | 0.00 |
| AR | *Caprella* sp | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 0.00 |
| AR | Crustacea (zoea) | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 0.00 |
| AR | Cumacea | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 0.00 |
| AR | *Cyclaspis* sp B SCAMIT 1989 | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 0.00 |
| AR | *Cyprideis stewarti* | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | 1 | 0.00 |
| AR | *Foxiphalus obtusidens* | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | 1 | 0.00 |
| AR | *Gammaropsis thompsoni* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | 0.00 |
| AR | *Holmesimysis costata* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | 1 | 0.00 |
| AR | *Hourstonius vilordes* | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 0.00 |
| AR | Ischyroceridae | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 0.00 |
| AR | *Laticorophium baconi* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | 0.00 |
| AR | *Listriella melanica* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | 1 | 0.00 |
| AR | *Monocorophium* sp | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | 1 | 0.00 |
| AR | *Munnogonium tillerae* | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 0.00 |

## Appendix F-5. (Cont.).

| | | Year | | | | | | | | | | | | | | | | | | | | | Percent |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Phy | Species | 1978 | 1980 | 1986 | 1988 | 1990 | 1991 | 1992 | 1993 | 1994 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | Total | Total |
| AR | *Mysidopsis intii* | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | 1 | 0.00 |
| AR | *Neomysis kadiakensis* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | 1 | 0.00 |
| AR | *Opisthopus transversus* | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 0.00 |
| AR | *Pacifacanthomysis nephrophthalma* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | 1 | 0.00 |
| AR | *Photis* sp A SCAMIT 1995 | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 0.00 |
| AR | *Pinnixa* sp | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 0.00 |
| AR | Pycnogonida | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 0.00 |
| AR | *Pyromaia tuberculata* | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | 1 | 0.00 |
| AR | *Rhepoxynius lucubrans* | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 0.00 |
| AR | *Rhepoxynius tridentatus* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | 1 | 0.00 |
| AR | *Tiron biocellata* | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | 1 | 0.00 |
| CN | *Hydractinia* sp | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | 1 | 0.00 |
| EC | *Amphiodia digitata* | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | 1 | 0.00 |
| EC | *Amphiura acrystata* | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 0.00 |
| EN | Entoprocta | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | 1 | 0.00 |
| EP | *Cryptoarachnidium argillum* | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 0.00 |
| EP | *Triticella elongata* | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | 1 | 0.00 |
| MO | *Acteocina* sp | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | 1 | 0.00 |
| MO | *Amiantis callosa* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | 1 | 0.00 |
| MO | *Crepidula onyx* | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | 1 | 0.00 |
| MO | *Ennucula tenuis* | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | 1 | 0.00 |
| MO | *Epitonium sawinae* | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | 1 | 0.00 |
| MO | *Kurtziella plumbea* | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 0.00 |
| MO | *Lyonsia californica* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | 1 | 0.00 |
| MO | *Macoma carlottensis* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | 1 | 0.00 |
| MO | *Mysella* sp | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 0.00 |
| MO | Mytilidae | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | 1 | 0.00 |
| MO | *Odostomia columbiana* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | 0.00 |
| MO | *Odostomia* sp | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 0.00 |
| MO | *Rochefortia compressa* | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | 1 | 0.00 |
| MO | *Sulcoretusa xystrum* | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 0.00 |
| MO | *Tellina nuculoides* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | 0.00 |
| NE | *Amphiporus* sp | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | 1 | 0.00 |
| NE | *Cerebratulus* sp | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 0.00 |
| NE | *Hoplonemertea* sp A Paquette 1988 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | 0.00 |
| NE | *Nemertea sp B Paquette 2005* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | 0.00 |
| PL | Platyhelminthes sp A of MBC | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 0.00 |
| PL | *Stylochus exiguus* | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | 1 | 0.00 |
| SI | Sipuncula | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | 1 | 0.00 |
| | Number of individuals | 504 | 1008 | 612 | 1041 | 699 | 1021 | 399 | 599 | 946 | 1737 | 5311 | 896 | 915 | 1161 | 1123 | 952 | 885 | 1726 | 843 | 1595 | 23073 | |
| | Number of species | 52 | 75 | 68 | 72 | 70 | 53 | 35 | 38 | 81 | 91 | 59 | 82 | 79 | 75 | 75 | 38 | 75 | 60 | 57 | 69 | 319 | |
| | 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 | 5/4 | |
| | Diversity (H') | 2.81 | 2.98 | 3.38 | 3.04 | 3.03 | 2.15 | 2.28 | 2.46 | 3.21 | 3.30 | 1.46 | 3.01 | 3.32 | 2.39 | 2.88 | 1.25 | 2.82 | 2.09 | 2.84 | 2.43 | 3.43 | |

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

Note: 0.00 = < 0.005

# 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, 2007.**

| Phylum / Class / Family / Species | Common name |
|---|---|
| Arthropoda | |
| Malacostraca | |
| Cancridae | |
| *Cancer anthonyi* | yellow crab |
| *Cancer gracilis* | graceful crab |
| *Cancer jordani* | hairy rock crab |
| Crangonidae | |
| *Crangon nigromaculata* | blackspotted bay shrimp |
| Cymothoidae | |
| *Elthusa vulgaris* | sea louse |
| Hippolytidae | |
| *Heptacarpus palpator* | intertidal coastal shrimp |
| *Heptacarpus stimpsoni* | Stimpson coastal shrimp |
| Majidae | |
| *Loxorhynchus grandis* | sheep crab |
| *Pyromaia tuberculata* | tuberculate pear crab |
| Palinuridae | |
| *Panulirus interruptus* | California spiny lobster |
| Penaeidae | |
| *Farfantepenaeus californiensis* | yellowleg shrimp |
| Pinnotheridae | |
| *Opisthopus transversus* | mottled pea crab |
| Portunidae | |
| *Portunus xantusii* | Xantus swimming crab |
| Cnidaria | |
| Hydrozoa | |
| Polyorchidae | |
| *Polyorchis penicillatus* | red jellyfish |
| Echinodermata | |
| Echinoidea | |
| Dendrasteridae | |
| *Dendraster excentricus* | Pacific sand dollar |
| Holothuroidea | |
| Caudinidae | |
| *Caudina arenicola* | sweet potato sea cucumber |
| Mollusca | |
| Cephalopoda | |
| Octopodidae | |
| *Octopus rubescens* | East Pacific red octopus |
| Gastropoda | |
| Nassariidae | |
| *Nassarius perpinguis* | fat western nassa |
| Chordata | |
| Chondrichthyes | |
| Myliobatidae | |
| *Myliobatis californica* | bat ray |
| Platyrhinidae | |
| *Platyrhinoidis triseriata* | thornback |
| Rajidae | |
| *Raja inornata* | California skate |
| Chondrichthyes (cont.) | |
| Rhinobatidae | |
| *Rhinobatos productus* | shovelnose guitarfish |
| Squatinidae | |
| *Squatina californica* | Pacific angel shark |
| Squalidae | |
| *Squalus acanthias* | spiny dogfish |
| Actinopterygii | |
| Embiotocidae | |
| *Cymatogaster aggregata* | shiner perch |
| *Amphistichus argenteus* | barred surfperch |
| *Brachyistius frenatus* | kelp perch |
| Engraulidae | |
| *Engraulis mordax* | northern anchovy |
| Sciaenidae | |
| *Genyonemus lineatus* | white croaker |
| *Seriphus politus* | queenfish |
| *Atractoscion nobilis* | white seabass |
| *Menticirrhus undulatus* | California corbina |
| Clinidae | |
| *Heterostichus rostratus* | giant kelpfish |
| Blennidae | |
| *Hypsoblennius gilberti* | rockpool blenny |
| Cottidae | |
| *Leptocottus armatus* | Pacific staghorn sculpin |
| Paralichthyidae | |
| *Paralichthys californicus* | California halibut |
| *Citharichthys stigmaeus* | speckled sanddab |
| *Xystreurys liolepis* | fantail sole |
| Stromateidae | |
| *Peprilus simillimus* | Pacific pompano |
| Atherinopsidae | |
| *Atherinopsis californiensis* | jacksmelt |
| Gasterosteidae | |
| *Aulorhynchus flavidus* | tubesnout |
| Clupeidae | |
| *Sardinops sagax* | Pacific sardine |
| Scombridae | |
| *Scomber japonicus* | Pacific chub mackerel |
| Agonidae | |
| *Stellerina xyosterna* | pricklebreast poacher |
| Syngnathidae | |
| *Syngnathus californiensis* | kelp pipefish |
| *Syngnathus exilis* | barcheek pipefish |
| Pleuronectidae | |
| *Pleuronichthys guttulatus* | diamond turbot |
| *Parophrys vetulus* | English sole |
| Synodontidae | |
| *Synodus lucioceps* | California lizardfish |

**Appendix G-2. Abundance of fish species in trawl replicates, winter and summer. Mandalay Generating Station NPDES, 2007.**

| | Winter | | | | | | | | | Summer | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T1 | | T2 | | T3 | | T4 | | | T1 | | T2 | | T3 | | T4 | | | Annual Total | Percent Total |
| Species | I | II | I | II | I | II | I | II | Total | I | II | I | II | I | II | I | II | Total | Total | Total |
| *Citharichthys stigmaeus* | 13 | 28 | 77 | 81 | 165 | 136 | 9 | 10 | 519 | 138 | 129 | 130 | 150 | 125 | 157 | 47 | 86 | 962 | 1,481 | 30.5 |
| *Cymatogaster aggregata* | - | - | - | - | 2 | - | - | - | 2 | 111 | 123 | 35 | 52 | 134 | 500 | 203 | 117 | 1,275 | 1,277 | 26.3 |
| *Genyonemus lineatus* | - | - | - | - | - | - | - | - | - | 209 | 1,046 | - | - | - | - | - | - | 1,255 | 1,255 | 25.9 |
| *Stellerina xyosterna* | - | - | - | - | 1 | - | - | - | 1 | 30 | 37 | 50 | 37 | 97 | 72 | 1 | 4 | 328 | 329 | 6.8 |
| *Engraulis mordax* | - | - | 1 | - | 9 | 10 | 61 | 32 | 113 | 12 | 7 | - | 35 | 4 | 34 | 28 | 18 | 138 | 251 | 5.2 |
| *Syngnathus californiensis* | 1 | 6 | 4 | - | 5 | 5 | 2 | 3 | 26 | 6 | 5 | 6 | 3 | 14 | 10 | - | - | 44 | 70 | 1.4 |
| *Syngnathus exilis* | - | - | - | - | - | - | - | - | - | 8 | 2 | 6 | 1 | 5 | 3 | 5 | 6 | 36 | 36 | 0.7 |
| *Amphistichus argenteus* | - | 3 | 2 | - | - | 1 | 3 | 1 | 10 | - | 1 | - | 9 | 1 | 2 | 6 | - | 19 | 29 | 0.6 |
| *Atherinopsis californiensis* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 4 | 17 | 21 | 21 | 0.4 |
| *Leptocottus armatus* | - | - | - | - | - | - | - | - | - | 1 | 3 | 1 | 3 | 7 | 4 | - | - | 19 | 19 | 0.4 |
| *Platyrhinoidis triseriata* | - | 2 | 1 | - | 3 | - | 3 | - | 9 | 2 | 2 | 2 | 1 | - | 2 | - | - | 9 | 18 | 0.4 |
| *Myliobatis californica* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 3 | 5 | 6 | 14 | 14 | 0.3 |
| *Synodus lucioceps* | 1 | - | - | 5 | 2 | 2 | - | - | 10 | - | - | - | - | - | - | - | - | - | 10 | 0.2 |
| *Sardinops sagax* | - | - | - | - | - | - | - | - | - | 6 | - | - | - | 2 | - | - | - | 8 | 8 | 0.2 |
| *Paralichthys californicus* | - | - | - | - | - | - | - | - | - | - | - | 1 | - | 2 | 1 | - | 1 | 5 | 5 | 0.1 |
| *Squatina californica* | - | - | - | - | - | 2 | - | - | 2 | - | - | 1 | 1 | 1 | - | - | - | 3 | 5 | 0.1 |
| *Rhinobatos productus* | - | - | - | - | - | - | 1 | - | 1 | - | 1 | - | - | - | - | 1 | - | 2 | 3 | 0.1 |
| *Seriphus politus* | - | - | - | - | - | - | - | - | - | - | 1 | - | 1 | - | - | 1 | - | 3 | 3 | 0.1 |
| *Squalus acanthias* | - | - | - | - | 1 | 2 | - | - | 3 | - | - | - | - | - | - | - | - | - | 3 | 0.1 |
| *Atractoscion nobilis* | - | - | - | - | 1 | 1 | - | - | 2 | - | - | - | - | - | - | - | - | - | 2 | 0.0 |
| *Heterostichus rostratus* | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | - | - | - | 2 | 2 | 0.0 |
| *Peprilus simillimus* | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | 1 | 2 | 2 | 0.0 |
| *Aulorhynchus flavidus* | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | 1 | 1 | 0.0 |
| *Brachyistius frenatus* | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | 1 | 1 | 0.0 |
| *Hypsoblennius gilberti* | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | 1 | 1 | 0.0 |
| *Menticirrhus undulatus* | - | - | - | - | - | - | 1 | - | 1 | - | - | - | - | - | - | - | - | - | 1 | 0.0 |
| *Parophrys vetulus* | - | - | - | - | 1 | - | - | - | 1 | - | - | - | - | - | - | - | - | - | 1 | 0.0 |
| *Pleuronichthys guttulatus* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | 1 | 1 | 0.0 |
| *Raja inornata* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | 1 | 0.0 |
| *Scomber japonicus* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | 1 | 1 | 0.0 |
| *Xystreurys liolepis* | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | 1 | 1 | 0.0 |
| Total abundance | 15 | 39 | 85 | 86 | 190 | 159 | 80 | 46 | 700 | 523 | 1,359 | 233 | 296 | 393 | 789 | 302 | 257 | 4,152 | 4,852 | |
| Species | 3 | 4 | 5 | 2 | 10 | 8 | 7 | 4 | 14 | 10 | 14 | 10 | 14 | 12 | 12 | 11 | 10 | 26 | 31 | |
| Diversity (H') | 0.49 | 0.88 | 0.43 | 0.22 | 0.63 | 0.65 | 0.90 | 0.85 | 0.93 | 1.50 | 0.85 | 1.26 | 1.50 | 1.47 | 1.14 | 1.12 | 1.40 | 1.63 | 1.69 | |
| Area Trawled ($m^2$) | 2,932.7 | 2,929.4 | 2,856.0 | 2,861.7 | 2,917.3 | 2,860.8 | 2,761.3 | 2,814.3 | | 2,912.7 | 2,842.4 | 2,879.3 | 2,901.8 | 2,947.9 | 2,906.1 | 2,967.7 | 2,916.3 | | | |
| Abundance less than 30 mm SL. | | | | | | | | | | | | | | | | | | | | |
| *Engraulis mordax* | - | - | - | - | - | 1 | - | - | 1 | - | - | - | - | - | - | - | - | - | 1 | |
| *Seriphus politus* | - | - | 2 | - | 20 | 13 | - | - | 35 | - | - | - | - | - | - | - | - | - | 35 | |
| Total Abundance < 30 mm SL | - | - | 2 | - | 20 | 14 | - | - | 36 | - | - | - | - | - | - | - | - | - | 36 | |

## Appendix G-3. Biomass (kg) of fish species in trawl replicates. Mandalay Generating Station NPDES, 2007.

| | 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 |
| *Squatina californica* | - | - | - | - | - | 22.50 | - | - | 22.50 | - | - | 4.00 | 8.50 | 8.00 | - | - | - | 20.50 | 43.00 | 42.32 |
| *Myliobatis californica* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0.77 | 11.20 | 8.40 | 20.37 | 20.37 | 20.05 |
| *Citharichthys stigmaeus* | 0.08 | 0.11 | 0.26 | 0.30 | 0.61 | 0.60 | 0.07 | 0.08 | 2.10 | 1.04 | 1.00 | 1.20 | 1.20 | 0.93 | 1.20 | 0.36 | 0.79 | 7.72 | 9.82 | 9.66 |
| *Genyonemus lineatus* | - | - | - | - | - | - | - | - | - | 1.26 | 6.80 | - | - | - | - | - | - | 8.06 | 8.06 | 7.93 |
| *Cymatogaster aggregata* | - | - | - | - | 0.02 | - | - | - | 0.02 | 0.25 | 0.37 | 0.10 | 0.17 | 0.56 | 2.00 | 2.02 | 1.50 | 6.96 | 6.98 | 6.87 |
| *Platyrhinoidis triseriata* | - | 0.74 | 0.08 | - | 0.67 | - | 0.91 | - | 2.40 | 0.75 | 0.75 | 0.81 | 0.23 | - | 0.86 | - | - | 3.40 | 5.80 | 5.71 |
| *Paralichthys californicus* | - | - | - | - | - | - | - | - | - | - | - | 0.21 | - | 0.62 | 0.21 | - | 0.26 | 1.30 | 1.30 | 1.28 |
| *Atherinopsis californiensis* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0.21 | 1.00 | 1.21 | 1.21 | 1.19 |
| *Squalus acanthias* | - | - | - | - | 0.36 | 0.46 | - | - | 0.82 | - | - | - | - | - | - | - | - | - | 0.82 | 0.81 |
| *Engraulis mordax* | - | - | 0.00 | - | 0.03 | 0.03 | 0.19 | 0.11 | 0.37 | 0.14 | 0.07 | - | 0.04 | 0.02 | 0.07 | 0.04 | 0.04 | 0.43 | 0.79 | 0.78 |
| *Amphistichus argenteus* | - | 0.07 | 0.06 | - | - | 0.05 | 0.10 | 0.03 | 0.31 | - | 0.02 | - | 0.19 | 0.02 | 0.10 | 0.09 | - | 0.42 | 0.74 | 0.72 |
| *Stellerina xyosterna* | - | - | - | - | 0.01 | - | - | - | 0.01 | 0.06 | 0.06 | 0.09 | 0.08 | 0.20 | 0.16 | 0.00 | 0.02 | 0.67 | 0.68 | 0.67 |
| *Leptocottus armatus* | - | - | - | - | - | - | - | - | - | 0.02 | 0.16 | 0.01 | 0.06 | 0.22 | 0.10 | - | - | 0.57 | 0.57 | 0.56 |
| *Pleuronichthys guttulatus* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0.27 | - | - | 0.27 | 0.27 | 0.27 |
| *Sardinops sagax* | - | - | - | - | - | - | - | - | - | 0.18 | - | - | - | 0.06 | - | - | - | 0.24 | 0.24 | 0.23 |
| *Rhinobatos productus* | - | - | - | - | - | - | 0.13 | - | 0.13 | - | 0.04 | - | - | - | - | 0.06 | - | 0.10 | 0.23 | 0.23 |
| *Menticirrhus undulatus* | - | - | - | - | - | - | 0.17 | - | 0.17 | - | - | - | - | - | - | - | - | - | 0.17 | 0.17 |
| *Scomber japonicus* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0.14 | - | 0.14 | 0.14 | 0.14 |
| *Syngnathus californiensis* | 0.00 | 0.01 | 0.00 | - | 0.01 | 0.01 | 0.00 | 0.00 | 0.03 | 0.01 | 0.01 | 0.01 | 0.00 | 0.02 | 0.02 | - | - | 0.06 | 0.09 | 0.09 |
| *Raja inornata* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0.09 | 0.09 | 0.09 | 0.09 |
| *Syngnathus exilis* | - | - | - | - | - | - | - | - | - | 0.01 | 0.00 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.06 | 0.06 | 0.06 |
| *Parophrys vetulus* | - | - | - | - | 0.06 | - | - | - | 0.06 | - | - | - | - | - | - | - | - | - | 0.06 | 0.06 |
| *Xystreurys liolepis* | - | - | - | - | - | - | - | - | - | - | 0.05 | - | - | - | - | - | - | 0.05 | 0.05 | 0.05 |
| *Seriphus politus* | - | - | - | - | - | - | - | - | - | - | 0.02 | - | 0.00 | - | - | 0.00 | - | 0.02 | 0.02 | 0.02 |
| *Synodus lucioceps* | 0.00 | - | - | 0.01 | 0.01 | 0.01 | - | - | 0.02 | - | - | - | - | - | - | - | - | - | 0.02 | 0.02 |
| *Peprilus simillimus* | - | - | - | - | - | - | - | - | - | - | 0.01 | - | - | - | - | - | 0.01 | 0.01 | 0.01 | 0.01 |
| *Heterostichus rostratus* | - | - | - | - | - | - | - | - | - | - | - | - | 0.01 | 0.00 | - | - | - | 0.01 | 0.01 | 0.01 |
| *Brachyistius frenatus* | - | - | - | - | - | - | - | - | - | - | - | - | 0.01 | - | - | - | - | 0.01 | 0.01 | 0.01 |
| *Atractoscion nobilis* | - | - | - | - | 0.00 | 0.00 | - | - | 0.00 | - | - | - | - | - | - | - | - | - | 0.00 | 0.00 |
| *Aulorhynchus flavidus* | - | - | - | - | - | - | - | - | - | - | - | 0.00 | - | - | - | - | - | 0.00 | 0.00 | 0.00 |
| *Hypsoblennius gilberti* | - | - | - | - | - | - | - | - | - | - | - | - | 0.00 | - | - | - | - | 0.00 | 0.00 | 0.00 |
| Total Biomass (kg) | 0.08 | 0.93 | 0.41 | 0.31 | 1.77 | 23.66 | 1.57 | 0.22 | 28.94 | 3.71 | 9.36 | 6.44 | 10.49 | 10.66 | 5.76 | 14.13 | 12.11 | 72.67 | 101.61 | |
| Biomass (kg) less than 30 mm SL. | | | | | | | | | | | | | | | | | | | | |
| *Engraulis mordax* | - | - | - | - | - | 0.00 | - | - | 0.00 | | - | - | - | - | - | - | - | - | 0.00 | |
| *Seriphus politus* | - | - | 0.00 | - | 0.00 | 0.00 | - | - | 0.00 | | - | - | - | - | - | - | - | - | 0.00 | |
| Total Biomass (kg) | - | - | 0.00 | - | 0.00 | 0.00 | - | - | 0.00 | - | - | - | - | - | - | - | - | - | 0.00 | |

Note: 0.00 = < 0.005

**Appendix G-4. Length of fish species in trawl replicates. Manalay Generating Station NPDES, winter 2007.**

| MGS T1-I | Length (cm) | | | | | | |
|---|---|---|---|---|---|---|---|
| Species | 4 | 5 | 6 | 7 | 8 | 9 | 12 |
| *Citharichthys stigmaeus* | 2 | 3 | 2 | 3 | 2 | 1 | - |
| *Syngnathus californiensis* | - | - | - | - | - | - | 1 |
| *Synodus lucioceps* | - | - | - | 1 | - | - | - |

| MGS T1-II | Length (cm) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 17 | 18 | 19 | 38 | 42 |
| *Amphistichus argenteus* | - | - | - | - | - | - | 3 | - | - | - | - | - | - |
| *Citharichthys stigmaeus* | 1 | 10 | 6 | 3 | 2 | 2 | 2 | 2 | - | - | - | - | - |
| *Platyrhinoidis triseriata** | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 |
| *Syngnathus californiensis* | - | - | - | - | - | - | - | - | 1 | 2 | 3 | - | - |

| MGS T2-I | Length (cm) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 13 | 14 | 17 | 20 | 24 |
| *Amphistichus argenteus* | - | - | - | - | - | - | 2 | - | - | - | - | - | - |
| *Citharichthys stigmaeus* | 8 | 28 | 23 | 4 | 5 | 1 | 4 | 4 | - | - | - | - | - |
| *Engraulis mordax* | - | - | - | - | 1 | - | - | - | - | - | - | - | - |
| *Platyrhinoidis triseriata** | - | - | - | - | - | - | - | - | - | - | - | - | 1 |
| *Syngnathus californiensis* | - | - | - | - | - | - | - | - | 1 | 1 | 1 | 1 | - |

| MGS T2-II | Length (cm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Species | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| *Citharichthys stigmaeus* | 9 | 37 | 16 | 4 | 3 | 7 | 2 | 1 | 2 |
| *Synodus lucioceps* | - | - | - | - | 4 | 1 | - | - | - |

| MGS T3-I | Length (cm) | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 13 | 17 | 19 | 21 | 22 | 23 | 34 | 39 | 47 |
| *Atractoscion nobilis* | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Citharichthys stigmaeus* | 21 | 47 | 41 | 10 | 13 | 21 | 6 | 6 | - | - | - | - | - | - | - | - | - | - |
| *Cymatogaster aggregata* | - | - | - | - | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Engraulis mordax* | - | - | - | - | 6 | 2 | - | 1 | - | - | - | - | - | - | - | - | - | - |
| *Parophrys vetulus* | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - |
| *Platyrhinoidis triseriata** | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | 1 | - |
| *Squalus acanthias** | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 |
| *Stellerina xyostema* | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - |
| *Syngnathus californiensis* | - | - | - | - | - | - | - | - | - | 1 | - | 1 | 1 | 2 | - | - | - | - |
| *Synodus lucioceps* | - | - | - | - | 1 | 1 | - | - | - | - | - | - | - | - | - | - | - | - |

| MGS T3-II | Length (cm) | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 14 | 17 | 21 | 38 | 43 | 108 | 113 |
| *Amphistichus argenteus* | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - |
| *Atractoscion nobilis* | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Citharichthys stigmaeus* | 14 | 38 | 37 | 6 | 6 | 15 | 9 | 9 | 1 | 1 | - | - | - | - | - | - | - |
| *Engraulis mordax* | - | - | - | 5 | 5 | - | - | - | - | - | - | - | - | - | - | - | - |
| *Squalus acanthias** | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | - | - |
| *Squatina californica** | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 |
| *Syngnathus californiensis* | - | - | - | - | - | - | - | - | - | - | 3 | 1 | 1 | - | - | - | - |
| *Synodus lucioceps* | - | - | - | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - |

| MGS T4-I | Length (cm) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | 4 | 5 | 6 | 7 | 8 | 9 | 11 | 18 | 19 | 23 | 31 | 33 | 34 | 41 |
| *Amphistichus argenteus* | - | - | - | - | - | 1 | 2 | - | - | - | - | - | - | - |
| *Citharichthys stigmaeus* | 1 | 2 | - | 1 | 2 | 3 | - | - | - | - | - | - | - | - |
| *Engraulis mordax* | - | - | 9 | 48 | 4 | - | - | - | - | - | - | - | - | - |
| *Menticirrhus undulatus* | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - |
| *Platyrhinoidis triseriata* | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | 1 |
| *Rhinobatos productus* | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - |
| *Syngnathus californiensis* | - | - | - | - | - | - | - | 1 | 1 | - | - | - | - | - |

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

| MGS T4-II | Length (cm) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Species | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 14 | 15 | 21 |
| *Amphistichus argenteus* | - | - | - | - | - | - | 1 | - | - | - |
| *Citharichthys stigmaeus* | 2 | 3 | - | - | 1 | 3 | 1 | - | - | - |
| *Engraulis mordax* | - | - | 3 | 28 | 1 | - | - | - | - | - |
| *Syngnathus californiensis* | - | - | - | - | - | - | - | 1 | 1 | 1 |

"*" = Total Length

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 2007.**

| MGS T1-I | Length (cm) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 16 | 17 | 18 | 19 | 20 | 36 | 39 |
| *Citharichthys stigmaeus* | 2 | 3 | 18 | 49 | 21 | 18 | 13 | 11 | 3 | - | - | - | - | - | - | - | - | - | - |
| *Cymatogaster aggregata* | 6 | 63 | 36 | 5 | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - |
| *Engraulis mordax* | - | - | - | 1 | - | - | 1 | 3 | 5 | 2 | - | - | - | - | - | - | - | - | - |
| *Genyonemus lineatus* | - | - | 7 | 82 | 90 | 19 | 2 | - | - | - | - | - | - | - | - | - | - | - | - |
| *Leptocottus armatus* | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - |
| *Platyrhinoidis triseriata* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 |
| *Sardinops sagax* | - | - | - | - | - | - | - | - | - | - | 3 | 3 | - | - | - | - | - | - | - |
| *Stellerina xyosterna* | - | 2 | 11 | 10 | 5 | 1 | 1 | - | - | - | - | - | - | - | - | - | - | - | - |
| *Syngnathus californiensis* | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 3 | 1 | - | 1 | - | - |
| *Syngnathus exilis* | - | - | - | - | - | - | - | - | - | - | - | - | 2 | 2 | 2 | 1 | 1 | - | - |

| MGS T1-II | Length (cm) | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | 1 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 18 | 20 | 23 | 27 | 46 |
| *Amphistichus argenteus* | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - |
| *Citharichthys stigmaeus* | 1 | - | 1 | 9 | 55 | 16 | 12 | 25 | 8 | 2 | - | - | - | - | - | - | - | - | - | - |
| *Cymatogaster aggregata* | - | 1 | 51 | 54 | 14 | - | 2 | 1 | - | - | - | - | - | - | - | - | - | - | - | - |
| *Engraulis mordax* | - | - | - | - | - | 1 | - | - | 4 | - | 2 | - | - | - | - | - | - | - | - | - |
| *Genyonemus lineatus* | - | - | - | 3 | 59 | 103 | 34 | - | 1 | - | - | - | - | - | - | - | - | - | - | - |
| *Leptocottus armatus* | - | - | - | - | - | - | - | - | - | - | 1 | - | 1 | 1 | - | - | - | - | - | - |
| *Peprilus simillimus* | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Platyrhinoidis triseriata** | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 |
| *Rhinobatos productus** | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - |
| *Seriphus politus* | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - |
| *Stellerina xyosterna* | - | - | - | 12 | 13 | 10 | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Syngnathus californiensis* | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | 1 | 2 | 1 | - | - | - |
| *Syngnathus exilis* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | - | - | - | - |
| *Xystreurys liolepis* | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - |

| MGS T2-I | Length (cm) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 14 | 15 | 16 | 18 | 19 | 23 | 24 | 25 | 37 | 44 | 73 |
| *Aulorhynchus flavidus* | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - |
| *Citharichthys stigmaeus* | 12 | 9 | 14 | 28 | 21 | 17 | 24 | 5 | - | - | - | - | - | - | - | - | - | - | - |
| *Cymatogaster aggregata* | 18 | 15 | 1 | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Leptocottus armatus* | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Paralichthys californicus* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - |
| *Platyrhinoidis triseriata* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | - |
| *Squatina californica* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 |
| *Stellerina xyosterna* | - | 9 | 25 | 15 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Syngnathus californiensis* | - | - | - | - | - | - | - | - | 1 | 1 | - | 3 | 1 | - | - | - | - | - | - |
| *Syngnathus exilis* | - | - | - | - | - | - | - | - | - | - | 1 | 2 | 1 | 1 | - | 1 | - | - | - |

| MGS T2-II | Length (cm) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 16 | 18 | 19 | 22 | 34 | 102 |
| *Amphistichus argenteus* | - | - | - | - | 4 | 4 | - | - | 1 | - | - | - | - | - | - |
| *Brachyistius frenatus* | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - |
| *Citharichthys stigmaeus* | 12 | 19 | 21 | 29 | 29 | 23 | 14 | 3 | - | - | - | - | - | - | - |
| *Cymatogaster aggregata* | 19 | 22 | 8 | 1 | - | 2 | - | - | - | - | - | - | - | - | - |
| *Engraulis mordax* | - | 17 | 16 | 2 | - | - | - | - | - | - | - | - | - | - | - |
| *Heterostichus rostratus* | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - |
| *Hypsoblennius gilberti* | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Leptocottus armatus* | - | - | - | - | - | 1 | 1 | 1 | - | - | - | - | - | - | - |
| *Platyrhinoidis triseriata** | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - |
| *Seriphus politus* | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Squatina californica** | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 |
| *Stellerina xyosterna* | - | 5 | 18 | 10 | 3 | 1 | - | - | - | - | - | - | - | - | - |
| *Syngnathus californiensis* | - | - | - | - | - | - | - | - | - | 1 | 1 | 1 | - | - | - |
| *Syngnathus exilis* | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - |

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

MGS T3-I

| | Length (cm) | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 23 | 31 | 101 |
| *Amphistichus argenteus* | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Citharichthys stigmaeus* | - | 2 | 9 | 37 | 34 | 17 | 13 | 7 | 5 | 1 | - | - | - | - | - | - | - | - | - | - | - |
| *Cymatogaster aggregata* | 2 | 23 | 72 | 23 | 4 | 1 | 6 | 3 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Engraulis mordax* | - | - | - | 2 | 1 | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - |
| *Heterostichus rostratus* | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Leptocottus armatus* | - | - | - | - | - | - | 1 | - | 2 | 3 | 1 | - | - | - | - | - | - | - | - | - | - |
| *Paralichthys californicus* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | 1 | - |
| *Sardinops sagax* | - | - | - | - | - | - | - | - | - | - | 1 | - | 1 | - | - | - | - | - | - | - | - |
| *Squatina califomica** | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 |
| *Stellerina xyosterna* | - | - | 11 | 40 | 39 | 7 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Syngnathus californiensis* | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | 2 | 2 | 4 | 2 | 1 | 1 | - | - |
| *Syngnathus exilis* | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | 1 | 3 | - | - | - | - |

MGS T3-II

| | Length (cm) | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 30 | 41 | 44 |
| *Amphistichus argenteus* | - | - | - | - | - | - | - | 1 | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Citharichthys stigmaeus* | - | 5 | 13 | 46 | 36 | 24 | 25 | 5 | 2 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Cymatogaster aggregata* | 1 | 22 | 110 | 56 | 4 | 4 | 3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Engraulis mordax* | - | - | 14 | 14 | 5 | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Leptocottus armatus* | - | - | - | - | - | - | - | 3 | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Myliobatis califomica*** | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | 1 | 1 | - | - |
| *Paralichthys californicus* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - |
| *Platyrhinoidis triseriata** | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 |
| *Pleuronichthys guttulatus* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - |
| *Stellerina xyosterna* | - | - | 5 | 41 | 20 | 5 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Syngnathus californiensis* | - | - | - | - | - | - | - | - | - | - | - | - | 2 | 2 | 2 | 1 | 1 | - | 1 | - | 1 | - | - | - | - |
| *Syngnathus exilis* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | 2 | - | - | - | - | - | - | - |

MGS T4-I

| | Length (cm) | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 16 | 17 | 20 | 22 | 24 | 25 | 46 | 49 | 62 |
| *Amphistichus argenteus* | - | - | - | - | 2 | 2 | 1 | 1 | - | - | - | - | - | - | - | - | - | - |
| *Atherinopsis californiensis* | - | - | - | - | - | - | - | - | - | - | 3 | 1 | - | - | - | - | - | - |
| *Citharichthys stigmaeus* | - | 2 | 8 | 15 | 9 | 11 | 1 | 1 | - | - | - | - | - | - | - | - | - | - |
| *Cymatogaster aggregata* | 12 | 50 | 50 | 17 | 21 | 40 | 9 | 1 | - | - | - | - | - | - | - | - | - | - |
| *Engraulis mordax* | - | 12 | 14 | 1 | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - |
| *Myliobatis califomica*** | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 | 2 | 1 |
| *Rhinobatos productus** | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - |
| *Scomber japonicus* | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - |
| *Seriphus politus* | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Stellerina xyosterna* | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Syngnathus exilis* | - | - | - | - | - | - | - | - | 1 | 1 | - | 2 | 1 | - | - | - | - | - |

MGS T4-II

| | Length (cm) | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 13 | 15 | 16 | 17 | 18 | 19 | 20 | 24 | 33 | 46 | 47 | 48 |
| *Atherinopsis californiensis* | - | - | - | - | - | - | - | - | - | 3 | 6 | 4 | 2 | 1 | 1 | - | - | - | - | - |
| *Citharichthys stigmaeus* | - | 5 | 28 | 19 | 11 | 12 | 7 | 4 | - | - | - | - | - | - | - | - | - | - | - | - |
| *Cymatogaster aggregata* | 5 | 22 | 12 | 7 | 27 | 38 | 6 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Engraulis mordax* | - | 6 | 10 | 1 | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - |
| *Myliobatis califomica*** | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 3 | 1 | 1 |
| *Paralichthys californicus* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - |
| *Peprilus simillimus* | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Raja inomata*** | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - |
| *Stellerina xyosterna* | - | - | - | 2 | 1 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Syngnathus exilis* | - | - | - | - | - | - | - | - | - | - | - | 1 | 2 | 2 | 1 | - | - | - | - | - |

"*" = Total Length, "***" = Disc Width

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, 2007.**

| | 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 |
| *Crangon nigromaculata* | 23 | 41 | 70 | 91 | 326 | 261 | 10 | 19 | 841 | 504 | 554 | 431 | 769 | 1,123 | 1,231 | 45 | 48 | 4,705 | 5,546 | 93.6 |
| *Cancer gracilis* | - | - | 5 | 6 | 4 | 6 | 1 | 4 | 26 | 5 | 4 | 6 | 9 | 28 | 50 | 23 | 13 | 138 | 164 | 2.8 |
| *Dendraster excentricus* | - | - | - | 2 | - | - | 101 | 55 | 158 | - | - | - | - | - | - | - | - | - | 158 | 2.7 |
| *Heptacarpus stimpsoni* | - | - | - | - | 1 | - | - | - | 1 | - | - | - | - | 11 | - | - | 3 | 14 | 15 | 0.3 |
| *Pyromaia tuberculata* | - | - | 1 | 3 | 2 | 5 | - | - | 11 | 1 | - | 1 | - | 1 | - | - | - | 3 | 14 | 0.2 |
| *Loxorhynchus grandis* | - | - | - | - | - | - | - | 1 | 1 | - | - | 1 | 2 | 1 | - | - | 1 | 5 | 6 | 0.1 |
| *Panulirus interruptus* | - | - | 1 | 1 | 1 | - | 2 | - | 5 | - | - | - | - | - | - | - | - | - | 5 | 0.1 |
| *Cancer anthonyi* | - | - | - | - | - | - | - | - | - | 1 | - | 1 | - | 1 | - | - | 1 | 4 | 4 | 0.1 |
| *Farfantepenaeus californiensis* | - | - | - | 1 | 1 | - | 1 | - | 3 | - | - | - | - | - | - | - | - | - | 3 | 0.1 |
| *Cancer jordani* | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | - | - | 2 | 2 | 0.0 |
| *Caudina arenicola* | - | - | 1 | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | 1 | 0.0 |
| *Heptacarpus palpator* | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | 1 | 1 | 0.0 |
| *Nassarius perpinguis* | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | 1 | 1 | 0.0 |
| *Octopus rubescens* | - | 1 | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | 1 | 0.0 |
| *Opisthopus transversus* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | 1 | 1 | 0.0 |
| *Polyorchis penicillatus* | - | - | - | - | 1 | - | - | - | 1 | - | - | - | - | - | - | - | - | - | 1 | 0.0 |
| *Portunus xantusii* | - | - | 1 | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | 1 | 0.0 |
| Total Abundance | 23 | 42 | 79 | 104 | 336 | 272 | 115 | 79 | 1,050 | 511 | 558 | 440 | 781 | 1,167 | 1,283 | 68 | 66 | 4,874 | 5,924 | |
| Species | 1 | 2 | 6 | 6 | 7 | 3 | 5 | 4 | 12 | 4 | 2 | 5 | 4 | 8 | 4 | 2 | 5 | 10 | 17 | |
| Diversity (H') | 0.00 | 0.11 | 0.50 | 0.55 | 0.18 | 0.20 | 0.48 | 0.80 | 0.68 | 0.08 | 0.04 | 0.12 | 0.09 | 0.20 | 0.18 | 0.64 | 0.82 | 0.18 | 0.32 | |
| Evenness (J') | 0.00 | 0.16 | 0.28 | 0.31 | 0.09 | 0.18 | 0.30 | 0.58 | 0.28 | 0.06 | 0.06 | 0.07 | 0.07 | 0.10 | 0.13 | 0.92 | 0.51 | 0.08 | 0.11 | |
| Area Trawled ($m^2$) | 2,932.7 | 2,929.4 | 2,856.0 | 2,861.7 | 2,917.3 | 2,860.8 | 2,761.3 | 2,814.3 | | 2,912.7 | 2,842.4 | 2,879.3 | 2,901.8 | 2,947.9 | 2,906.1 | 2,967.7 | 2,916.3 | | | |
| Fish Parasites Not Included Above | | | | | | | | | | | | | | | | | | | | |
| *Elthusa vulgaris* | 2 | 10 | 7 | 6 | 10 | 5 | 3 | - | 43 | - | - | - | - | - | - | - | - | - | 43 | |

Appendix G-7. Biomass (kg) of macroinvertebrates species in trawl replicates, winter and summer. Mandalay Generating Station NPDES, 2007.

| | 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 |
| *Crangon nigromaculata* | 0.06 | 0.11 | 0.16 | 0.21 | 0.75 | 0.60 | 0.04 | 0.07 | 1.99 | 0.66 | 0.72 | 0.56 | 1.00 | 1.46 | 1.60 | 0.06 | 0.06 | 6.11 | 8.10 | 52.9 |
| *Cancer gracilis* | - | - | 0.14 | 0.13 | 0.07 | 0.03 | 0.07 | 0.10 | 0.54 | 0.21 | 0.10 | 0.21 | 0.13 | 0.70 | 0.85 | 0.14 | 0.20 | 2.54 | 3.08 | 20.1 |
| *Loxorhynchus grandis* | - | - | - | - | - | - | - | 1.10 | 1.10 | - | - | 0.15 | 0.58 | 0.03 | - | - | 0.11 | 0.87 | 1.97 | 12.9 |
| *Panulirus interruptus* | - | - | 0.16 | 0.37 | 0.19 | - | 0.68 | - | 1.40 | - | - | - | - | - | - | - | - | - | 1.40 | 9.1 |
| *Dendraster excentricus* | - | - | - | 0.00 | - | - | 0.41 | 0.21 | 0.62 | - | - | - | - | - | - | - | - | - | 0.62 | 4.1 |
| *Farfantepenaeus californiensis* | - | - | - | 0.03 | 0.01 | - | 0.02 | - | 0.06 | - | - | - | - | - | - | - | - | - | 0.06 | 0.4 |
| *Pyromaia tuberculata* | - | - | 0.00 | 0.00 | 0.00 | 0.01 | - | - | 0.01 | 0.00 | - | 0.00 | - | 0.00 | - | - | - | 0.00 | 0.02 | 0.1 |
| *Portunus xantusii* | - | - | 0.02 | - | - | - | - | - | 0.02 | - | - | - | - | - | - | - | - | - | 0.02 | 0.1 |
| *Cancer anthonyi* | - | - | - | - | - | - | - | - | - | 0.00 | - | 0.00 | - | 0.00 | - | - | 0.00 | 0.01 | 0.01 | 0.0 |
| *Caudina arenicola* | - | - | 0.01 | - | - | - | - | - | 0.01 | - | - | - | - | - | - | - | - | - | 0.01 | 0.0 |
| *Octopus rubescens* | - | 0.00 | - | - | - | - | - | - | 0.00 | - | - | - | - | - | - | - | - | - | 0.00 | 0.0 |
| *Cancer jordani* | - | - | - | - | - | - | - | - | - | - | - | - | - | 0.00 | 0.00 | - | - | 0.00 | 0.00 | 0.0 |
| *Heptacarpus stimpsoni* | - | - | - | - | 0.00 | - | - | - | 0.00 | - | - | - | - | 0.00 | - | - | 0.00 | 0.00 | 0.00 | 0.0 |
| *Heptacarpus palpator* | - | - | - | - | - | - | - | - | - | - | - | - | - | 0.00 | - | - | - | 0.00 | 0.00 | 0.0 |
| *Nassarius perpinguis* | - | - | - | - | - | - | - | - | - | - | - | - | 0.00 | - | - | - | - | 0.00 | 0.00 | 0.0 |
| *Opisthopus transversus* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0.00 | - | - | 0.00 | 0.00 | 0.0 |
| *Polyorchis penicillatus* | - | - | - | - | 0.00 | - | - | - | 0.00 | - | - | - | - | - | - | - | - | - | 0.00 | 0.0 |
| Total Biomass (kg) | 0.06 | 0.11 | 0.49 | 0.75 | 1.03 | 0.64 | 1.22 | 1.48 | 5.77 | 0.87 | 0.82 | 0.92 | 1.71 | 2.20 | 2.46 | 0.20 | 0.37 | 9.54 | 15.30 | |
| Fish parasites not included above | | | | | | | | | | | | | | | | | | | | |
| *Elthusa vulgaris* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | - | 0.01 | - | - | - | - | - | - | - | - | - | 0.01 | |

Note: 0.00 = < 0.005

**Appendix G-8. Abundance of fish species in trawl replicates, 1978 - 2007. Mandalay Generating Station NPDES, 2007.**

| Species | 1978 | 1980 | 1986 | 1988 | 1990 | 1991 | 1992 | 1993 | 1994 | 1997 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Genyonemus lineatus* | 6713 | 8446 | 1464 | 1150 | 1592 | 2291 | 2756 | 3043 | 7237 | 20 | 363 | 5363 |
| *Seriphus politus* | 966 | 4889 | 830 | 195 | 957 | 1341 | 6049 | 3009 | 5483 | - | 76 | 1352 |
| *Engraulis mordax* | 1476 | 494 | 2 | 52 | 88 | 359 | 1469 | 159 | 115 | - | 640 | 256 |
| *Citharichthys stigmaeus* | 36 | 8 | 40 | 64 | 76 | 217 | 4 | 75 | 16 | 7 | 143 | 219 |
| *Cymatogaster aggregata* | 107 | 24 | - | 4 | 33 | 63 | 4 | 58 | 88 | 17 | 190 | 42 |
| *Syngnathus californiensis* | - | - | - | - | - | - | - | - | - | - | 80 | 149 |
| *Amphistichus argenteus* | 210 | 172 | 46 | 223 | 38 | 95 | 29 | 115 | 41 | 18 | 1 | 33 |
| *Phanerodon furcatus* | 245 | 321 | 2 | 17 | 18 | 26 | 5 | 5 | 80 | 12 | 25 | - |
| *Hyperprosopon argenteum* | 335 | 340 | 8 | 18 | - | 50 | 5 | 26 | 28 | 1 | 1 | 16 |
| *Platyrhinoidis triseriata* | 27 | 21 | 12 | 16 | 6 | 56 | 4 | 167 | 2 | 3 | 13 | 14 |
| *Stellerina xyosterna* | - | - | - | - | - | - | - | - | - | - | - | - |
| *Paralichthys californicus* | 25 | 54 | 66 | 58 | 21 | 27 | 1 | 8 | 11 | - | 2 | 5 |
| *Menticirrhus undulatus* | 15 | 3 | 79 | - | - | 3 | 2 | 33 | 19 | - | 2 | 73 |
| *Synodus lucioceps* | 17 | 5 | - | - | 8 | - | 1 | 2 | 4 | - | 1 | 1 |
| *Syngnathus exilis* | 3 | - | - | 77 | 5 | - | - | - | 58 | - | - | - |
| *Umbrina roncador* | 2 | - | 11 | 1 | - | 1 | - | 79 | 50 | - | - | - |
| *Parophrys vetulus* | 22 | 8 | 5 | 49 | 7 | - | - | 1 | 4 | 1 | 7 | - |
| *Xystreurys liolepis* | - | 10 | 17 | 10 | 1 | 3 | 1 | 1 | 5 | 1 | 39 | 27 |
| *Ophidion scrippsae* | 1 | 3 | 9 | - | 8 | 45 | - | 28 | 4 | - | 1 | 5 |
| *Rhinobatos productus* | 6 | 11 | 6 | 22 | 13 | 18 | - | 19 | 2 | - | 1 | 2 |
| *Squalus acanthias* | 6 | 37 | 3 | - | - | 5 | - | - | - | - | - | - |
| *Peprilus simillimus* | 2 | 23 | - | 6 | - | 1 | 7 | - | 3 | - | - | 30 |
| *Leptocottus armatus* | - | 2 | 7 | 19 | 3 | 6 | - | 8 | 1 | - | 1 | - |
| *Myliobatis californica* | 4 | 4 | - | - | 5 | 2 | 4 | 2 | 2 | - | 5 | 3 |
| *Syngnathus* spp | - | 6 | 17 | - | - | 18 | 11 | 25 | - | - | - | - |
| *Pleuronichthys verticalis* | 8 | 17 | - | - | - | 31 | - | - | 3 | - | 1 | 9 |
| *Pleuronichthys guttulatus* | 9 | 15 | 3 | 6 | 8 | 3 | - | 5 | - | - | 1 | - |
| *Sardinops sagax* | - | - | 2 | - | 1 | 1 | 15 | 2 | 1 | - | - | 9 |
| *Atherinopsis californiensis* | - | - | - | 12 | 1 | - | - | 1 | 1 | 9 | - | - |
| *Embiotoca jacksoni* | 2 | 3 | - | - | - | - | 3 | - | 3 | - | - | - |
| *Pleuronichthys ritteri* | 5 | - | 3 | - | 3 | 1 | - | 5 | 23 | - | - | - |
| *Hyperprosopon anale* | 17 | 17 | - | - | - | - | - | - | - | - | - | - |
| *Porichthys myriaster* | 2 | 2 | - | - | - | - | - | - | - | - | 1 | - |
| *Atractoscion nobilis* | 4 | - | - | - | - | 2 | 4 | 12 | - | - | - | - |
| *Brachyistius frenatus* | 2 | 27 | - | - | - | - | - | - | - | - | - | - |
| *Rhacochilus toxotes* | - | - | 1 | - | - | - | - | - | 3 | - | - | - |
| *Squatina californica* | 1 | - | 1 | - | - | - | - | - | - | - | - | 6 |
| *Mustelus californicus* | 1 | 3 | 8 | - | - | - | - | 2 | 2 | - | - | 1 |
| *Rhacochilus vacca* | 11 | 5 | - | 1 | - | - | - | - | 2 | - | - | - |
| *Atherinops affinis* | - | 1 | - | - | - | - | 16 | - | - | - | - | - |
| *Sebastes auriculatus* | 1 | 6 | - | - | - | - | - | - | - | - | - | - |
| *Triakis semifasciata* | - | - | 1 | 4 | - | 1 | - | 1 | 1 | - | - | - |
| *Sphyraena argentea* | - | - | - | - | - | - | 9 | - | - | - | - | - |
| *Mustelus henlei* | 1 | - | - | 2 | - | 3 | - | - | 1 | - | - | - |
| *Raja inornata* | - | - | 1 | 2 | 1 | 2 | - | - | - | - | - | - |
| *Zalembius rosaceus* | 5 | - | - | - | - | - | - | - | - | - | 1 | - |
| *Lepidogobius lepidus* | - | - | - | - | - | - | - | - | - | - | - | - |
| *Symphurus atricaudus* | 5 | - | - | - | - | - | - | - | - | - | - | - |
| *Anchoa compressa* | - | - | - | - | 3 | - | - | 1 | - | - | - | - |
| *Heterostichus rostratus* | 1 | - | - | 1 | - | - | - | - | - | - | - | - |
| *Paralabrax nebulifer* | - | - | 2 | - | - | 1 | - | - | 1 | - | - | - |
| *Porichthys notatus* | - | 3 | - | - | - | - | - | - | - | - | - | - |
| *Roncador stearnsii* | - | 4 | - | - | - | - | - | - | - | - | - | - |
| *Raja binoculata* | 2 | 1 | - | - | - | - | - | - | - | - | - | - |
| *Urolophus halleri* | - | - | 1 | - | - | - | - | - | 2 | - | - | - |
| *Aulorhynchus flavidus* | - | - | - | - | - | - | - | - | - | - | - | - |
| *Platichthys stellatus* | 1 | 1 | - | - | - | - | - | - | - | - | - | - |
| *Sebastes carnatus* | - | - | - | - | - | 2 | - | - | - | - | - | - |
| *Chilara taylori* | 1 | - | - | - | - | - | - | - | - | - | - | - |
| *Clupea pallasii* | - | - | - | - | - | - | - | - | - | - | - | - |
| *Odontophyxis trispinosa* | - | - | - | - | - | - | - | - | - | - | - | - |
| *Raja kincaidii* | - | - | 1 | - | - | - | - | - | - | - | - | - |
| *Sebastes miniatus* | - | - | - | - | - | - | - | - | - | - | 1 | - |
| *Sebastes paucispinis* | - | - | - | - | - | - | - | - | - | - | - | 1 |
| *Sebastes serranoides* | 1 | - | - | - | - | - | - | - | - | - | - | - |
| *Torpedo californica* | 1 | - | - | - | - | - | - | - | - | - | - | - |
| *Trichiurus nitens* | - | - | - | - | - | - | - | - | - | - | 1 | - |
| *Scomber japonicus* | - | - | - | - | - | - | - | - | - | - | - | - |
| *Hypsoblennius gilberti* | - | - | - | - | - | - | - | - | - | - | - | - |
| Number of individuals | 10299 | 14986 | 2648 | 2009 | 2896 | 4674 | 10399 | 6892 | 13296 | 89 | 1597 | 7616 |
| Number of species | 41 | 35 | 29 | 24 | 23 | 30 | 21 | 28 | 33 | 10 | 25 | 22 |
| 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 |
| 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 |
| Seasons | W / S | W / S | W / S | W / S | W / S | W / S | W / S | W / S | W / S | S | W / S | W / S |
| Number of Trawls | 28 | 24 | 12 | 12 | 16 | 16 | 16 | 16 | 16 | 8 | 16 | 16 |

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

**Appendix G-8. (cont.).**

| Species | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | Total | Percent Total | F.O. |
|---|---|---|---|---|---|---|---|---|---|---|
| *Genyonemus lineatus* | 1033 | 9342 | - | 16 | 4632 | 3656 | 1255 | 60372 | 49.5 | 18 |
| *Seriphus politus* | 4630 | 3971 | 8 | 138 | 1106 | 34 | 3 | 35037 | 28.7 | 18 |
| *Engraulis mordax* | 383 | 1216 | 9 | 3322 | 202 | 231 | 251 | 10724 | 8.8 | 18 |
| *Citharichthys stigmaeus* | 38 | 224 | 51 | 476 | 325 | 1148 | 1481 | 4648 | 3.8 | 19 |
| *Cymatogaster aggregata* | 11 | 529 | 18 | 118 | 135 | 330 | 1277 | 3048 | 2.5 | 18 |
| *Syngnathus californiensis* | 104 | 179 | 3 | 118 | 346 | 245 | 70 | 1294 | 1.1 | 9 |
| *Amphistichus argenteus* | 9 | 42 | - | 45 | 67 | 4 | 29 | 1217 | 1.0 | 18 |
| *Phanerodon furcatus* | 1 | 225 | - | - | 23 | 39 | - | 1044 | 0.9 | 15 |
| *Hyperprosopon argenteum* | 37 | 28 | 1 | 9 | 53 | 67 | - | 1023 | 0.8 | 17 |
| *Platyrhinoidis triseriata* | 6 | 52 | - | 2 | 24 | 15 | 18 | 458 | 0.4 | 18 |
| *Stellerina xyosterna* | - | - | - | 15 | - | 25 | 329 | 369 | 0.3 | 3 |
| *Paralichthys californicus* | 1 | 4 | - | - | 1 | 6 | 5 | 295 | 0.2 | 16 |
| *Menticirrhus undulatus* | 24 | 9 | - | 8 | 6 | 3 | 1 | 280 | 0.2 | 15 |
| *Synodus lucioceps* | 26 | 115 | - | 1 | 9 | - | 10 | 200 | 0.2 | 13 |
| *Syngnathus exilis* | - | - | - | - | - | - | 36 | 179 | 0.1 | 5 |
| *Umbrina roncador* | 3 | - | - | - | - | - | - | 147 | 0.1 | 7 |
| *Parophrys vetulus* | - | 15 | - | 1 | 13 | 10 | 1 | 144 | 0.1 | 14 |
| *Xystreurys liolepis* | 1 | 16 | - | - | 1 | - | 1 | 134 | 0.1 | 15 |
| *Ophidion scrippsae* | - | - | - | - | 18 | - | - | 122 | 0.1 | 10 |
| *Rhinobatos productus* | - | 2 | - | - | 1 | 4 | 3 | 110 | 0.1 | 14 |
| *Squalus acanthias* | 1 | - | - | - | 41 | 12 | 3 | 108 | 0.1 | 8 |
| *Peprilus simillimus* | 2 | 20 | - | 1 | 2 | 1 | 2 | 100 | 0.1 | 13 |
| *Leptocottus armatus* | - | 5 | - | 3 | 1 | 15 | 19 | 90 | 0.1 | 13 |
| *Myliobatis californica* | 5 | 2 | - | 17 | 9 | 4 | 14 | 82 | 0.1 | 15 |
| *Syngnathus* spp | - | - | - | - | - | - | - | 77 | 0.1 | 5 |
| *Pleuronichthys verticalis* | 2 | - | - | - | 3 | 1 | - | 75 | 0.1 | 9 |
| *Pleuronichthys guttulatus* | - | 2 | 1 | - | 1 | - | 1 | 55 | 0.0 | 12 |
| *Sardinops sagax* | 1 | - | - | 7 | 3 | - | 8 | 50 | 0.0 | 11 |
| *Atherinopsis californiensis* | - | 1 | - | 1 | - | - | 21 | 47 | 0.0 | 8 |
| *Embiotoca jacksoni* | - | 30 | - | 2 | 4 | - | - | 47 | 0.0 | 7 |
| *Pleuronichthys ritteri* | 3 | 1 | - | - | 1 | - | - | 45 | 0.0 | 9 |
| *Hyperprosopon anale* | - | - | - | - | - | - | - | 34 | 0.0 | 2 |
| *Porichthys myriaster* | - | 1 | - | - | 27 | - | - | 33 | 0.0 | 5 |
| *Atractoscion nobilis* | - | - | - | - | 2 | 4 | 2 | 30 | 0.0 | 7 |
| *Brachyistius frenatus* | - | - | - | - | - | - | 1 | 30 | 0.0 | 3 |
| *Rhacochilus toxotes* | - | 18 | - | - | 1 | - | - | 23 | 0.0 | 4 |
| *Squatina californica* | 1 | 5 | - | - | 1 | 2 | 5 | 22 | 0.0 | 8 |
| *Mustelus californicus* | - | 2 | - | - | - | - | - | 19 | 0.0 | 7 |
| *Rhacochilus vacca* | - | - | - | - | - | - | - | 19 | 0.0 | 4 |
| *Atherinops affinis* | - | - | - | - | - | - | - | 17 | 0.0 | 2 |
| *Sebastes auriculatus* | - | - | - | 2 | 1 | 3 | - | 13 | 0.0 | 5 |
| *Triakis semifasciata* | - | - | - | - | 2 | - | - | 10 | 0.0 | 6 |
| *Sphyraena argentea* | - | - | - | - | - | - | - | 9 | 0.0 | 1 |
| *Mustelus henlei* | - | - | - | - | - | - | - | 7 | 0.0 | 4 |
| *Raja inornata* | - | - | - | - | - | - | 1 | 7 | 0.0 | 5 |
| *Zalembius rosaceus* | - | - | - | 1 | - | - | - | 7 | 0.0 | 3 |
| *Lepidogobius lepidus* | - | - | - | - | - | 6 | - | 6 | 0.0 | 1 |
| *Symphurus atricauda* | - | - | - | - | - | 1 | - | 6 | 0.0 | 2 |
| *Anchoa compressa* | - | - | - | - | - | - | - | 4 | 0.0 | 2 |
| *Heterostichus rostratus* | - | - | - | - | - | - | 2 | 4 | 0.0 | 3 |
| *Paralabrax nebulifer* | - | - | - | - | - | - | - | 4 | 0.0 | 3 |
| *Porichthys notatus* | 1 | - | - | - | - | - | - | 4 | 0.0 | 2 |
| *Roncador stearnsii* | - | - | - | - | - | - | - | 4 | 0.0 | 1 |
| *Raja binoculata* | - | - | - | - | - | - | - | 3 | 0.0 | 2 |
| *Urolophus halleri* | - | - | - | - | - | - | - | 3 | 0.0 | 2 |
| *Aulorhynchus flavidus* | 1 | - | - | - | - | - | 1 | 2 | 0.0 | 2 |
| *Platichthys stellatus* | - | - | - | - | - | - | - | 2 | 0.0 | 2 |
| *Sebastes carnatus* | - | - | - | - | - | - | - | 2 | 0.0 | 1 |
| *Chilara taylori* | - | - | - | - | - | - | - | 1 | 0.0 | 1 |
| *Clupea pallasii* | - | - | - | 1 | - | - | - | 1 | 0.0 | 1 |
| *Odontophyxis trispinosa* | - | - | - | - | 1 | - | - | 1 | 0.0 | 1 |
| *Raja kincaidii* | - | - | - | - | - | - | - | 1 | 0.0 | 1 |
| *Sebastes miniatus* | - | - | - | - | - | - | - | 1 | 0.0 | 1 |
| *Sebastes paucispinis* | - | - | - | - | - | - | - | 1 | 0.0 | 1 |
| *Sebastes serranoides* | - | - | - | - | - | - | - | 1 | 0.0 | 1 |
| *Torpedo californica* | - | - | - | - | - | - | - | 1 | 0.0 | 1 |
| *Trichiurus nitens* | - | - | - | - | - | - | - | 1 | 0.0 | 1 |
| *Scomber japonicus* | - | - | - | - | - | - | 1 | 1 | 0.0 | 1 |
| *Hypsoblennius gilberti* | - | - | - | - | - | - | 1 | 1 | 0.0 | 1 |
| Number of individuals | 6324 | 16056 | 91 | 4304 | 7062 | 5866 | 4852 | 121956 | | |
| Number of species | 24 | 27 | 7 | 22 | 33 | 25 | 31 | 69 | | |
| Total Biomass (kg) | 87.1 | 289.3 | 1.3 | 107.5 | 73.9 | 59.1 | 101.6 | 3371.4 | | |
| Stations / Replicates | 4/2 | 4/2 | 4/1 | 4/2 | 4/2 | 4/2 | 4/2 | | | |
| Seasons | W / S | W / S | S | W / S | W / S | W / S | W / S | | | |
| Number of Trawls | 16 | 16 | 4 | 16 | 16 | 16 | 16 | | | |

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

**Appendix G-9. Abundance of macroinvertebrates in trawl replicates, 1978 - 2007. Mandalay Generating Station NPDES, 2007.**

| Species | 1978 | 1980 | 1986 | 1988 | 1990 | 1991 | 1992 | 1993 | 1994 | 1997 | 1999 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Dendraster excentricus* | 10 | - | 3,853 | 165 | 536 | 681 | 5 | 3 | 1,322 | 11 | 17,860 |
| *Crangon nigromaculata* | 55 | 8 | 237 | 116 | 246 | 402 | 18 | 70 | 353 | 5 | 2,232 |
| *Cancer gracilis* | 3 | 3 | 3 | 1 | 141 | 7 | - | 4 | 5 | - | 12 |
| *Pyromaia tuberculata* | 1 | - | - | - | - | - | - | - | 1 | - | 46 |
| *Astropecten verrilli* | 95 | - | - | - | 3 | - | - | - | - | - | - |
| *Farfantepenaeus californicus* | - | 38 | 1 | - | - | - | - | - | - | - | - |
| *Pleurobranchia bachei* | - | - | - | - | - | 45 | - | - | - | - | - |
| *Portunus xantusii* | 12 | - | - | - | - | 5 | - | 4 | 5 | - | 6 |
| *Panulirus interruptus* | 3 | 2 | 2 | - | 2 | 1 | 2 | 2 | 1 | - | 1 |
| *Polyorchis pencillata* | - | - | 1 | 1 | - | - | - | - | - | - | 23 |
| *Heptacarpus stimpsoni* | - | - | - | - | 4 | - | - | - | 12 | - | - |
| *Cancer anthonyi* | - | - | 9 | 6 | 2 | 1 | - | - | 2 | - | - |
| *Heptacarpus* sp A of MBC | - | - | - | - | 4 | - | - | - | 26 | - | - |
| *Loxorhynchus grandis* | 1 | 2 | - | - | 2 | 4 | - | 2 | - | 2 | - |
| *Caudina arenicola* | - | - | - | - | - | - | - | - | - | - | - |
| *Nassarius perpinguis* | - | - | 1 | - | - | - | - | - | - | - | - |
| *Opisthopus transversus* | 5 | 4 | 1 | - | - | - | - | - | - | - | - |
| *Randallia ornata* | 10 | - | - | - | - | - | - | - | - | - | 1 |
| *Astropecten armatus* | - | - | - | - | 5 | 1 | - | 1 | 1 | - | - |
| *Cancer antennarius* | 3 | - | - | - | - | 1 | - | 4 | - | - | - |
| *Nassarius fossatus* | - | - | - | - | 1 | 4 | - | - | 1 | - | - |
| *Renilla kollikeri* | - | - | - | - | - | - | - | - | - | - | 6 |
| *Pugettia producta* | 5 | - | 1 | - | - | - | - | - | - | - | - |
| *Heterocrypta occidentalis* | 6 | - | - | - | - | - | - | - | - | - | - |
| *Heptacarpus palpator* | - | - | - | - | - | - | - | - | - | - | - |
| *Thetys vagina* | - | - | - | - | - | - | - | - | - | - | - |
| *Cancer* spp | - | - | 1 | - | - | 1 | - | 1 | - | - | - |
| *Isocheles pilosus* | - | - | - | 1 | - | 1 | - | - | - | - | - |
| *Loxorhynchus crispatus* | - | - | - | - | 1 | - | - | - | - | - | 1 |
| *Aphrodita* sp | - | - | - | - | - | - | - | - | - | - | - |
| *Blepharipoda occidentalis* | - | - | 2 | - | - | - | - | - | - | - | - |
| *Calliostoma* sp | - | - | - | - | - | - | - | - | - | - | - |
| *Nassarius* sp | - | - | - | - | - | - | - | - | - | - | 2 |
| *Pisaster brevispinis* | 1 | - | - | 1 | - | - | - | - | - | - | - |
| *Pisaster ochraceus* | 2 | - | - | - | - | - | - | - | - | - | - |
| *Polinices* sp | 2 | - | - | - | - | - | - | - | - | - | - |
| *Cancer jordani* | - | - | - | - | - | - | - | - | - | - | - |
| *Astropecten* sp | - | - | 1 | - | - | - | - | - | - | - | - |
| *Hippolytes californiensis* | - | - | - | - | - | 1 | - | - | - | - | - |
| *Idotea* sp | - | - | - | - | - | 1 | - | - | - | - | - |
| *Muricea californica* | - | - | - | - | 1 | - | - | - | - | - | - |
| *Octopus bimaculatus/bimaculoides* | - | - | - | - | - | - | - | - | - | - | - |
| Paguridae | - | - | - | - | 1 | - | - | - | - | - | - |
| *Pagurus spilocarpus* | - | - | 1 | - | - | - | - | - | - | - | - |
| *Pelagia noctiluca* | - | - | - | 1 | - | - | - | - | - | - | - |
| Penaeid shrimp | - | - | - | - | - | - | - | 1 | - | - | - |
| *Rossia pacifica* | - | - | - | - | - | - | - | - | - | - | 1 |
| *Salpa* sp | 1 | - | - | - | - | - | - | - | - | - | - |
| *Solen* sp | - | - | 1 | - | - | - | - | - | - | - | - |
| *Synidotea harfordi* | - | - | - | - | - | - | - | - | 1 | - | - |
| *Octopus rubescens* | - | - | - | - | - | - | - | - | - | - | - |
| *Triopha maculata* | - | - | - | - | - | - | - | - | - | - | - |
| Number of Individuals | 215 | 57 | 4,115 | 292 | 949 | 1,156 | 25 | 92 | 1,730 | 18 | 20,191 |
| Number of species | 17 | 6 | 15 | 8 | 14 | 15 | 3 | 10 | 12 | 3 | 12 |
| 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 |
| Stations / Replicates | 14/1 | 12/1 | 3/2 | 3/2 | 4/2 | 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 |
| Number of Trawls | 28 | 24 | 12 | 12 | 16 | 16 | 16 | 16 | 16 | 8 | 16 |
| Parasitic species (not included above): | | | | | | | | | | | |
| *Elthusa vulgaris* | 9 | - | 1 | 2 | - | 19 | 31 | 11 | 34 | - | 2 |
| *Elthusa* sp | - | - | - | - | 6 | - | - | - | - | - | - |
| *Elthusa californica* | - | - | - | - | - | - | - | - | - | - | - |
| *Nerocila* sp | - | - | - | - | - | - | - | - | - | - | - |
| Copepoda | - | - | - | 2 | - | - | - | - | - | - | - |
| Bopyridae, unid. | - | - | - | - | - | - | - | - | - | - | - |

Notes: N/A = not available; W = winter, S = summer

**Appendix G-9. (Cont.).**

| Species | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | Total | Percent Total |
|---|---|---|---|---|---|---|---|---|---|---|
| *Dendraster excentricus* | 12,878 | 11,761 | 2,832 | 132 | 47 | 529 | 6,002 | 158 | 58,785 | 62.6 |
| *Crangon nigromaculata* | 3,340 | 732 | 1,011 | 706 | 3,046 | 7,485 | 7,370 | 5,546 | 32,978 | 35.1 |
| *Cancer gracilis* | 19 | 103 | 59 | 16 | 93 | 76 | 737 | 164 | 1,446 | 1.5 |
| *Pyromaia tuberculata* | 2 | 3 | 1 | 1 | 1 | 6 | 53 | 14 | 129 | 0.1 |
| *Astropecten verrilli* | - | - | - | - | - | - | - | - | 98 | 0.1 |
| *Farfantepenaeus californicus* | 7 | - | - | - | - | - | - | 3 | 49 | 0.1 |
| *Pleurobranchia bachei* | - | - | - | - | - | - | - | - | 45 | 0.0 |
| *Portunus xantusii* | 1 | 1 | - | - | 3 | 3 | 1 | 1 | 42 | 0.0 |
| *Panulirus interruptus* | 11 | 3 | 4 | - | - | - | 2 | 5 | 41 | 0.0 |
| *Polyorchis pencillata* | 5 | - | 3 | - | - | - | 6 | 1 | 40 | 0.0 |
| *Heptacarpus stimpsoni* | - | - | - | - | - | - | 8 | 15 | 39 | 0.0 |
| *Cancer anthonyi* | 1 | 1 | - | - | 3 | - | 7 | 4 | 36 | 0.0 |
| *Heptacarpus* sp A of MBC | - | - | - | - | - | - | - | - | 30 | 0.0 |
| *Loxorhynchus grandis* | - | - | 2 | - | - | 1 | 4 | 6 | 26 | 0.0 |
| *Caudina arenicola* | 1 | 1 | - | - | 2 | - | 13 | 1 | 18 | 0.0 |
| *Nassarius perpinguis* | - | 1 | 4 | - | 1 | - | 7 | 1 | 15 | 0.0 |
| *Opisthopus transversus* | - | - | - | - | - | 1 | 1 | 1 | 13 | 0.0 |
| *Randallia ornata* | - | - | - | - | - | - | 1 | - | 12 | 0.0 |
| *Astropecten armatus* | - | - | - | - | - | - | - | - | 8 | 0.0 |
| *Cancer antennarius* | - | - | - | - | - | - | - | - | 8 | 0.0 |
| *Nassarius fossatus* | - | - | 1 | - | 1 | - | - | - | 8 | 0.0 |
| *Renilla kollikeri* | - | 1 | 1 | - | - | - | - | - | 8 | 0.0 |
| *Pugettia producta* | - | - | 1 | - | - | - | - | - | 7 | 0.0 |
| *Heterocrypta occidentalis* | - | - | - | - | - | - | - | - | 6 | 0.0 |
| *Heptacarpus palpator* | - | 3 | - | - | - | - | - | 1 | 4 | 0.0 |
| *Thetys vagina* | - | - | 4 | - | - | - | - | - | 4 | 0.0 |
| *Cancer* spp | - | - | - | - | - | - | - | - | 3 | 0.0 |
| *Isocheles pilosus* | 1 | - | - | - | - | - | - | - | 3 | 0.0 |
| *Loxorhynchus crispatus* | - | - | - | - | 1 | - | - | - | 3 | 0.0 |
| *Aphrodita* sp | - | - | - | - | - | - | 2 | - | 2 | 0.0 |
| *Blepharipoda occidentalis* | - | - | - | - | - | - | - | - | 2 | 0.0 |
| *Calliostoma* sp | - | 2 | - | - | - | - | - | - | 2 | 0.0 |
| *Nassarius* sp | - | - | - | - | - | - | - | - | 2 | 0.0 |
| *Pisaster brevispinis* | - | - | - | - | - | - | - | - | 2 | 0.0 |
| *Pisaster ochraceus* | - | - | - | - | - | - | - | - | 2 | 0.0 |
| *Polinices* sp | - | - | - | - | - | - | - | - | 2 | 0.0 |
| *Cancer jordani* | - | - | - | - | - | - | - | 2 | 2 | 0.0 |
| *Astropecten* sp | - | - | - | - | - | - | - | - | 1 | 0.0 |
| *Hippolytes californiensis* | - | - | - | - | - | - | - | - | 1 | 0.0 |
| *Idotea* sp | - | - | - | - | - | - | - | - | 1 | 0.0 |
| *Muricea californica* | - | - | - | - | - | - | - | - | 1 | 0.0 |
| *Octopus bimaculatus/bimaculoides* | - | - | - | - | - | - | 1 | - | 1 | 0.0 |
| Paguridae | - | - | - | - | - | - | - | - | 1 | 0.0 |
| *Pagurus spilocarpus* | - | - | - | - | - | - | - | - | 1 | 0.0 |
| *Pelagia noctiluca* | - | - | - | - | - | - | - | - | 1 | 0.0 |
| Penaeid shrimp | - | - | - | - | - | - | - | - | 1 | 0.0 |
| *Rossia pacifica* | - | - | - | - | - | - | - | - | 1 | 0.0 |
| *Salpa* sp | - | - | - | - | - | - | - | - | 1 | 0.0 |
| *Solen* sp | - | - | - | - | - | - | - | - | 1 | 0.0 |
| *Synidotea harfordi* | - | - | - | - | - | - | - | - | 1 | 0.0 |
| *Octopus rubescens* | - | - | - | - | - | - | - | 1 | 1 | 0.0 |
| *Triopha maculata* | - | - | - | - | 1 | - | - | - | 1 | 0.0 |
| Number of Individuals | 16,266 | 12,612 | 3,923 | 855 | 3,199 | 8,101 | 14,215 | 5,924 | 93,935 | |
| Number of species | 11 | 12 | 12 | 4 | 11 | 7 | 16 | 17 | 52 | |
| Total Biomass (kg) | 40.64 | 63.05 | 29.00 | 2.42 | 6.93 | 31.67 | 38.11 | 15.30 | 288.15 | |
| Stations / Replicates | 4/2 | 4/2 | 4/2 | 4/1 | 4/2 | 4/2 | 4/2 | 4/2 | | |
| Seasons | W / S | W / S | W / S | S | W / S | W / S | W / S | W / S | | |
| Number of Trawls | 16.00 | 16 | 16 | 4 | 16 | 16 | 16 | 16 | | |
| Parasitic species (not included above): | | | | | | | | | | |
| *Elthusa vulgaris* | 2 | - | 31 | 15 | 4 | 4 | 95 | 43 | 303 | |
| *Elthusa* sp | 3 | 5 | - | - | 52 | 52 | - | - | 118 | |
| *Elthusa californica* | - | 4 | - | - | - | - | - | - | 4 | |
| *Nerocila* sp | 2 | 1 | - | - | - | - | - | - | 3 | |
| Copepoda | - | - | - | - | - | - | - | - | 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, 2007.**

| Phylum<br>Class<br>Family<br>Taxa | Common name |
|---|---|
| Arthropoda | |
| Malacostraca | |
| Grapsidae | |
| *Pachygrapsus crassipes* | striped shore crab |
| Hippolytidae | |
| *Heptacarpus brevirostris* | stout coastal shrimp |
| Palinuridae | |
| *Panulirus interruptus* | California spiny lobster |
| Mollusca | |
| Cephalopoda | |
| Octopodidae | |
| *Octopus bimaculatus/bimaculoides* | California two-spot octopus |
| Chordata | |
| Chondrichthyes | |
| Myliobatidae | |
| *Myliobatis californica* | bat ray |
| Actinopterygii | |
| Atherinopsidae | |
| *Atherinops affinis* | topsmelt |
| Clinidae | |
| *Gibbonsia elegans* | spotted kelpfish |
| *Gibbonsia montereyensis* | crevice kelpfish |
| *Heterostichus rostratus* | giant kelpfish |
| Clupeidae | |
| *Sardinops sagax* | Pacific sardine |
| Cottidae | |
| *Leptocottus armatus* | Pacific staghorn sculpin |
| Embiotocidae | |
| *Cymatogaster aggregata* | shiner perch |
| *Embiotoca jacksoni* | black perch |
| *Hyperprosopon argenteum* | walleye surfperch |
| *Phanerodon furcatus* | white seaperch |
| *Rhacochilus toxotes* | rubberlip seaperch |
| Engraulidae | |
| *Anchoa compressa* | deepbody anchovy |
| *Engraulis mordax* | northern anchovy |
| Gobiidae | |
| *Acanthogobius flavimanus* | yellowfin goby |
| *Lepidogobius lepidus* | bay goby |
| Haemulidae | |
| *Anisotremus davidsonii* | sargo |
| Hexagrammidae | |
| *Hexagrammos decagrammus* | kelp greenling |
| Kyphosidae | |
| *Girella nigricans* | opaleye |
| Paralichthyidae | sand flounder unid |
| *Paralichthys californicus* | California halibut |
| Sciaenidae | |
| *Seriphus politus* | queenfish |
| *Umbrina roncador* | yellowfin croaker |
| Serranidae | |
| *Paralabrax clathratus* | kelp bass |
| *Paralabrax nebulifer* | barred sand bass |
| 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, 2007.**

| Taxa | 11/1/2006 | 11/8/2006 | 11/29/2006 | 12/7/2006 | 12/20/2006 | 1/17/2007 | 3/29/2007 | 5/2/2007 | 7/12/2007 | 9/6/2007 | Total Abundance |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Cymatogaster aggregata* | - | - | 394 | 37 | - | 2 | - | - | 1 | 14 | 448 |
| *Engraulis mordax* | 2 | - | 34 | 19 | 3 | - | - | - | - | - | 58 |
| *Anisotremus davidsonii* | - | - | 50 | 1 | - | - | - | - | - | - | 51 |
| *Leptocottus armatus* | - | - | 20 | 1 | 1 | 2 | - | - | 1 | 4 | 29 |
| *Atherinops affinis* | 1 | - | 6 | 6 | 2 | 6 | - | 2 | 1 | 1 | 25 |
| *Sardinops sagax* | - | - | 2 | 1 | 12 | - | - | - | - | - | 15 |
| *Seriphus politus* | 2 | - | 3 | - | - | - | - | - | - | 4 | 9 |
| *Syngnathus leptorhynchus* | 1 | - | 2 | - | - | 1 | - | - | 2 | - | 6 |
| *Myliobatis californica* | 1 | - | - | - | - | 1 | 2 | - | 1 | - | 5 |
| *Gibbonsia montereyensis* | - | - | - | 1 | 2 | - | 1 | - | 1 | - | 5 |
| *Paralichthys californicus* | - | - | - | - | - | 2 | - | - | - | - | 2 |
| *Anchoa compressa* | - | - | - | - | - | - | - | - | - | 2 | 2 |
| *Paralabrax clathratus* | 1 | - | - | - | 1 | - | - | - | - | - | 2 |
| *Hexagrammos decagrammus* | - | - | - | - | 2 | - | - | - | - | - | 2 |
| *Girella nigricans* | - | - | - | - | - | 2 | - | - | - | - | 2 |
| *Rhacochilus toxotes* | - | - | - | 1 | 1 | - | - | - | - | - | 2 |
| *Gibbonsia elegans* | 1 | - | 1 | - | - | - | - | - | - | - | 2 |
| *Hyperprosopon argenteum* | - | - | 1 | - | - | 1 | - | - | - | - | 2 |
| *Paralabrax nebulifer* | - | - | - | - | - | 1 | - | - | - | - | 1 |
| *Lepidogobius lepidus* | - | - | 1 | - | - | - | - | - | - | - | 1 |
| *Heterostichus rostratus* | - | - | 1 | - | - | - | - | - | - | - | 1 |
| Paralichthyidae | - | - | - | - | 1 | - | - | - | - | - | 1 |
| *Phanerodon furcatus* | - | - | - | - | - | 1 | - | - | - | - | 1 |
| *Umbrina roncador* | - | - | - | - | - | - | - | - | 1 | - | 1 |
| *Acanthogobius flavimanus* | - | - | 1 | - | - | - | - | - | - | - | 1 |
| Total Abundance | 9 | - | 516 | 67 | 25 | 19 | 3 | 2 | 8 | 25 | 674 |
| Number of Taxa | 7 | - | 13 | 8 | 9 | 10 | 2 | 1 | 7 | 5 | 25 |

**Appendix H-3. Biomass (kg) of fish impinged during normal operations by survey date at Mandalay Generating Station. Mandalay Generating Station NPDES, 2007.**

| Taxa | 11/1/2006 | 11/8/2006 | 11/29/2006 | 12/7/2006 | 12/20/2006 | 1/17/2007 | 3/29/2007 | 5/2/2007 | 7/12/2007 | 9/6/2007 | Total Biomass (kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Cymatogaster aggregata* | - | - | 1.864 | 0.135 | - | 0.011 | - | - | 0.020 | 0.042 | 2.072 |
| *Leptocottus armatus* | - | - | 0.856 | 0.036 | 0.400 | 0.111 | - | - | 0.027 | 0.101 | 1.531 |
| *Myliobatis californica* | 0.288 | - | - | - | - | 0.356 | 0.561 | - | 0.103 | - | 1.308 |
| *Rhacochilus toxotes* | - | - | - | 0.031 | 0.568 | - | - | - | - | - | 0.599 |
| *Girella nigricans* | - | - | - | - | - | 0.364 | - | - | - | - | 0.364 |
| *Atherinops affinis* | 0.002 | - | 0.023 | 0.086 | 0.028 | 0.112 | - | 0.020 | 0.012 | 0.002 | 0.285 |
| *Sardinops sagax* | - | - | 0.002 | 0.006 | 0.268 | - | - | - | - | - | 0.276 |
| *Anisotremus davidsonii* | - | - | 0.132 | 0.002 | - | - | - | - | - | - | 0.134 |
| *Umbrina roncador* | - | - | - | - | - | - | - | - | 0.133 | - | 0.133 |
| *Hyperprosopon argenteum* | - | - | 0.044 | - | - | 0.082 | - | - | - | - | 0.126 |
| *Paralabrax clathratus* | 0.089 | - | - | - | 0.008 | - | - | - | - | - | 0.097 |
| *Paralabrax nebulifer* | - | - | - | - | - | 0.093 | - | - | - | - | 0.093 |
| *Paralichthys californicus* | - | - | - | - | - | 0.090 | - | - | - | - | 0.090 |
| *Engraulis mordax* | 0.001 | - | 0.030 | 0.022 | 0.035 | - | - | - | - | - | 0.088 |
| *Gibbonsia montereyensis* | - | - | - | 0.021 | 0.027 | - | 0.018 | - | 0.002 | - | 0.068 |
| *Lepidogobius lepidus* | - | - | 0.035 | - | - | - | - | - | - | - | 0.035 |
| *Phanerodon furcatus* | - | - | - | - | - | 0.031 | - | - | - | - | 0.031 |
| *Hexagrammos decagrammus* | - | - | - | - | 0.029 | - | - | - | - | - | 0.029 |
| *Heterostichus rostratus* | - | - | 0.017 | - | - | - | - | - | - | - | 0.017 |
| *Anchoa compressa* | - | - | - | - | - | - | - | - | - | 0.016 | 0.016 |
| *Acanthogobius flavimanus* | - | - | 0.013 | - | - | - | - | - | - | - | 0.013 |
| *Seriphus politus* | 0.002 | - | 0.002 | - | - | - | - | - | - | 0.008 | 0.012 |
| *Gibbonsia elegans* | 0.001 | - | 0.009 | - | - | - | - | - | - | - | 0.010 |
| *Syngnathus leptorhynchus* | 0.002 | - | 0.004 | - | - | 0.001 | - | - | 0.002 | - | 0.009 |
| Paralichthyidae | - | - | - | - | 0.006 | - | - | - | - | - | 0.006 |
| Total Biomass (kg) | 0.385 | - | 3.031 | 0.339 | 1.369 | 1.251 | 0.579 | 0.020 | 0.299 | 0.169 | 7.442 |
| Number of Taxa | 7 | - | 13 | 8 | 9 | 10 | 2 | 1 | 7 | 5 | 25 |

**Appendix H-4. Estimated monthly abundance of fish impinged during normal operations at Mandalay Generating Station. Manalay Generating Station NPDES, 2007.**

| Taxa | Nov | Dec | Jan | Mar | May | Jul | Sep | Total Abundance |
|---|---|---|---|---|---|---|---|---|
| *Cymatogaster aggregata* | 1,453 | 295 | 19 | - | - | 203 | 301 | 2,271 |
| *Atherinops affinis* | 29 | 60 | 57 | - | 91 | 203 | 22 | 462 |
| *Syngnathus leptorhynchus* | 14 | - | 10 | - | - | 405 | - | 429 |
| *Leptocottus armatus* | 74 | 22 | 19 | - | - | 203 | 86 | 404 |
| *Myliobatis californica* | 7 | - | 10 | 79 | - | 203 | - | 299 |
| *Gibbonsia montereyensis* | - | 29 | - | 40 | - | 203 | - | 272 |
| *Engraulis mordax* | 139 | 124 | - | - | - | - | - | 263 |
| *Umbrina roncador* | - | - | - | - | - | 203 | - | 203 |
| *Anisotremus davidsonii* | 184 | 5 | - | - | - | - | - | 189 |
| *Sardinops sagax* | 7 | 128 | - | - | - | - | - | 135 |
| *Seriphus politus* | 25 | - | - | - | - | - | 86 | 111 |
| *Anchoa compressa* | - | - | - | - | - | - | 43 | 43 |
| *Hexagrammos decagrammus* | - | 20 | - | - | - | - | - | 20 |
| *Girella nigricans* | - | - | 19 | - | - | - | - | 19 |
| *Paralichthys californicus* | - | - | 19 | - | - | - | - | 19 |
| *Paralabrax clathratus* | 7 | 10 | - | - | - | - | - | 17 |
| *Rhacochilus toxotes* | - | 15 | - | - | - | - | - | 15 |
| *Hyperprosopon argenteum* | 4 | - | 10 | - | - | - | - | 14 |
| *Gibbonsia elegans* | 10 | - | - | - | - | - | - | 10 |
| *Paralabrax nebulifer* | - | - | 10 | - | - | - | - | 10 |
| *Phanerodon furcatus* | - | - | 10 | - | - | - | - | 10 |
| Paralichthyidae | - | 10 | - | - | - | - | - | 10 |
| *Acanthogobius flavimanus* | 4 | - | - | - | - | - | - | 4 |
| *Heterostichus rostratus* | 4 | - | - | - | - | - | - | 4 |
| *Lepidogobius lepidus* | 4 | - | - | - | - | - | - | 4 |
| Total Abundance | 1,965 | 718 | 183 | 119 | 91 | 1,623 | 538 | 5,237 |
| Number of Taxa | 15 | 11 | 10 | 2 | 1 | 7 | 5 | 25 |
| Analysis Flow (mg) | 2,436 | 2,190 | 1,622 | 8,540 | 13,178 | 25,690 | 21,718 | |

**Appendix H-5. Estimated monthly biomass (kg) of fish impinged during normal operations at Mandalay Generating Station. Mandalay Generating Station NPDES, 2007.**

| Taxa | Nov | Dec | Jan | Mar | May | Jul | Sep | Total Biomass (kg) |
|---|---|---|---|---|---|---|---|---|
| *Myliobatis californica* | 2.002 | - | 3.399 | 22.300 | - | 20.877 | - | 48.578 |
| *Umbrina roncador* | - | - | - | - | - | 26.957 | - | 26.957 |
| *Leptocottus armatus* | 3.235 | 4.365 | 1.060 | - | - | 5.473 | 2.173 | 16.306 |
| *Cymatogaster aggregata* | 7.046 | 1.068 | 0.105 | - | - | 4.054 | 0.904 | 13.177 |
| *Rhacochilus toxotes* | - | 5.713 | - | - | - | - | - | 5.713 |
| *Atherinops affinis* | 0.101 | 0.974 | 1.069 | - | 0.911 | 2.432 | 0.043 | 5.530 |
| *Girella nigricans* | - | - | 3.475 | - | - | - | - | 3.475 |
| *Sardinops sagax* | 0.008 | 2.719 | - | - | - | - | - | 2.727 |
| *Gibbonsia montereyensis* | - | 0.462 | - | 0.715 | - | 0.405 | - | 1.582 |
| *Hyperprosopon argenteum* | 0.166 | - | 0.783 | - | - | - | - | 0.949 |
| *Paralabrax nebulifer* | - | - | 0.888 | - | - | - | - | 0.888 |
| *Paralichthys californicus* | - | - | 0.859 | - | - | - | - | 0.859 |
| *Paralabrax clathratus* | 0.619 | 0.080 | - | - | - | - | - | 0.699 |
| *Engraulis mordax* | 0.120 | 0.457 | - | - | - | - | - | 0.577 |
| *Anisotremus davidsonii* | 0.499 | 0.009 | - | - | - | - | - | 0.508 |
| *Syngnathus leptorhynchus* | 0.029 | - | 0.010 | - | - | 0.405 | - | 0.444 |
| *Anchoa compressa* | - | - | - | - | - | - | 0.344 | 0.344 |
| *Phanerodon furcatus* | - | - | 0.296 | - | - | - | - | 0.296 |
| *Hexagrammos decagrammus* | - | 0.290 | - | - | - | - | - | 0.290 |
| *Seriphus politus* | 0.021 | - | - | - | - | - | 0.172 | 0.193 |
| *Lepidogobius lepidus* | 0.132 | - | - | - | - | - | - | 0.132 |
| *Heterostichus rostratus* | 0.064 | - | - | - | - | - | - | 0.064 |
| Paralichthyidae | - | 0.060 | - | - | - | - | - | 0.060 |
| *Acanthogobius flavimanus* | 0.049 | - | - | - | - | - | - | 0.049 |
| *Gibbonsia elegans* | 0.041 | - | - | - | - | - | - | 0.041 |
| Grand Total | 14.132 | 16.197 | 11.944 | 23.015 | 0.911 | 60.603 | 3.636 | 130.438 |
| Number of Taxa | 15 | 11 | 10 | 2 | 1 | 7 | 5 | 25 |
| Analysis Flow (mg) | 2,436 | 2,190 | 1,622 | 8,540 | 13,178 | 25,690 | 21,718 | |

**Appendix H-6. Length frequency of impinged fish measured during heat treatment and normal operation surveys at Mandalay Generating Station. Mandalay Generating Station NPDES, 2007.**

| | size class (cm) | | | | | | | | | | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Taxa | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 26 | 30 | 44 | Measured |
| *Cymatogaster aggregata* | - | 18 | 76 | 42 | 10 | 1 | 3 | 10 | 9 | 4 | - | - | - | - | - | - | - | - | - | - | 173 |
| *Engraulis mordax* | 2 | 24 | 26 | 2 | - | 1 | - | - | 1 | 2 | - | - | - | - | - | - | - | - | - | - | 58 |
| *Anisotremus davidsonii* | - | 10 | 30 | 11 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 51 |
| *Leptocottus armatus* | - | - | - | - | - | - | 1 | 1 | 7 | 10 | 3 | 4 | 1 | 2 | - | - | - | - | - | - | 29 |
| *Atherinops affinis* | - | 1 | 3 | 2 | 5 | - | 1 | 2 | 5 | 1 | 2 | 1 | 1 | 2 | - | - | - | - | - | - | 26 |
| *Sardinops sagax* | - | 1 | 1 | - | - | - | 1 | - | - | 3 | 3 | 3 | 2 | 1 | - | - | - | - | - | - | 15 |
| *Seriphus politus* | - | 5 | 2 | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 9 |
| *Syngnathus leptorhynchus* | - | - | - | - | - | - | 1 | 1 | 1 | - | - | 1 | - | - | 2 | - | - | - | - | - | 6 |
| *Gibbonsia elegans* | - | - | - | 1 | - | - | 2 | 2 | - | - | - | - | - | - | - | - | - | - | - | - | 5 |
| *Gibbonsia montereyensis* | - | - | 1 | - | - | - | 1 | - | 3 | - | - | - | - | - | - | - | - | - | - | - | 5 |
| *Myliobatis californica** | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | 1 | 2 | 1 | 5 |
| *Embiotoca jacksoni* | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | 2 | - | - | - | - | - | 4 |
| *Paralabrax clathratus* | - | - | - | - | 1 | - | - | - | - | - | - | - | 1 | 1 | - | - | - | - | - | - | 3 |
| *Anchoa compressa* | - | - | - | - | - | - | - | 2 | - | - | - | - | - | - | - | - | - | - | - | - | 2 |
| *Girella nigricans* | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | 1 | - | - | - | - | 2 |
| *Hexagrammos decagrammus* | - | - | - | - | - | - | - | - | 2 | - | - | - | - | - | - | - | - | - | - | - | 2 |
| *Hyperprosopon argenteum* | - | - | - | - | - | - | - | - | - | 1 | - | - | - | 1 | - | - | - | - | - | - | 2 |
| *Paralichthys californicus* | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | 1 | - | - | - | - | - | 2 |
| *Rhacochilus toxotes* | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | 1 | - | - | 2 |
| *Acanthogobius flavimanus* | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 |
| *Heterostichus rostratus* | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | 1 |
| *Lepidogobius lepidus* | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 |
| *Paralabrax nebulifer* | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | 1 |
| *Phanerodon furcatus* | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | 1 |
| *Umbrina roncador* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | 1 |
| Paralichthyidae | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 |

Note: * = Disc Width

**Appendix H-7. Abundance of macroinvertebrates impinged during normal operations by survey date at Mandalay Generating Station. Mandalay Generating Station NPDES, 2007.**

| Species | 11/1/2006 | 11/8/2006 | 11/29/2006 | 12/7/2006 | 12/20/2006 | 1/17/2007 | 3/29/2007 | 5/2/2007 | 7/12/2007 | 9/6/2007 | Total Abundance |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Pachygrapsus crassipes* | - | - | - | - | - | - | - | - | 2 | - | 2 |
| *Octopus bimaculatus/bimaculoides* | - | - | - | - | - | 1 | - | - | - | - | 1 |
| Total Abundance | - | - | - | - | - | 1 | - | - | 2 | - | 3 |
| Number of Species | - | - | - | - | - | 1 | - | - | 1 | - | 2 |

**Appendix H-8. Biomass (kg) of macroinvertebrates impinged during normal operations by survey date at Mandalay Generating Station. Mandalay Generating Station NPDES, 2007.**

| Species | 11/1/2006 | 11/8/2006 | 11/29/2006 | 12/7/2006 | 12/20/2006 | 1/17/2007 | 3/29/2007 | 5/2/2007 | 7/12/2007 | 9/6/2007 | Total Biomass(kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Octopus bimaculatus/bimaculoides* | - | - | - | - | - | 0.066 | - | - | - | - | 0.066 |
| *Pachygrapsus crassipes* | - | - | - | - | - | - | - | - | 0.009 | - | 0.009 |
| Total Biomass (kg) | - | - | - | - | - | 0.066 | - | - | 0.009 | - | 0.075 |
| Number of Species | - | - | - | - | - | 1 | - | - | 1 | - | 2 |

**Appendix H-9. Estimated monthly abundance of macroinvertebrates impinged during normal operations at Mandalay Generating Station. Mandalay Generating Station NPDES, 2007.**

| Species | Nov | Dec | Jan | Mar | May | Jul | Sep | Total Abundance |
|---|---|---|---|---|---|---|---|---|
| *Pachygrapsus crassipes* | - | - | - | - | - | 405 | - | 405 |
| *Octopus bimaculatus/bimaculoides* | - | - | 10 | - | - | - | - | 10 |
| Total Abundance | - | - | 10 | - | - | 405 | - | 415 |
| Number of Species | - | - | 1 | - | - | 1 | - | 2 |
| Analysis Flow (mg) | 2378 | 2190 | 1622 | 8540 | 13178 | 25690 | 21718 | |

**Appendix H-10. Estimated monthly biomass (kg) of macroinvertebrates impinged during normal operations at Mandalay Generating Station. Mandalay Generating Station NPDES, 2007.**

| Species | Nov | Dec | Jan | Mar | May | Jul | Sep | Total Biomass(kg) |
|---|---|---|---|---|---|---|---|---|
| *Pachygrapsus crassipes* | - | - | - | - | - | 1.824 | - | 1.824 |
| *Octopus bimaculatus/bimaculoides* | - | - | 0.630 | - | - | - | - | 0.630 |
| Total Biomass(kg) | - | - | 0.630 | - | - | 1.824 | - | 2.454 |
| Number of Species | - | - | 1 | - | - | 1 | - | 2 |
| Analysis Flow (mg) | 2378 | 2190 | 1622 | 8540 | 13178 | 25690 | 21718 | |

**Appendix H-11. Total abundance of fish impinged during heat treatments and extrapolated normal operations, 2001 - 2007. Mandalay Generating Station NPDES, 2007.**

| Taxa | Year 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | Total | Percent Total | Mean |
|---|---|---|---|---|---|---|---|---|---|---|
| *Leuresthes tenuis* | - | 114883 | 6502 | 4273 | 39910 | - | - | 165568 | 48.40 | 23652.6 |
| *Cymatogaster aggregata* | 27 | 14305 | 563 | 14709 | 8883 | 48209 | 2295 | 88991 | 26.01 | 12713.0 |
| *Engraulis mordax* | 3 | 101 | 1 | 1607 | 3137 | 45950 | 263 | 51062 | 14.93 | 7294.6 |
| *Atherinops affinis* | - | 6232 | - | - | - | 6830 | 463 | 13525 | 3.95 | 1932.1 |
| *Lepidogobius lepidus* | - | - | - | - | 79 | 3665 | 4 | 3748 | 1.10 | 535.4 |
| *Hyperprosopon ellipticum* | - | - | - | - | - | 3664 | - | 3664 | 1.07 | 523.4 |
| *Phanerodon furcatus* | - | 1 | - | 45 | 20 | 3369 | 10 | 3445 | 1.01 | 492.1 |
| *Sardinops sagax* | - | 246 | 92 | 1224 | 260 | 1173 | 135 | 3130 | 0.91 | 447.1 |
| *Leptocottus armatus* | 81 | 605 | 98 | 402 | 113 | 542 | 404 | 2245 | 0.66 | 320.7 |
| *Syngnathus leptorhynchus* | - | - | 50 | 334 | 26 | 207 | 429 | 1046 | 0.31 | 149.4 |
| *Myliobatis californica* | - | - | 26 | 43 | 179 | 223 | 299 | 770 | 0.23 | 110.0 |
| *Pleuronichthys guttulatus* | - | - | - | 156 | 444 | 108 | - | 708 | 0.21 | 101.1 |
| *Clupea pallasii* | - | - | - | - | - | 481 | - | 481 | 0.14 | 68.7 |
| *Girella nigricans* | - | - | - | - | - | 432 | 19 | 451 | 0.13 | 64.4 |
| *Gibbonsia montereyensis* | - | 28 | - | - | - | 31 | 272 | 331 | 0.10 | 47.3 |
| *Seriphus politus* | - | 2 | - | - | 44 | 172 | 111 | 329 | 0.10 | 47.0 |
| *Paralichthys californicus* | 27 | 1 | 36 | 43 | 174 | 19 | 19 | 319 | 0.09 | 45.6 |
| *Hypsopsetta guttulata* | - | 236 | 53 | - | - | - | - | 289 | 0.08 | 41.3 |
| *Atractoscion nobilis* | - | - | - | - | 22 | 261 | - | 283 | 0.08 | 40.4 |
| *Anchoa compressa* | - | - | - | - | 127 | 76 | 43 | 246 | 0.07 | 35.1 |
| *Umbrina roncador* | - | 3 | - | - | - | - | 203 | 206 | 0.06 | 29.4 |
| *Anisotremus davidsonii* | - | - | - | - | - | - | 189 | 189 | 0.06 | 27.0 |
| *Trachurus symmetricus* | - | 28 | - | 87 | 19 | 35 | - | 169 | 0.05 | 24.1 |
| *Peprilus simillimus* | - | 33 | - | 129 | 1 | - | - | 163 | 0.05 | 23.3 |
| *Hyperprosopon argenteum* | - | - | - | - | - | 94 | 14 | 108 | 0.03 | 15.4 |
| *Gibbonsia elegans* | - | 4 | 1 | - | 41 | 28 | 13 | 87 | 0.03 | 12.4 |
| *Atherinopsis californiensis* | - | - | - | - | - | 79 | - | 79 | 0.02 | 11.3 |
| *Embiotoca jacksoni* | - | - | - | - | 77 | - | - | 77 | 0.02 | 11.0 |
| *Platyrhinoidis triseriata* | - | - | - | - | 23 | 34 | - | 57 | 0.02 | 8.1 |
| *Acanthogobius flavimanus* | - | 26 | - | - | - | 25 | 4 | 55 | 0.02 | 7.9 |
| *Sphyraena argentea* | - | - | - | - | - | 47 | - | 47 | 0.01 | 6.7 |
| *Mugil cephalus* | - | - | - | - | - | 44 | - | 44 | 0.01 | 6.3 |
| *Hypsurus caryi* | - | - | - | - | - | 30 | - | 30 | 0.01 | 4.3 |
| *Urobatis halleri* | 24 | - | - | - | - | 1 | - | 25 | 0.01 | 3.6 |
| *Syngnathus* sp | 24 | - | - | - | - | - | - | 24 | 0.01 | 3.4 |
| *Hexagrammos decagrammus* | - | - | - | 1 | - | - | 20 | 21 | 0.01 | 3.0 |
| *Paralabrax clathratus* | - | 1 | - | - | - | - | 18 | 19 | 0.01 | 2.7 |
| *Xystreurys liolepis* | - | - | - | - | 19 | - | - | 19 | 0.01 | 2.7 |
| *Rhacochilus toxotes* | - | - | - | - | - | - | 15 | 15 | 0.00 | 2.1 |
| *Paralabrax nebulifer* | - | - | 2 | - | - | - | 10 | 12 | 0.00 | 1.7 |
| *Porichthys myriaster* | - | 12 | - | - | - | - | - | 12 | 0.00 | 1.7 |
| Paralichthyidae | - | - | - | - | - | - | 10 | 10 | 0.00 | 1.4 |
| *Heterostichus rostratus* | - | 1 | - | - | - | - | 4 | 5 | 0.00 | 0.7 |
| *Embiotoca jacksoni* | - | - | - | - | - | - | 4 | 4 | 0.00 | 0.6 |
| *Cheilotrema saturnum* | - | 1 | - | - | - | - | - | 1 | 0.00 | 0.1 |
| Number of individuals | 186 | 136,749 | 7,424 | 23,053 | 53,598 | 115,829 | 5,270 | 342,109 | | 48,873 |
| Number of taxa | 6 | 20 | 11 | 13 | 20 | 28 | 26 | 45 | | 17.7 |

Note: 0.00 = <0.005.

**Appendix H-12. Total abundance of macroinvertebrates impinged during heat treatments and extrapolated normal operations, 2001 - 2007. Mandalay Generating Station NPDES, 2007.**

| | Year | | | | | | | | Percent | |
|---|---|---|---|---|---|---|---|---|---|---|
| Species | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | Total | Total | Mean |
| *Protothaca staminea* | - | - | 4 | - | - | 27020 | - | 27024 | 94.70 | 3860.6 |
| *Pachygrapsus crassipes* | 27 | - | 1 | 4 | 156 | 76 | 451 | 715 | 2.51 | 102.1 |
| *Navanax inermis* | - | - | - | 48 | - | 153 | - | 201 | 0.70 | 28.7 |
| *Octopus bimaculoides* | 1 | 41 | 12 | - | - | 106 | 10 | 170 | 0.60 | 24.3 |
| *Hemigrapsu nudus* | - | - | - | 129 | - | - | - | 129 | 0.45 | 18.4 |
| *Loligo opalescens* | 124 | - | - | - | - | - | - | 124 | 0.43 | 17.7 |
| *Panulirus interruptus* | - | 3 | 3 | 1 | 3 | 85 | 26 | 121 | 0.42 | 17.3 |
| *Crangon nigromaculata* | - | - | - | - | - | 19 | - | 19 | 0.07 | 2.7 |
| *Farfantepenaeus californiensis* | - | - | - | - | - | 16 | - | 16 | 0.06 | 2.3 |
| *Aplysia californica* | - | 2 | - | - | 4 | - | - | 6 | 0.02 | 0.9 |
| *Cancer antennarius* | 1 | - | - | 2 | - | - | - | 3 | 0.01 | 0.4 |
| Polchaeta, unid | - | - | - | 3 | - | - | - | 3 | 0.01 | 0.4 |
| *Macoma* sp | - | - | - | 2 | - | - | - | 2 | 0.01 | 0.3 |
| *Aplysia* sp | 1 | - | - | - | - | - | - | 1 | 0.00 | 0.1 |
| *Heptacarpus brevirostris* | - | - | - | - | - | - | 1 | 1 | 0.00 | 0.1 |
| *Pugettia producta* | - | - | - | 1 | - | - | - | 1 | 0.00 | 0.1 |
| Number of individuals | 154 | 46 | 20 | 190 | 163 | 27,475 | 488 | 28,536 | | 4,077 |
| Number of species | 5 | 3 | 4 | 8 | 3 | 7 | 4 | 16 | | 5 |

Note: 0.00 = <0.005.