Fish Surveys at the Moss Landing Power Plant Outfall

A report submitted to the Monterey Bay National Marine Sanctuary
Sanctuary Integrated Monitoring Network (SIMoN)
and
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Executive Summary: During 2007 and 2008 a study of the fishes and other organisms associated with the Moss Landing Power Plant outfall was undertaken by Moss Landing Marine Laboratories as requested by the Sanctuary Integrated Monitoring Network (SIMoN) of the Monterey Bay National Marine Sanctuary. The purpose was to provide a brief but quantitative overview of the fish fauna potentially affected by the Moss Landing Power Plant (MLPP) discharge plume, both positively and negatively, to identify and inform future research to be conducted on this outfall. We focused on fishes in this study because the thermal impacts on plankton, benthic invertebrates that reside within the substrate (also known as benthos), and birds were addressed in a previous report (i.e., Oliver et al., 2006). The current study was not designed to determine the causal factors of any trends that were observed. Instead, this study used a variety of methods to characterize the abundance and species composition of fishes at the outfall during a short period, and to determine if there were any differences with sites nearby, whenever possible.

The fish assemblages were sampled by three methods: visual census from vessels above water, net tows through the water in the area of the plume itself, and diver surveys via SCUBA of the outfall region and the nearby jetty that acted as a site with comparable structure as a control. Other vertebrate megafauna were also recorded during the sampling periods as these organisms may interact with the fishes present and could serve as indicators of the presence of fishes.

Bat rays (*Myliobatis californicus*) and a variety of other vertebrate megafauna were observed during the visual surveys. Their behaviors, when it was possible to observe them, included resting, active foraging, and swimming in the area. Birds and marine mammals were also observed in the area of the outfall plume; diving, actively foraging, or resting on the water.

Fishes were rarely captured in the midwater trawls, and jellyfish (medusae) made up most of the catch during the study. Pacific tomcod were captured on only one sample day and made up ~1% of the total catch. Fish schools were not observed using echo sounders (fish finders) either at or away from the outfall. The lack of pelagic fishes in midwater trawls at the outfall may be explained by extreme patchiness or a paucity of fishes in this nearshore, midwater habitat all along the coast. Given the transient nature of fish schools, and the shallow depth at which we were sampling (where the outfall lies), we expected fish catches to be low. The ubiquitous presence of jellies, readily observable from the surface, in nets and well away from the outfall site, further suggests pelagic fish catches may have been low because oceanographic conditions favored jellies and not fishes during the sample period.

SCUBA surveys revealed a number of fishes in and among the rock and cobble habitats, including juvenile and adult rockfishes, surfperches, sculpins, and greenlings. Benthic-associated fishes were observed more often at the outfall than at the jetty. Roughly two-thirds of the fish counted during the systematic survey were at the outfall site, which equates to a density estimate of 0.063 fishes/m^2 of habitat surveyed at the outfall, versus 0.036 fishes/m^2 of habitat surveyed at the jetty for all sample dates combined. We hypothesize that the structure of the outfall itself attracts fishes and the outfall has more structure than anything around for several meters. If the outfall were absent, the area would be simply a sandy bottom habitat.

Introduction

The Moss Landing Power Plant (MLPP) has a subtidal outfall that rests in about 10 m of water just offshore of Moss Landing Marine Laboratories (Figure 1). The outfall has been there since the 1960s. As a product of once-through cooling, warm water is discharged through this outfall into the surrounding waters of the bay. This plume is generally 2-4 degrees C above ambient surface water temperatures, based upon studies attempting to characterize the impacts of the power plant outfall on the immediate area (Tenera, 2000a,b). In a recent (2002-2005) study, Wagner and Welshmeyer (2006) characterized the bacterial and plankton communities within the MLPP outfall and surrounding discharge plume and found that the mean temperature of water immediately exiting the outfall was 22.3 °C, and dropped to 14.5 °C 100 m from the discharge site, which is essentially ambient.

Oliver et al. (2006) noted that, at high tide, the warm water discharge plume from the outfall is a distinct feature that can be detected from the air (Tenera, 2000 a,b). However, there are also measurable areas of warm water in the south and north sections of Moss Landing Harbor that are not the result of the outfall (Breaker and Broenkow, 1994). Furthermore, at low tide, all of these warm surface-water features are potentially masked by the extensive outflow of water from Elkhorn Slough into Monterey Bay, which often extends over a kilometer into the bay. A recent study funded by SIMoN noted that Elkhorn Slough and the discharge introduced similar thermal loadings to the surrounding environment, though the temperatures of the discharge plume were slightly more variable, experiencing temperatures up to ~6 °C warmer and ~4 °C cooler (Fischer, 2006). There are net up-canyon currents that pulse deeper, colder water into the same shallow region as the thermal discharge (Breaker and Broenkow, 1994). Within one day, the temperature around the canyon head, including the adjacent sand flats, can plummet from 15 to 9 °C from the surface to the sea floor in over 10 m of water. All of these variations are then subject to the effects of larger scale currents that sweep through the entire bay episodically during the year (Breaker and Broenkow, 1994). Thus, the thermal plume is subjected to mixing events tidally, seasonally, and episodically throughout the year (Tenera, 2000 a,b),

The warm water in this outfall is thought to potentially attract species such as the bat ray, *Myliobatis californica*, that may come to the outfall plume to forage on the prey items attracted to the plume, or for behavioral thermoregulation (Hopkins and Cech, 2003; Hoisington and Lowe, 2005; Matern et al., 2000; Vaudo and Lowe, 2006;). We speculate that other fish species may also be attracted by the increased temperatures, or by the physical structure for refuge, the presence of food items living within the structure, by nutrients carried within the discharge, or by the micro-scale oceanography caused by the discharge. The outfall provides a potential food source for benthic invertebrates, primarily anemones, which have grown on the structure itself and seem to thrive on the nutrient-rich water exiting the structure (authors' personal observations). The outfall itself is surrounded and supported by large cobble and boulders that form a three-dimensional structure in what would otherwise be a sandy-bottom habitat. Fishes are attracted to the presence of such structure, presumably for refuge (e.g., Anderson and Yoklavich, 2006). It is possible that the warm water may also deter fish species with a lower thermal preference, though the small area of the plume should make increased temperatures easy to avoid. In truth, while enigmatic species such as the bat ray have received some attention locally, nothing is known regarding the effects of the outfall on the local fish assemblage.

We focus on fishes in this study because the thermal impacts on plankton (Wagner and Welschmeyer, 2006), benthic intertidal invertebrates that reside near the plume (Oliver et al., 2006), and birds (Phillips et al., 2006) were addressed in previous reports. Our goal was to supplement the report by Oakden et al. (2006) and determine if there is an assemblage of fishes at the outfall that is different from the surrounding area.

Methods

During 2008, the fish assemblage at the outfall was sampled by three methods: visual census from vessels above water, net tows through the water in the area of the plume itself, and diver surveys via SCUBA of the outfall region. Additional diver surveys were made at the nearby jetty, which served as a site with comparable structure for comparison. These three sampling methods each have inherent biases (Hickford and Schiel, 1995; Perez-Matus et al., in review), yet these complementary methods should allow for the detection of patterns if they exist. Visual surveys, including those underwater using SCUBA, are useful for detecting less mobile organisms that would not swim up and be captured by a net, such as gobies or blennies. Visual surveys are also useful for observing species in areas the net cannot tow, such as directly within the outfall structure. Net tows are more useful for capturing rapidly-moving species in the water column that cannot be identified accurately from either surface observations or echo sounder traces. For example, specimens are important for identifying whether "silvery schooling fishes" are smelt (Osmeridae), silversides (Atherinidae) or herring (Clupeidae).

Surface Visual Surveys:

Fishes in the surficial outfall plume were observed using visual census methods in two ways. Fishes were observed daily through a telescope from a northwest facing location at the entrance of Moss Landing Marine Laboratories called "John Martin's Point of View." Fishes at the surface were also observed from a Boston Whaler while circling the outfall itself during the SCUBA surveys, and from the R/V John Martin during the net tows (see next section). A summary of sampling effort using each of these visual census methods is listed in Table 1. Note that the visual surveys from the Boston Whaler were performed at both the outfall and a control site (described in the SCUBA survey section below). Visual surveys were not similarly performed at the control site from the R/V John Martin as it would be considered a navigational hazard to block an active thoroughfare with this sized vessel. The control site is not clearly visible from John Martin's Point of View for comparable telescopic surveys. These methods are effective for only those fishes visible from the surface (i.e., schooling fishes, sharks, bat rays, ocean sunfish). We chose these coarse approaches for sampling the water column assemblage in an attempt to capture nomadic organisms hypothesized to be a part of the outfall assemblage and especially bat rays. We also observed vertebrate megafauna using this method under the assumption that they regularly interact with the fishes present and could serve as indicator species (i.e., harbor seals, California seal lions, marine birds that forage on fishes). The exact area of the plume is difficult to calculate because it varies depending upon the discharge rate and local oceanographic conditions. However, using the findings of Wagner and Welschmeyer (2006), we chose to observe an area within 30 m of the outfall structure with the expectation that this fully contained the potential area of effect in terms of the water outflow and the temperature effect.

Midwater Tows:

Fishes and other macrofauna present in the outfall plume and nearby waters were collected using a custom midwater trawl net towed by the R/V John Martin. To determine the most effective and safest use of this net, a small mapping project was funded separately by the SIMoN program and completed by the Habitat Center at Moss Landing Marine Labs using side scan sonar (Figure 2). Current maps of areas near the outfall lacked sufficient resolution, so the Habitat Center surveyed the area specifically around this structure (Figure 2), and produced a high-resolution map of the region (Figure 3). Additionally, we sought areas of similar depth, topography, and relief to serve as control sites that could be sampled via nets. However, no useful features were located within the region sampled by the Habitat Center (Figure 3). The resultant area sampled by net tows is in the area of the outfall only (Figure 4).

Three net tows were conducted per sample day, always in the morning, and always starting and ending at the same GPS positions as closely as can be approximated when at sea, such that they passed as close as possible (navigationally) to the region directly over the outfall (Figure 4). The net was towed at an average of 1-2 knots for ten minutes per tow in order to completely cover the potential area of effect. The net itself is a 16-ft midwater trawl with stretched mesh ranging from 3 inches near the opening to approximately one inch near the cod end, which was fitted with a one-quarter inch mesh liner (Figure 5). This method is effective for only those fishes that reside off the bottom. Net tows were conducted once or twice a month for a period of five months (Table 1). The catch data for fishes and invertebrates were expressed as total numbers per month and not densities as the actual volume of water filtered was not known. Sea surface temperature and tidal height varied among sample dates, as we could not control this variable due to boat availability (Table 2).

The boat is also equipped with a hydro-acoustic (echo-sounding) system that was used during the surveys to record information on fish schools beneath the boat. While this method cannot provide information on the composition of any fish school traces seen, it could be used to capture information regarding the frequency and abundance of schools visiting the sites. It could also provide a quantitative estimate of school-size, which can be difficult to assess accurately when underwater. Data obtained by the system, as well as environmental data recorded by the R/V John Martin Underway Data Acquisition System, were downloaded directly to a laptop for later analysis.

SCUBA Visual Surveys:

Fishes on or near the outfall structure were counted along three depth contours, 12, 9, and 6 m (40, 30, and 20 ft), during three separate SCUBA surveys (Table 1, Figure 4). A transect tape was extended for 20 m along the contour being sampled. Divers swam at a steady pace along the transect line, counting and recording fishes within 1 m above and 1 m on one side of the transect line (chosen randomly), switching sides of the transect line at the next depth contour. Data were recorded each meter, and included observations of substrate type, invertebrates, algae, and fishes, as well as fishes that were opportunistically spotted outside the transect area (treated separately due to haphazard sampling).

Lee Genz of the Moss Landing Power Plant provided estimated outfall discharge rates for days to weeks in advance of the sampling, depending upon the season and energy demand. Sampling occurred only during “low” flow days, as required by the Diving Safety Officer and the safety requirements of MLML. Samples were always conducted at or near the slack tide, when water is neither entering nor exiting nearby Elkhorn Slough, and when visibility tended to be most favorable (Table 3). This requirement determined the time of day that sampling could occur, based upon the seasonal tidal cycle, but is unlikely to influence the daytime fish assemblage observed by divers.

The bottom in this area is sandy, with little or no structural relief except for the outfall itself (Tenera, 2000), and it was quickly determined that transects over sand-habitat yielded no fishes. During some months storms and currents resulted in large-scale movement of the sand and some of the sample contours were subsequently buried. These were not sampled since the habitat had changed and no longer served as a comparison for the structure at the outfall.

The Moss Landing Jetty was chosen as a control site after extensive surveys of the region searching for areas with comparable structure (Figure 4). SCUBA surveys were conducted here on the same days as at the outfall site, using the same depth contours and counting protocols.

Note that surface visual surveys (see previous section) were conducted at the outfall and at the control site from the Boston Whaler used to deliver and tend to the divers.

Results

Surface Visual Surveys:

Bat rays and a variety of other vertebrate fauna were observed during the visual surveys. Additionally, a number of marine birds and mammals were observed (Table 4), and their behaviors, in the most general sense, ranged from resting to active foraging to swimming through the area (Table 5). The bat rays were not obviously foraging or resting at the site, but were swimming through and within the area of the plume. Species such as the Least Tern (*Sternula antillarum*), the Caspian Tern (*Hydroprogne caspia*), Heerman’s Gulls (*Larus heermanni*), Brown Pelicans (*Pelecanus occidentalis*), and Brandt’s Cormorants (*Phalacrocorax penicillatus*) were obviously foraging within the area of the plume. In the case of the terns, the fish prey were visible as these birds left the water and took flight with the prey in their mouths. However, no identification of the species of these fish prey was possible. Western Grebes (*Aechmophorus occidentalis*), Surf Scoters (*Melanitta perspicillata*) and one Common Murre (*Uria aalge*) were also observed.

In addition to fishes and sea birds, Southern Sea Otters (*Enhydra lutris nereis*) and one species of pinniped (the California Sea Lion, *Zalophus californianus*) were also occasionally observed

(Table 5). There is no direct evidence that they were feeding on any organisms, including fishes, at or near the outfall site.

Midwater Tows:

Fish were rarely captured in the midwater trawls (Table 6). Only on one occasion were fish (Pacific tomcod, *Microgadus proximus*, 2 juveniles < 10 cm) present in the net, making them about 1% of the total catch over the course of the survey. Fish schools also were not observed using the echo-sounding gear, either at or away from the outfall. That fish schools were never observed via the echo sounder on board the R/V John Martin indicates that schools are highly transient in this area.

Seven species of jellies were captured over the study period (Table 6), including the moon jelly (*Aurelia aurita*), the "egg-yolk" jelly, (*Phacellophora camtschatica*), the giant bell jelly (*Scrippsia pacifica*), the bell jelly (*Polyorchis penicillatus*), the purple-striped jelly, (*Chrysaora colorata*), the brown sea nettle (*Chrysaora fuscescens*), and unidentified "gooseberry" jellies.

SCUBA Visual Surveys:

SCUBA visual surveys noted a number of fishes in and among the rock and cobble habitats. A total of at least seven fish species was observed along transects at the outfall and north jetty (control) sites (Table 7), while 10 species were observed adjacent to the transects at the outfall and near the north jetty (Table 8). These included juvenile and adult rockfishes (Scorpaenidae: at least 4 species), 3 species of surfperches (Embiotocidae), 2 sculpins (Cottidae), and 2 greenlings (Hexagrammidae).

The majority of fish observations were at the outfall. The prominence of zero data in Table 7 prevents us from comparing the outfall with the control site using parametric statistics. Yet, the trends are fairly striking. Fishes were detected along the transects at the jetty (control) site only in September 2008 (Table 7). Thus, roughly two-thirds of the fish counted during the systematic survey were at the outfall site (Table 7), which equates to a density estimate of 0.063 fishes/m^2 of habitat surveyed at the outfall, versus 0.036 fishes/m^2 of habitat surveyed at the jetty for all sample dates combined.

The scarcity of fishes within the transect surveys (Table 7) suggests that the inclusion of observations from beyond the transect are informative (Table 8), even if not systematically collected. The distance from the transect line over which fishes could be observed depended upon visibility, and this varied among dive days. This makes comparison among days using Table 8 data tenuous, though we include mention of the overall trends here to gain some inference regarding potential differences between the two sites in terms of fish abundance.

Fishes were observed more often at the jetty site in the areas opportunistically sampled, which were adjacent to the transects (Table 8). Roughly twice as many fishes were observed adjacent to the transects when compared with the number of fishes counted on the transects at the jetty site. However, when fishes were observed at the jetty site, the outfall still tended to have the same or greater numbers of fishes, with twice the number of fishes at the outfall in September (Table 8).

Macroinvertebrates noted at the outfall, which may serve as food or shelter for fishes, included the anemones *Metridium senile*, *Urticina piscivora*, *Anthopleura sola*, *Anthopleura elegantissima*, and *Anthopleura xanthogrammica*; the seastars *Pisaster giganteus*, *Pisaster brevispinus*, and *P. ochraceus;* the tubeworm *Diopatra ornata*; mussels *Mytilus* spp.; and several sponge species. In addition, algal species at the outfall included the kelps *Desmarestia ligulata* and *Laminaria setchellii*, and a number of fleshy red algae species that could not be identified in the field. The jetty, in contrast, was dominated by snails (unknown species), anemones (*Anthopleura* spp.), kelp (*Desmarestia ligulata*, *Laminaria setchellii*, and *Macrocystis pyrifera*), fleshy red algae (unknown species), and surfgrass (*Phyllospadix scouleri*).

Discussion

This study clearly demonstrated that benthic, habitat-associated fishes were observed more often at the power plant outfall than at the jetty, as indicated by the SCUBA surveys. We have insufficient evidence to determine if these differences were biologically significant and attributable to the outfall itself. It seems likely, however, that fishes simply are attracted to structure, and the outfall has more structure than anything around for tens of meters (Figure 4). Prior to the construction of the outfall, this area was devoid of hard substrate. Once built, the outfall structure attracted mobile species and continues to act as suitable substrate for settling invertebrates and algae, which provide a positive feedback loop of sorts, in that these add further complexity and available biological structure to the artificial habitat. These fish species are often widely dispersed and their general movement patterns unlikely to be measurably affected by the placement of the small outfall structure.

The lack of fishes captured via the net tows should not be viewed as evidence for a negative impact of the outfall plume on the water column fish community. The presence of foraging birds within the area of the plume suggests that pelagic fishes, as prey for these seabirds, do enter the plume, and birds are undeterred from entering the area to search for and capture these fishes. Schooling fishes have been episodically observed in the plume by divers (S. Lonhart, SIMoN, pers comm.). While our tows were conducted during times when it was reasonable to assume these fish might have been present (i.e., we do not suspect experimental bias or other artifacts for the absence of fish), there are multiple reasons why they might not have appeared in our nets. First, the species targeted by such tows are inherently mobile and transient in nature. The probability of capturing such fish is always much lower than the probability of observing benthic-associated fishes via SCBUA. Second, the shallow depth at which we were sampling (where the outfall is located) is inherently more difficult for capturing fish because very short tows are required to prevent the gear from entanglement on the bottom or on the outfall structure itself. Shorter tows inherently decrease the probability of capturing fish. And, third, there was a prevalence of jellies during the sample period, which may have reduced the overall abundance of fishes available for capture, and further compounding problems one and two listed here.

The abundance of jellies both in our nets and in the surrounding area, clearly visible from the surface, may suggest this was a "jelly season" in terms of oceanographic conditions favoring the growth and production of certain organisms (Shenker ,1984; Breaker and Broenkow, 1994;

Chavez, 1996; Purcell, 2005). The phenomenon of a "jelly season" occurs when favorable winds, light levels, temperatures, salinities, upwelling events, tidal cycles, and ocean surface currents provide jellies the opportunity to increase their reproduction and to aggregate in large clusters along the coastline (Shenker, 1984; Graham et al., 2001). In Monterey Bay, these conditions seem to be sub-optimal for fishes that rely on upwelling to provide nutrients for feeding larvae recently released into the water column. It has been suggested that particularly during years or seasons in which upwelling is delayed, as in 2008, jellies thrive because they are the only species that can flourish (J. Harvey, MLML, pers. comm.). Local retention factors such as tidal cycles between an estuary and ocean allow jellies to remain in a concentrated area along the nearshore coastline (Wang et al. 1995). An upwelling shadow in the northern part of Monterey Bay also acts to retain jellies in a concentrated area, thus being able to maximize their food consumption in these locations (Graham et al., 1992, Graham and Largier, 1997).

We did observe the charismatic fish fauna often associated with the warm water plume, such as the bat ray, during the study period. It has been hypothesized that the bat ray uses the warmer waters either to locate food that is flourishing there, or to rest and digest food consumed at another location (Mattern et al., 2000; Oakden, 2006). Because bat rays are ectothermic (meaning they derive their body temperature from the surrounding waters), moving to warmer waters serves to enhance the efficiency of digestion as well as muscle activity (Mattern et al., 2000). A similar behavioral pattern has been suggested for other elasmobranchs at other locations, such as the leopard shark (Hopkins and Cech, 2002), and the round stingray (Hoisigton and Lowe, 2005). These charismatic fauna have been observed at the outfall on and off for many years (Oakden, 2006), but not in any sort of consistent way that would make their absence during the study alarming.

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Tables and Figures

Table 1. Sampling effort to assess fish assemblages at the Moss Landing Power Plant outfall. Sampling occurred November 2007 through September 2008. Methods included were visual observations of the surface of the outfall plume from three observation points: John Martin's Point of View, which is a west-facing point at MLML (Land); from aboard the R/V John Martin during midwater trawls (Martin); and during diver transects (Diver). Frequency of midwater tows aboard the R/V John Martin and SCUBA transects at the outfall and the control sites are also shown. X denotes sampling was conducted during a particular month. The frequency of sampling is as indicated by the footnotes.

Date: / Sample Method:	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Visual: Land	X[A]	X[B]	X[B]	X[B]	X[A]	X[A]	X[A]		X[A]	X[A]	X[A]
Visual: Martin					X[C]	X[B]	X[B]	X[B]	X[B]	X[C]	
Visual: Diver	X[B]				X[C]				X[C]		X[C]
Midwater Tows						X[B]	X[B]	X[B]	X[B]	X[C]	
SCUBA Transects					X[C]				X[C]		X[C]

[A] daily
[B] twice-monthly
[C] monthly

Table 2. Midwater trawl dates, duration and oceanographic description for tows at the outfall. Included is discharge flow rates at the outfall, SST during the transect, and tidal information.

	Sample Duration		Outfall Flow[1]	Sea Surface Temperature (°C)[2]			Tides[3]		
Date	Start	End	Rate (MGD)l	Ambient	Max.	Difference	Time of High Tide	Height (m) of High Tide	Direction during sampling
4/9/2008	9:15	10:35	791.4	11.00	12.00	1.00	14:57	1.18	incoming
4/24/2008	8:42	9:42	168.5	10.82	11.90	1.07	15:19	1.05	slack/incoming
5/15/2008	8:35	9:27	1043.7	11.27	11.44	0.19	8:34	1.08	slack/outgoing
5/30/2008	8:29	9:18	239.4	12.02	12.99	0.97	7:38	1.02	outgoing
6/12/2008	9:03	9:53	513.5	17.37	17.43	0.063	7:09	1.52	outgoing
6/25/2008	8:37	9:14	314.9	13.73	14.80	1.08	3:11	1.14	outgoing
7/7/2008	10:42	11:20	1166.2	14.25	14.58	0.32	15:26	1.46	incoming
7/29/2008	8:40	9:28	345.3	14.95	15.15	0.20	10:04	1.20	incoming
8/14/2008	11:18	12:03	1,223.4	14.35	15.53	1.19	11:02	1.25	slack/outgoing

[1] Flow rates include all four operating units combined in millions of gallons per day (MGD) as reported to us by MLPP (courtesy of Lee Genz, MLPP). These are actual rates, provided after the fact, as opposed to predicted rates.

[2] Sea surface temperature (SST) was recorded from the R/V John Martin Underway Data Acquisition System. SST was recorded every 5-10 seconds from the start of the first tow through the end of the third and final tow. Ambient is the temperature at the start of each tow, averaged across the three tows per sample date. Maximum is the highest temperature recorded during each tow, which is the temperature in the plume, averaged across the three tows per sample date.

[3] Tidal data from Highway 1 Bridge at entrance to Elkhorn Slough (using the XTide program courtesy of the Monterey Bay Aquarium Research Institute).

Table 3. SCUBA survey dates, duration and oceanographic description for dives at the outfall and the Moss Landing Harbor Jetty control sites. Included is discharge flow rates at the outfall, SST during the transect, and tidal information.

	Outfall Dive Duration		Control Site Dive Duration		Outfall Flow	Tides[2]		
Date	Time In	Time Out	Time In	Time Out	Rate (MGD)	Time of High Tide	Height (m) of High Tide	Direction of Tide during Sampling
3/5/2008	10:24	11:05	9:05	9:45	359.4	8:23	1.58	high, outgoing
7/23/2008	14:20	14:54	15:20	15:50	791.4	15:08	1.49	high, incoming
9/29/2008	10:39	11:12	11:37	12:05	698.7	11:09	1.58	high, incoming

[1] Flow rates include all four operating units combined in millions of gallons per day (MGD) as reported to us by MLPP (courtesy of Lee Genz, MLPP). These are actual rates, provided after the fact, as opposed to predicted rates provided for use in determining safe dive conditions. Dives were not performed during summer months because flow was always high, in response to electricity demand.

[2] Tidal data from Highway 1 Bridge at entrance to Elkhorn Slough (using the XTide program courtesy of the Monterey Bay Aquarium Research Institute).

Table 4. Total number of vertebrate megafauna counted during visual observations of the Moss Landing Power Plant outfall site from three observation points: 1) John Martin's Point of View, which is a west-facing point at MLML (Land); 2) aboard the R/V John Martin during midwater trawls (R/V Martin), and 3) during transects using a Boston whaler (Whaler). Animals were also observed at both the outfall and at the control site using the Whaler.

	Outfall			Control
Species	Land	R/V Martin	Whaler	Whaler
Southern Sea Otter (*Enhydra lutris nereis*)		8		
Western Grebe (*Aechmophorus occidentalis*)		11		
Brandt's Cormorant (*Phalacrocorax penicillatus*)	2	14	4	
California Sea Lion (*Zalophus californianus*)		20	4	1
Brown Pelican (*Pelecanus occidentalis*)		1	2	
Heerman's Gull (*Larus heermanni*)		3		
Bat ray (*Myliobatis californica*)	6		15	
Surf Scoter (*Melanitta perspicillata*)		5		
Least Tern (*Sternula antillarum*)	1		2	
Caspian Tern (*Hydroprogne caspia*)			7	
Common Murre (*Uria aalge*)			1	
Total:	**9**	**62**	**35**	**1**

Table 5. Most common activities of vertebrate megafauna observed at the Moss Landing Power Plant outfall site. Locations are as in previous tables.

Species	Land	R/V Martin	Whaler
Southern Sea Otter (*Enhydra lutris nereis*)		drifting by	
Western Grebe (*Aechmophorus occidentalis*)		floating by	
Brandt's Cormorant (*Phalacrocorax penicillatus*)	feeding	feeding	feeding
California Sea Lion (*Zalophus californianus*)		swimming	swimming
Brown Pelican (*Pelecanus occidentalis*)		flying/diving	
Heerman's Gull (*Larus heermanni*)		flying/diving	
Bat ray (*Myliobatis californica*)		swimming at surface	
Surf Scoter (*Melanitta perspicillata*)		floating	
Least Tern (*Sternula antillarum*)	catching fish		diving/catching fish
Caspian Tern (*Hydroprogne caspia*)			catching fish
Common Murre (*Uria aalge*)			floating by

Table 6. Species captured via midwater trawls off the R/V John Martin. Numbers are the totals captured for those tows in that month.

Species	April	May	June	July	Aug.	**Total**
Moon jelly (*Aurelia aurita*)		92			2	**94**
Egg yolk jelly (*Phacellophora camtschatica*)				2	1	**3**
Giant bell jelly (*Scrippsia pacifica*)	32	8	16	4		**60**
Bell jelly (*Polyorchis penicillatus*)	3					**3**
Purple-striped jelly (*Chrysaora colorata*)				1		**1**
Sea nettle (*Chrysaora fuscescens*)		2			1	**3**
Gooseberries (unidentified species)		9	1			**10**
Pacific tomcod (*Microgadus proximus*)*					2	**2**
Total	**35**	**111**	**17**	**7**	**6**	**176**

*These were the only fish caught throughout the midwater trawl sampling period.

Table 7. Total numbers of fishes observed by divers along transects at the Moss Landing Power Plant outfall site and the Moss Landing Harbor north jetty control site at depths of 12, 9, and 6 m (40, 30, and 20 ft, respectively). Not all depths were accessible on all dates due to sand movement and scour. Substrate types are denoted as in footnotes.

	March						July						September			
	Outfall			Control			Outfall			Control			Outfall		Control	
Species	12	9	6	12	9	6	12	9	6	12	9	6	9	6	9	6
Cabezon (*Scorpaenichthys marmoratus*)	2^{R}							1^{R}								
Sculpin (unidentified Cottid species)		$1^{R/C}$														
Kelp rockfish (*Sebastes atrovirens*)													2^{C}			
Juvenile KGB* rockfish (*Sebastes* spp.)													1^{C}		2^{R}	
Black surfperch (*Embiotoca jacksoni*)															3^{R}	
Kelp greenling (male) (*Hexagrammos decagrammus*)																1^{R}
Painted greenling (*Oxylebius pictus*)		$1^{R/C}$											1^{R}; 1^{C}			

Substrate types: ^{R} rock; ^{C} cobble; ^{S} sand

*At the juvenile stage these rockfishes are difficult to tell apart so they are denoted as KGB: Kelp (*S. atrovirens*), Gopher (*S. carnatus*), or Black (*S. melanops*).

Table 8. Total numbers of fishes observed adjacent to the transects (1 – 3 m off the transect) at the Moss Landing Power Plant outfall site and the Moss Landing Harbor north jetty control site at three different depths: 12, 9, and 6 m (40, 30, and 20 ft, respectively). Substrate types are denoted as in footnotes.

	March						July						September			
	Outfall			Control			Outfall			Control			Outfall		Control	
Species	12	9	6	12	9	6	12	9	6	12	9	6	9	6	9	6
Cabezon (*Scorpaenichthys marmoratus*)											1^{R}					
Sculpin (unidentified Cottid species)								1^{R}								
Black rockfish (*Sebastes melanops*)															1^{R}	
Rockfish (Unidentified adults) (*Sebastes* spp.)													5^{C}			
KGB* rockfish (Juveniles) (*Sebastes* spp.)													5^{C}; 5^{R}			
Striped surfperch (*Embiotoca lateralis*)											1^{R}					
Black surfperch (*Embiotoca jacksoni*)															3^{R}; 2^{R}	
Pile surfperch (*Damalichthys vacca*)															2^{R}	
Painted greenling (*Oxylebius pictus*)								1^{R}								
Lingcod (*Ophiodon elongatus*)													1^{R}			

Substrate types: ^{R} rock; ^{C} cobble; ^{S} sand

* KGB: Kelp (*S. atrovirens*), Gopher (*S. carnatus*), or Black (*S. melanops*).

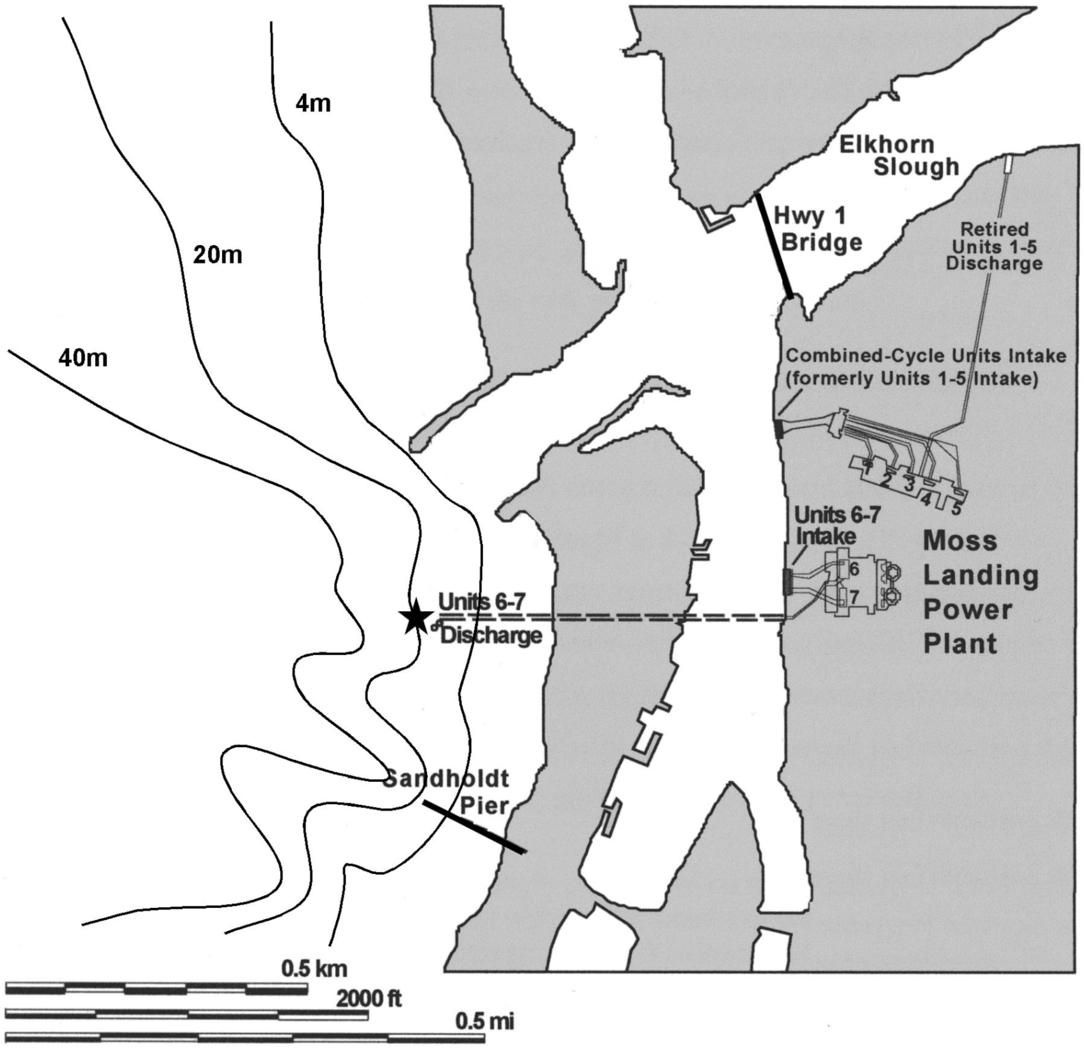

Figure 1. Map of the study site with Moss Landing Power Plant outfall depicted. Modified after Tenera (2000). Depth contours estimated from maps provided by the Seafloor Mapping Lab at California State University Monterey Bay. A filled star is placed *next to* the outfall location, so as not to occlude the actual location of the outfall on the map.

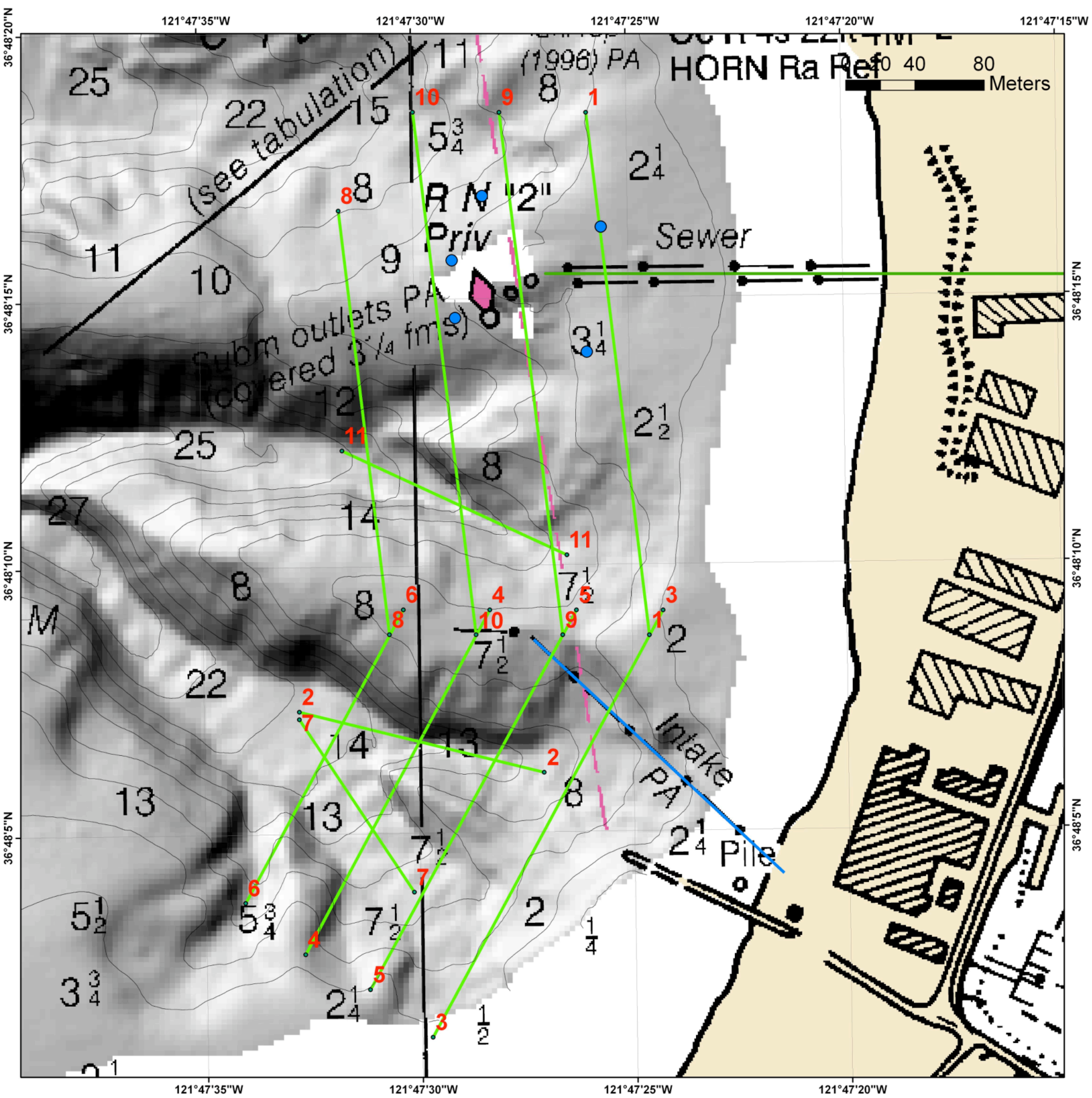

Figure 2. Side scan sonar survey tracks (in green) performed by the Habitat Center at Moss Landing Marine Labs. Depths are as noted in fathoms. The blue points near the outfall are reference points for placing the resultant higher-resolution map of the region into a spatial context (see Figure 3).

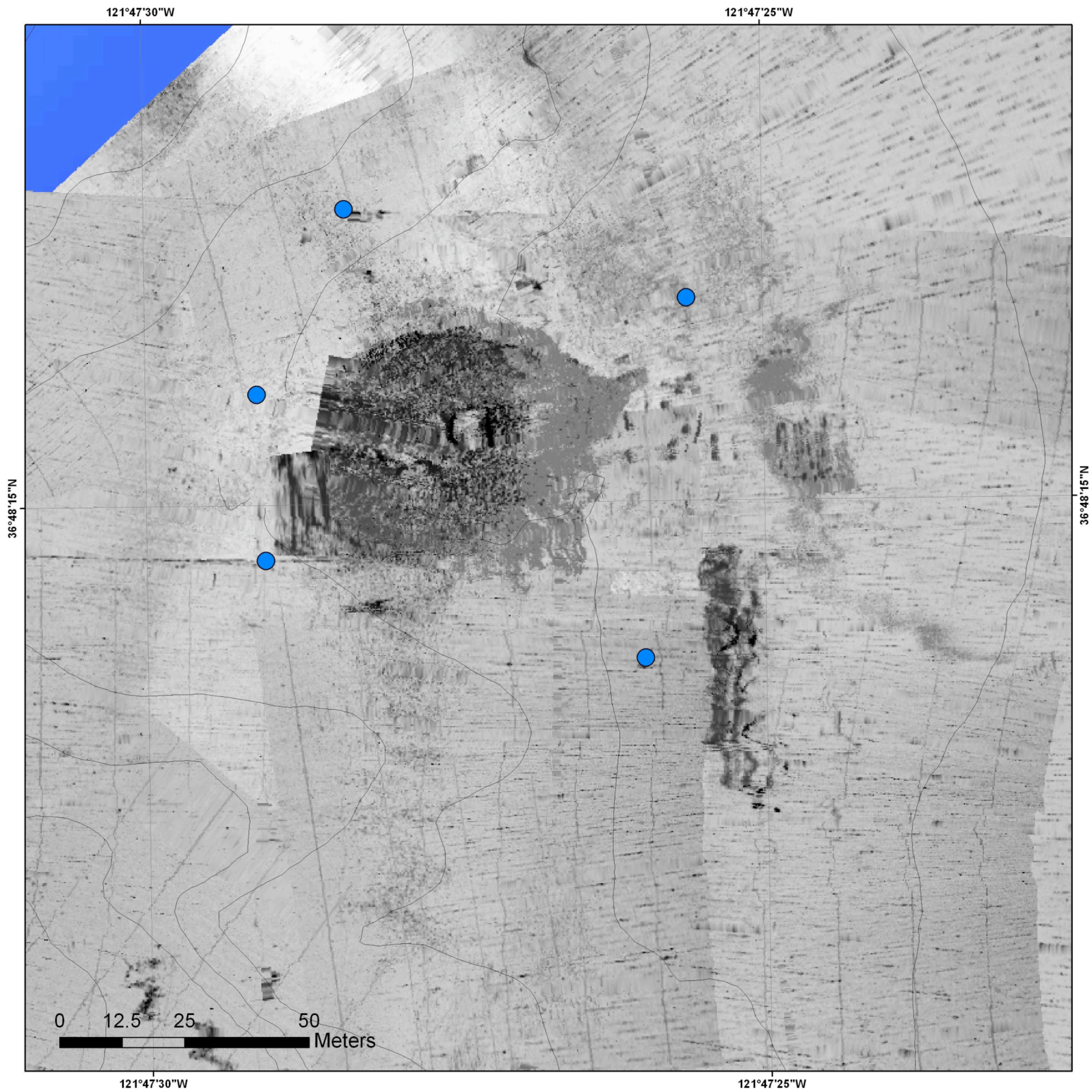

Figure 3. Higher-resolution image of the outfall area resulting from the side scan sonar study by the Habitat Center at Moss Landing Marine Labs. The blue points correspond to the blue points in Figure 2, and provide for the placement of the image into a larger spatial context.

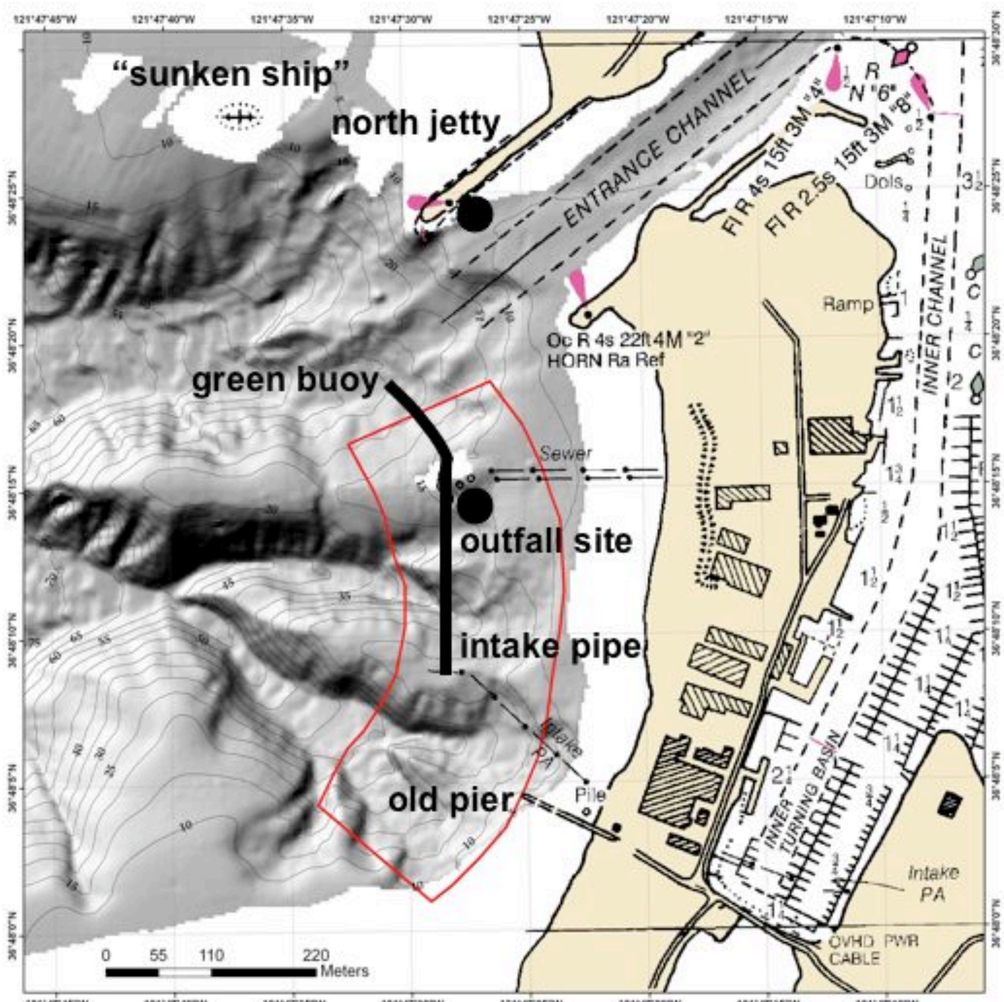

Figure 4. Midwater trawl survey route of the R/V John H. Martin, indicated by a thick black line. The net was deployed adjacent to the intake pipe, towed due west of the outfall site, and retrieved at the green buoy. The SCUBA survey sites are indicated as black circles. The control dive site is next to the Moss Landing Harbor North Jetty and the outfall dive site is at the end of the Moss Landing Power Plant outfall pipe. Also shown are scouted sites, the old pier and a "sunken ship," which were eliminated as suitable control sites based upon the lack of comparable structure as fish habitat.

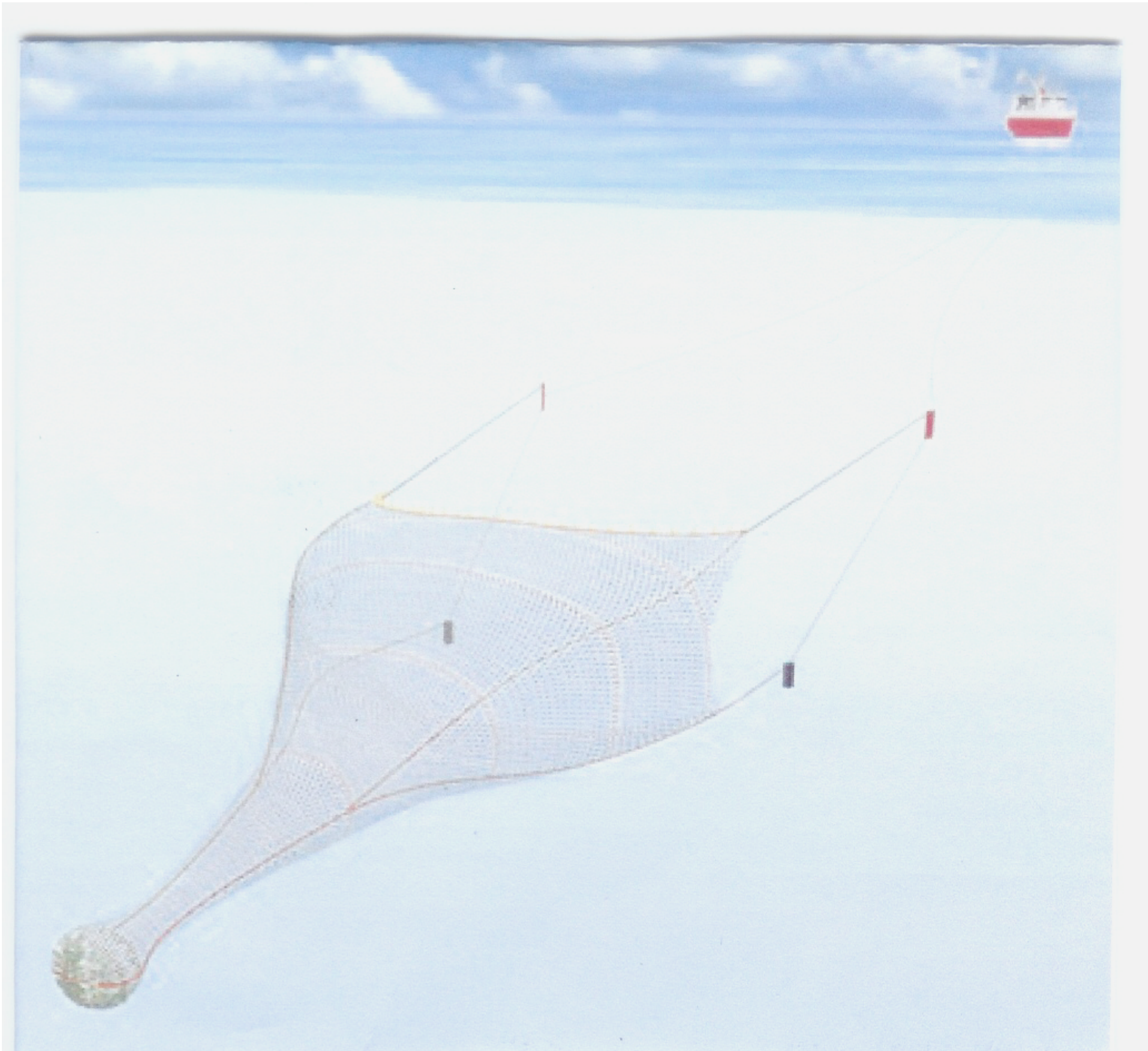

Figure 5. Midwater net used to sample schooling fish in front of the MLPP outfall. The bottom lines are weighted to keep the net open vertically, and the doors located at the junction of the paired lines on either side keep the net open horizontally. Image courtesy of Alba Net Builders