# CENTRAL COAST TRAWL IMPACT AND RECOVERY STUDY: 2009-2011 SUMMARY REPORT

(State Coastal Conservancy Grant #10-058 to TNC)

A Report to the California Ocean Protection Council
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*"This report was prepared for the California Ocean Protection Council under requirements of a grant and represents results to date from the first two years of a multi-year research study. All results are preliminary and no conclusions should be drawn at this point in the study; the contents of this report should not be quoted or cited out of context."*

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# Executive Summary

This report summarizes accomplishments and results for the period from June 1, 2009 to December 31, 2011, and covers Years 1 and 2 of a multi-year study to assess the impacts of bottom trawling on seafloor habitats and associated biological communities. The Central Coast Trawl Impact and Recovery (CCTIR) study is funded by the California Ocean Protection Council (OPC) through a State Coastal Conservancy grant (#10-058) to The Nature Conservancy (TNC) and by private funders. This is a collaborative research project conducted in unconsolidated, soft-sediment habitat on the continental shelf off of Morro Bay, California that has involved numerous federal, academic, NGO and fishing partners in the design and execution of the research.

The aim of this research project is to compare any changes in microtopographic complexity of the seafloor and associated species that is attributable to bottom trawling across a gradient of trawling effort on the continental shelf and to monitor the changes in seafloor communities' recovery post-trawling. The research questions that are being addressed by this study include:

- How does microtopographic complexity of the seafloor, invertebrate density and fish density differ between trawled plots and control plots over time in a depositional soft-sediment environment?
- How do spatial and temporal patterns in seafloor community structure vary under different levels of trawling intensity?
- What is the catch of flatfish and bycatch of associated species using trawl gear in this soft-bottom habitat?

These questions are being addressed using a remotely operated vehicle (ROV) to survey fishes, epifaunal macroinvertebrates, and seafloor microhabitats; a modified Van Veen bottom grab sampler to sample infaunal invertebrates; and a 33 ft. small-footrope otter trawl to disturb the seafloor and to collect additional information on trawl-caught fishes. The experimental design for this project underwent extensive peer-review by the OPC science advisory team and external reviewers.

The study area was apportioned into eight treatment plots, each measuring 1000 m x 300 m at a water depth of approximately 170 m, over soft-bottom habitat on the continental shelf off Morro Bay, California. Four of the plots were selected to be trawled at specific levels of intensity (based on historical effort data), while the remaining four plots serve as non-trawled control plots against which changes in the trawled plots can be evaluated over time.

Pre-trawling baseline surveys were conducted in the fall of 2009. The first directed trawling treatment occurred in October 2009, with 'low-intensity' trawling equivalent to

two trawl passes over the entirety of each of the four trawl treatment study plots. In October 2010 the ‘high-intensity’ trawling treatment was conducted, with five trawl passes over the entirety of each trawl treatment plot. Post-trawling surveys to assess impacts and recovery occurred at two-weeks, six months, and one year after each of the directed trawling efforts. A final survey to complete Year 3 of the study is planned for May 2012, approximately one and one-half years post-high-intensity trawling.

Analyses of project data are on-going pending the completion of the final research cruise.  In this report we present the results of our analyses *to-date*, which offer preliminary insights into the ecological effects of bottom trawling activity on the structural attributes of habitat in unconsolidated sediments of the outer continental shelf. These are initial results and no conclusions should be drawn at this point in the study, however the primary results thus far include,

- *Both low- and high-intensity bottom trawling reduced microtopographic complexity of the seafloor.*

  We quantified a small, but persistent, difference between control and trawled study plots with respect to the percentage of the seafloor that was ‘bioturbated,’ the primary source of microtopographic complexity in unconsolidated sediments.

- *Significant spatiotemporal variation in macro-faunal invertebrate densities.*

  We found that densities of both sessile and mobile invertebrates varied considerably across the study plots and between study periods. This suggests that any effect on epifaunal invertebrate communities that is attributable to low- or high-intensity bottom trawling must be considered in the context of significant background environmental variation.  Potential effects of the trawling treatments on invertebrates groups are still being analyzed.

- *Significant spatiotemporal variation in demersal fishes*

  We found that while community composition remained fairly constant over the entire study period, there was considerable seasonal and inter-annual variability in the demersal fish community with respect to abundance and spatial distribution across the study plots and between study periods.

- *No difference in the composition of infaunal invertebrates*

  We found that species diversity in the infaunal community was low relative to other locations along the continental shelf at similar depths, and that diversity did not vary significantly between trawled and control plots immediately following low-intensity trawling.

- *An aperiodic ‘event’ may confound results for recovery following high-intensity trawling*

  We observed that the trawl door scour marks visible in November 2010, immediately after the high-intensity trawling in October 2010, were no longer visible in May 2011 and there was a noted decline in abundance of mobile invertebrates. This was in stark contrast to the persistence over a full year of the low-intensity trawl scour marks in year 1 of the study. We have hypothesized that some kind of large scale (across the whole study site or larger) event may have smoothed out the seafloor sediments.

- *Unique research partnership advancing discourse on fisheries management*

  One of the great benefits of this project has been the collaborative partnership that has evolved among diverse stakeholders interested in moving toward a more quantitative evaluation of the impacts of bottom trawling on seafloor communities and a greater understanding of ecosystem dynamics and resilience to inform fishery management.

Analysis of project results will be on-going through the end of 2012.

# Introduction

Bottom trawling – where weighted nets and heavy door-spreaders are dragged across the seafloor - has been identified as a key threat to seafloor habitats. Based on limited evidence, it is thought that soft-bottom habitats tend to recover more quickly than rocky habitat s (see National Research Council [NRC] 2002); however, relatively little is known about the nature of the impacts of trawling on soft-botttom seafloor communities. Currently, flatfish — which are an important component of the groundfish fishery in central California — can be caught in commercially-viable quantities only using bottom trawl gear. Understanding the impact of trawl gear on soft-bottom habitats and the time it takes those communities to recover will help us determine the most appropriate locations for bottom trawling in the “working seascape” to minimize adverse impacts on seafloor habitats, while allowing the catch of economically important fish.

Our current understanding of bottom trawling impacts to soft sediment environments is limited both by the small number of studies in these habitats and by the lack of precise estimates of fishing effort applied to the areas being studied (Collie et al 1997; Schwinghamer et al 1998; Engel and Kvitek 1998; Watling and Norse, 1998; Collie et al 2000; Kaiser et al 2000; Lindholm et al. 2004). To-date there are only a few trawl impact studies from the U.S. West Coast (Engel and Kvitek 1998; Hixon and Tissot 2007; de Marignac et al., 2008; Lindholm et al. 2009). These studies, while instructive, have largely been snap-shots based on limited data collected post-trawling with little knowledge of the intensity of trawling effort and there continues to be a general paucity of relevant studies of this type on the U.S. west coast.

The Nature Conservancy (TNC) and the Institute for Applied Marine Ecology (IfAME) at California State University Monterey Bay (CSUMB), working with fishermen and other key partners, implemented a multi-year study to examine the impacts of bottom trawling on soft-bottom habitats, and the amount of time it takes for seafloor habitats to recover post-trawling. This collaborative research project is part of a larger Central Coast Groundfish Project, managed by TNC, that aims to help reform the groundfish fishery to improve the economical and environmental performance of the fishery. The goal of this collaborative research project is to inform best management practices and management decisions for bottom trawling in soft-bottom habitats along the continental shelf of California by quantifying impacts and recovery patterns after trawling.

Bottom trawling for groundfish occurs, or has occurred, on much of the continental shelf and upper slope area of the west coast over the last 80-100 years, with little information on impacts of that fishery to inform spatial management. Collecting data and information on the impacts of trawling on soft-bottom habitats, and the time it takes for seafloor communities to recover, will provide a foundation to advance spatial planning in the ocean and help reduce conflicts between conservation and fishing.

The continental shelf in California is dominated by soft-bottom habitats and very little is known about the background environmental variability or the impact of fishing gear on the habitats and associated species. One of the defining characteristics of this project is that we experimentally controlled the effort applied to the trawled study plots in partnership with local fishermen. The vast majority of studies worldwide, and all of the studies on the west coast (including studies by PI Lindholm in northern California), have been conducted without the ability to control this critical factor and have instead been forced to site their studies opportunistically in areas where specific quantitative data on trawling effort were not available.

The research questions addressed by this study include:

- How does microtopographic complexity of the seafloor, invertebrate density and fish density differ between trawled plots and control plots over time in a depositional soft-sediment environment?

- How do spatial and temporal patterns in seafloor community structure vary under different levels of trawling intensity?

- What is the catch of flatfish and bycatch of associated species using trawl gear in this soft-bottom habitat?

This research is funded by the California Ocean Protection Council (OPC), through a State Coastal Conservancy grant, two private foundations (Kabcenell Family Foundation and the Victoria Seaver Foundation), and through in-kind contributions of project partners. The study design has been reviewed by the California Ocean Science Trust team and an external review panel of scientists and gear experts who provided important input on the research. The project represents a broad collaborative partnership among non-profits, state and federal agencies, academia, and members of the fishing community. The research effort involves key staff and resources from:

- The Nature Conservancy (TNC): TNC is managing the research project and providing scientific design and support; funding and fund-raising; use of a federal trawl permit and trawl vessel; use of a remotely-operated vehicle (ROV); and contracting with partners. Dr. Mary Gleason, TNC's lead marine scientist in California and an expert on disturbance ecology, is a co-prinicipal investigator on this study. Steve Rienecke, a fishery biologist, assists with field operations and data analysis.
- Institute for Applied Marine Ecology (IfAME), California State University Monterey Bay (CSUMB): Dr. James Lindholm, Rote Distinguished Professor of Marine Science and Policy, is an expert on trawling impacts and has conducted similar studies on soft-bottom habitats elsewhere. He is co-principal investigator and leads on study design and analyses. Donna Kline assists with oversight of field operations, data collection, and analyses on all videographic and still photographic data.
- Marine Applied Research and Exploration (MARE): Dirk Rosen and staff are providing operational support for the ROV system and associated technology.
- Central Coast commercial fishermen: Several Central Coast fishermen are collaborating in the design of the study and implementation of the field research or

directed trawling including: the late Ed Ewing, Tim Maricich, David Wainscott, Gordon Fox, Michelle Leary, and Mark Tognazzini and their crew members.

- Monterey Bay National Marine Sanctuary (MBNMS): Dr. Andrew DeVogelaere and other staff from MBNMS are providing scientific input and coordinating use of NOAA resources (ship time, equipment, and crew) to support the research effort.
- National Marine Fisheries Service (NMFS): Dr. Elizabeth Clarke and other NMFS staff provided design and analytical advice, as well as analytical support for the project.

# Methods

**Study Site**: The study site is located on the outer-continental shelf in Estero Bay in a primarily soft-sediment, depositional environment approximately eight nautical miles offshore from the town of Morro Bay, California. This site was selected based on site-prospecting and baseline surveys conducted aboard NOAA’s RV *Fulmar* using the ROV in September 2008, and in consultation with some members of the commercial fishing community in Morro Bay. It was located in a relatively productive area just shoreward of the Rockfish Conservation Area and the shelf-slope break in an area that was historically trawled for flatfish (Petrale sole, Dover sole). Trawling has since ceased in the area and the experimental site has not been trawled since before 2000, based on conversations with staff at NMFS who have access to Vessel Monitoring System data, and local fishermen.

The study plots were situated at a depth of 160-170 meters and were located to avoid an area where a number of undersea cables were installed. The study site and eight study plots (each approximately 1 kilometer by 300 meters in size) are shown in Figure 1.

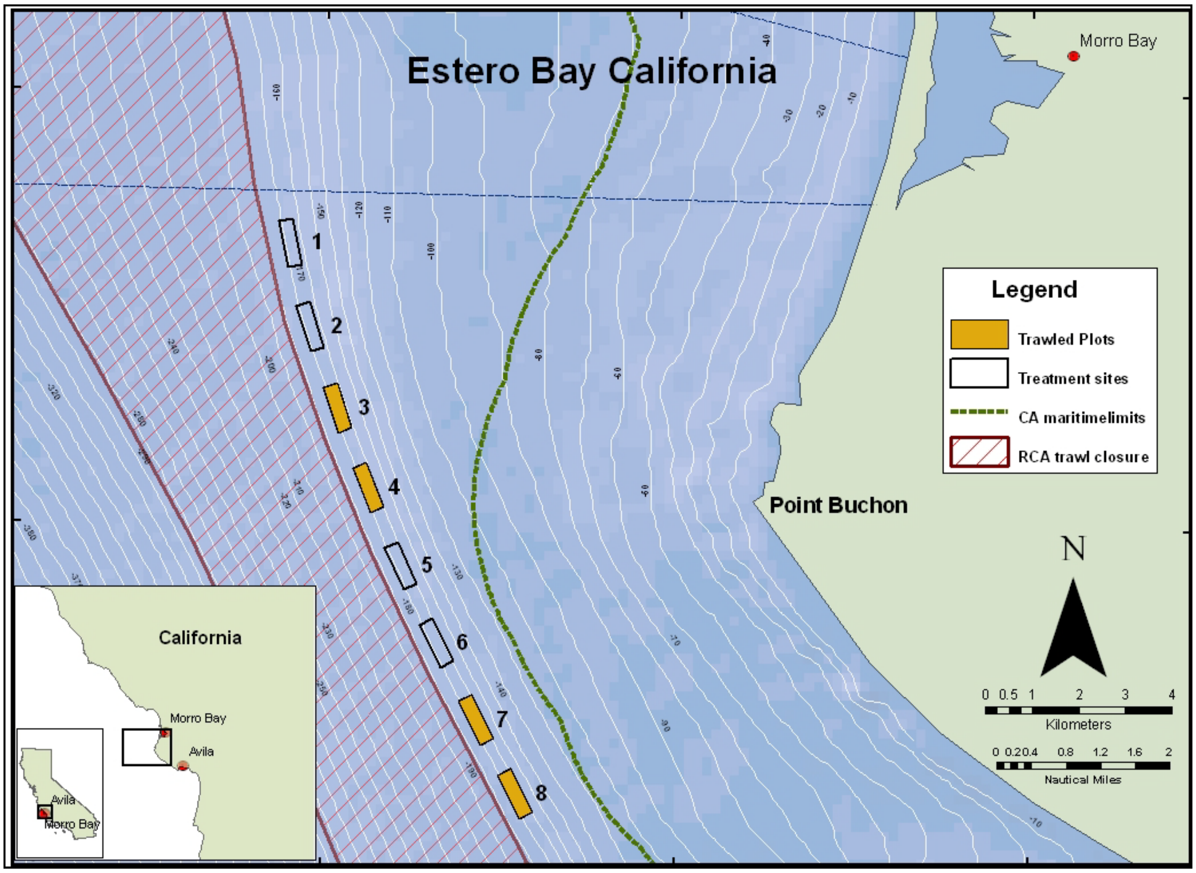

**Figure 1.** The study plots include four control plots (black outline) and four treatment plots (yellow filled) that were subjected to directed trawling of known intensity in October 2009 and 2010.

**Research Objectives**: The primary research objective of this project was to compare attributes of the seafloor and the associated faunal community across a gradient of bottom trawling effort, ranging from no recent trawling (control) to low-intensity trawling to higher intensity trawling. These seafloor attributes evaluated included 1) microtopographic complexity[1] of the seafloor, which can be reduced by trawling activity, and 2) the densities of associated fauna (both epifaunal and infaunal), which can be altered by trawling activity.

The study incorporated a “Before-After-Control-Impact” (BACI) design where monitoring was conducted before directed trawling, within 2-weeks after trawling, and 6-months and 1-year after trawling to provide a time series for assessing impacts and recovery relative to control plots.

The pre-trawling and post-trawling monitoring efforts utilized two primary sources of data (Figure 2):

- Visual surveys with a Remotely-Operated Vehicle (ROV) to capture video and still photo images
- Grab samples of benthic sediment and infauna

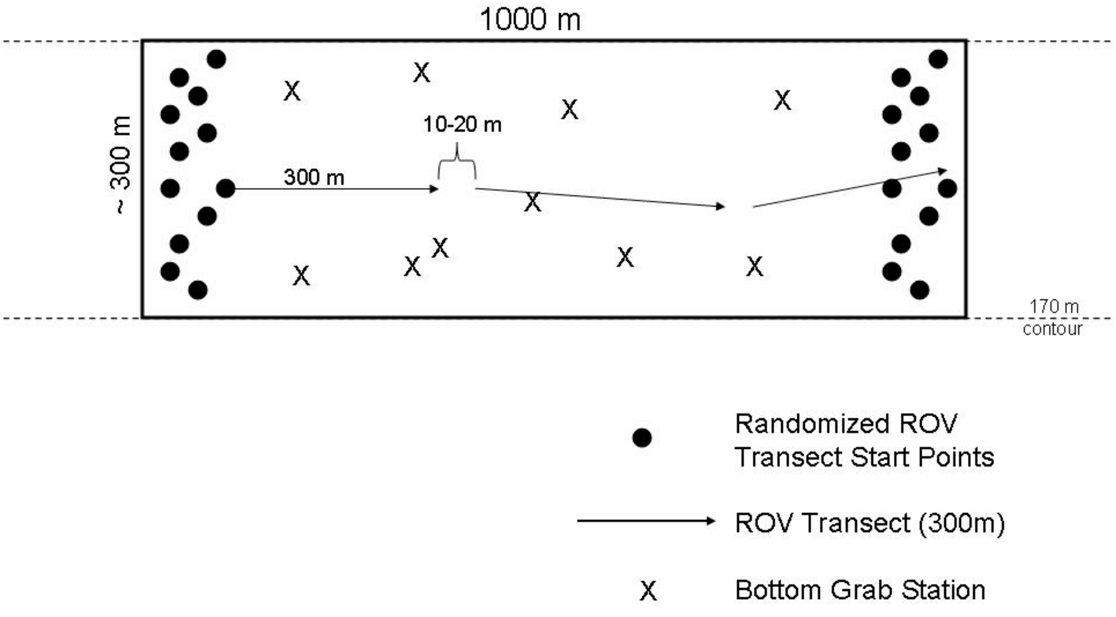

**Figure 2:** Idealized schematic of a study plot depicting 1) a set of randomized ROV transect start points, 2) a minimum of three ROV transects with 10-20 m separation between, and 3) randomized grab sample locations. The same scheme was used for both control and trawled plots.

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[1] Microtopographic complexity refers to both the physical substratum (e.g., sand waves), any associated structure-forming taxa (e.g., anemones, hydroids, sea whips, sea pens) and any biogenically-built structure (e.g., mounds and depressions). In addition to the organisms that form them, microhabitats are critical for a variety of fish species at different life history stages.

**Visual surveys with a Remotely Operated Vehicle:** The TNC ROV “Beagle” was configured with two video cameras (forward-oblique and down-looking), a down-looking digital still camera, two down-looking lasers for image calibration, and two forward-looking lasers for estimating size of organisms and data collection area. The ROV was equipped with an altimeter and was “flown” at an altitude of approximately 0.6 – 0.8 m above the seafloor.

Each ROV transect was ~300 m in length (20 minutes in time); this length was determined based on species and habitat accumulation curves plotted from data in soft sediment communities (Lindholm et al., 2004; Lindholm et al, 2009) and from a review of preliminary data collected at the study site in the Fall of 2008. Transects were begun at randomly selected starting points located at the northwest or southeast ends of each treatment plot and follow the isobath; the precise direction of each transect depended on local conditions (winds, currents, etc.) at the time of the dive. A minimum of three, and up to six, transects were flown in each study plot during each sampling period.

Each ROV transect consisted of continuous video and digital-still photographs recorded on DVD and digital tape. Each video transect was treated as a series of non-overlapping video frames (or quadrats). The size of a down-looking video frame at a height of 0.75 m from the seafloor was approximately 0.40 $m^2$. Still photographs were taken at approximately 1-minute intervals along each transect for a minimum of 20 photographs. Each still photograph covered an area of approximately 0.42 $m^2$. Paired parallel lasers (10-cm spacing) are used to indicate a consistent reference for still photographs (to maintain constancy in area of coverage for each image) and to size individual organisms where desired.

Still photographs from survey transects were used to assess:

- percent coverage of microtopographic complexity of the seafloor
- relative abundance and density of epifaunal macro-invertebrates
- relative abundance of benthic fishes

In selected cases, down video imagery was used to evaluate habitat attributes and/or organisms that were clearly visible on the video but that are not well-sampled by the still photographs.

**Microtopographic complexity of the seafloor:** We found the primary form of microtopographic complexity of the seafloor to be bioturbated sediments. Bioturbation in this context refers to changes in the plane of the sediment (including ridges, burrows, mounds and holes) created by the movement of organisms on (such as seastars and fishes) or through (such as mud urchins) the upper centimeters of the seafloor at the sediment-water interface. These small features resulting from bioturbation serve as habitat for small demersal fishes from a variety of species (including many flatfishes found in the study area). Video imagery and digital-still photographs were used to assess the spatial extent of bioturbation in each of the eight study plots. The percent area bioturbated was quantified for each still photo using a digitally rendered 5 cm grid that is superimposed over each photo.

***Epifaunal Macro-Invertebrates:*** Digital-still photographs were also used to assess the abundance and density of epifaunal invertebrate species (macro-invertebrates that live on top of the sediment and include both sessile and mobile species) in each study plot. Sessile, erect epifaunal organisms that extend above the plane of the seafloor (such as sea pens, sea whips, and anemones) provide habitat structure for fishes and mobile invertebrates. Counts (and ultimately densities) were made of each identifiable organism in a photograph (identified to the lowest taxonomic level possible).

***Fishes:*** Though this was primarily a study of fish habitat rather than of fishes themselves, we collected information on all fishes (i.e. flatfishes, eel pouts, rockfishes) observed in still photographs (and to some extent video imagery). Individuals of all observed fishes were identified to the lowest taxonomic level possible and were measured when the entire fish was present within the frame of the photo. Further, an IfAME-CSUMB undergraduate Honors Thesis is currently investigating the distribution of small fishes in the study plots relative to the percent of the sediment that has been bioturbated.

***Grab samples*****:** Protocols for the collection and analysis of seafloor sediment and infaunal invertebrate organisms using grab samples were developed based on similar studies conducted by PI Lindholm in northern California (de Marignac 2009) and the Gulf of Maine (Grannis 2001). Up to five bottom grab samples were collected using a 0.1 $m^2$ Van Veen bottom grab at randomly selected locations within each study plot using a Latin square design to achieve equal distribution across plots.

The grab sampling was conducted from a separate collaborative fishing vessel than the vessel used to support ROV surveys. Samples were live-sieved in the field through a 1.0-mm mesh screen and preserved in 10%-buffered formalin. All infaunal samples were transferred to 70% ethanol after returning to the laboratory, where animals were sorted from sample debris under a microscope and identified to the lowest taxonomic level possible. An additional sub-sample for grain-size analysis was removed from the homogenate and placed in a 500-mL plastic jar with lid and stored frozen. Infaunal invertebrate samples were collected from each grab and subsequently identified to the lowest taxonomic level possible.

***Directed trawling*****:** The directed bottom trawling was conducted by experienced trawl fishermen using a TNC-owned federal trawl permit and vessel (F/V *South Bay*). The trawl gear used was selected to represent the small-footrope trawl gear that was fished in the vicinity (Attachment A2).

The vessel made multiple passes over each trawled plot in a pattern analogous to ‘mowing the lawn’ (Figure 3). The four experimental trawled plots were first trawled at a low (2x) level of intensity in October 2009 and again at a high (5x) level of intensity in October 2010. These levels of trawl effort were determined based on meetings with NMFS staff and their review of historical trawl effort aggregated by fishing block along the Central Coast (Jan Mason, NMFS, personal communication). Our two trawling intensities (2x and 5x) were selected to reflect both the actual range of historical trawling effort in the vicinity and to capture the potential intensity of effort in the future. Due to logistical constraints we could not separate the two trawling intensities in space but only in time; thus the low-intensity trawling was conducted in Year 1 while the higher intensity trawling followed in Year 2 of the study.

The trawling effort was carefully monitored by project staff and a NOAA-trained Groundfish Observer to ensure accurate trawling inside the trawl treatment plots and to record trawl catch. All species caught were recorded and identified to the lowest taxonomic level possible.

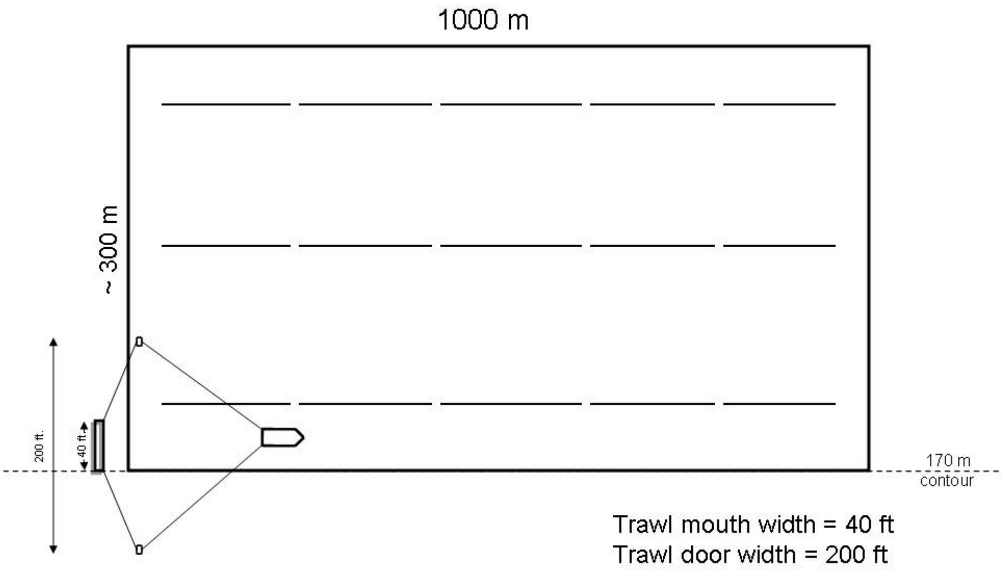


**Figure 3**. Idealized schematic depicting the planned distribution of bottom trawling effort across each of the eight study plots. Dotted lines represent the planned path of the bottom trawl based on the width of the footrope.

***Data Analyses*:** This study incorporated a “Before-After-Control-Impact” (BACI) design. Multiple measures were used to compare trawled and control plots to test for differences between metrics pre-trawling (before) and to track the trajectories of communities at each location over time following trawling at the two different intensities (after-control-impact).

***Please note that this report provides a summary of our analyses to-date and is not intended to serve as the final assessment of project data collected to-date***.

Ultimately, the goal of this project will be to evaluate impacts to species, seafloor communities and habitats under varying levels of trawling intensity and against a backdrop of natural environmental variation in the study area. To that end, we will employ standard community analyses such as multiple comparisons, principal components analyses, dominance plots, and clustering analysis to explore any changes in the study plots over time. These techniques extract series of interrelations between two or more related data sets, either by location or by time period. Differences between treatments, or within treatments but between years, are being tested statistically using ANOVA or ANCOVA and identified using SIMPER. Mixed effects modeling techniques are being used to test for relationships among species and/or physical structure and to quantify any effect of spatial autocorrelation on those relationships.

## Research Timeline

This study was designed as a four-year project. This report summarizes results from the first two years (through January 2012). Table 1 summarizes the research cruises conducted to date.

**Table 1.** Summary of research cruises completed to-date and a description of associated activities. ROV transects and benthic samples represent the number of unique samples, while trawl tows represents the total number of trawls necessary in each year to achieve the desired level of effort in each pair of trawled plots. Additional ROV transects (across the study plots) were added in May and September 2011 to investigate smoothing of the seafloor following an aperiodic event in the study area.

| Cruise | Vessel | Description | ROV transects | Benthic samples | Trawl tows | Notes |
|---|---|---|---|---|---|---|
| Sep '09 | Fulmar | Pre-trawling baseline ROV survey | 18 | | | |
| Sep '09 | Rita G | Pre-trawling baseline grab sampling | | 80 | | |
| Oct '09 | South Bay | Directed trawling (low-intensity) | | | 16 | |
| Nov '10 | Donna Kathleen | Immediate post-trawling (low-intensity) ROV survey | 46 | | | |
| Nov '10 | Bonnie Marietta | Immediate post-trawling (low-intensity) grab sampling | | 80 | | |
| May '10 | Donna Kathleen | 6-months post-trawling ROV survey | 48 | | | |
| Sep '10 | Fulmar | 1-year post-trawling ROV survey | 29 | | | |
| Sep '10 | Bonnie Marietta | 1-year post-trawling grab sampling | | 80 | | |
| Oct '10 | South Bay | Directed trawling (high-intensity) | | | 40 | |
| Nov '10 | Donna Kathleen | Immediate post-trawling (high-intensity) ROV survey | 48 | | | |
| May '11 | Donna Kathleen | 6-months post-trawling (high-intensity) ROV survey | 54 | | | **48 transects + 6 cross plots* |
| Sep '11 | Donna Kathleen | 1-year post-trawling (high-intensity) ROV survey | 60 | | | **48 transects + 12 cross plots and 4 exploratory transects* |
| Sep '11 | Bonnie Marietta | 1-year post-trawling (high-intensity) grab sampling | | 24 | | |
| May ‘12 | Donna Kathleen | 1.5-year post-trawling (high-intensity) ROV survey | TBD | | | |

# Results to Date

Here we provide a summary of our analyses *to-date* in an interim report for what is intended to be a multi-year study. While we do not expect the results presented here to change, it is important to note that 1) we have yet to complete many of the planned analyses that will explore the data in greater detail, and 2) only at the end of the study, with the entirety of data collected and analyzed, will the results from any particular year be placed in the context of the entire study to inform conclusions.

# Persistence of Trawl Tracks

**Figure 4.** Trawl door scour in one of the trawled plots as depicted in an ROV still photograph (left) and ROV sonar (right).

**Summary:** In Year 1, trawl door scour from the low-intensity trawling effort was clearly evident in ROV surveys conducted immediately after the directed trawling and persisted a full year until September 2010 (pictured above in an ROV still photograph (left) and in ROV-mounted sonar (right)).

In Year 2, similar trawl tracks were observed in November 2010 immediately following the high-intensity trawling treatment; however, by the May 2011 surveys six months later, no trawl door scour marks were visible in the video or sonar images from the ROV surveys. To confirm the absence of trawl door scour marks we conducted multiple additional ROV transects  perpendicular to the direction of trawling activities across the plots with the goal of increasing the chance of encountering door scour marks (Table 1). Though small-scale bioturbation continued to be evident, the larger-scale door scour marks were completely absent. We hypothesize that this smoothing over of the study site may have been caused by an as-yet-unidentified event sometime between November 2010 and May 2011 (identified as ‘event?’ in several figures below).

## Sediment Grain Size

**Summary:** Grab samples were collected across the eight study plots before the low-intensity trawling (September 2009) and one-year post low-intensity trawling (September 2010) to sample the sediment grain size and infauna (Table 1). Grain size analyses revealed that the bulk portion of all sediment samples could be categorized as coarse silt and/or fine sand. An overlay grain size distribution analysis was conducted using LS Coulter software to evaluate the average distribution of sediment per plot within a given sampling period. Analysis of pre-trawl samples indicated that all eight plots shared the same general curvature, including major peaks around 45 µm and 160 µm. Both the fine sand and silt fraction each account for 40-50% of the total volume, with about 5-10% of the sample consisting of clay.

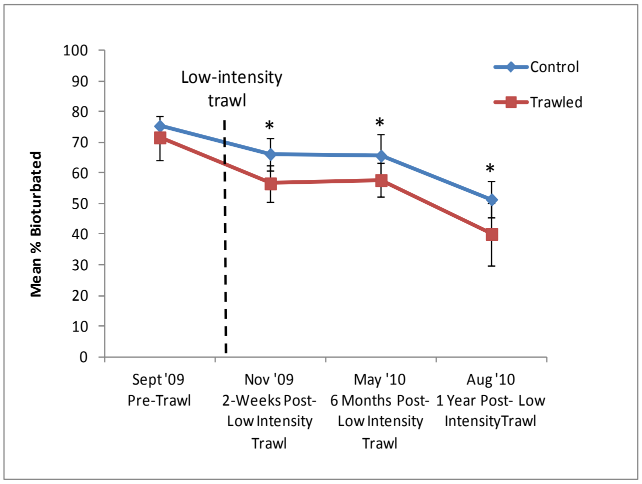
The post-trawl samples displayed the same major peaks as the pre-trawl samples at ~ 45 µm and 160 µm, although the post-trawl curves showed a slight increase in silt content, with an accompanying decrease of 2% in the fine sand fraction. No quantifiably significant sedimentary differences were recorded between the plots and sample periods. The average mean grain size per plot (ranging from 27 to 43 µm) indicated no visible differences between the pre-trawl samples and the post-trawl samples.

## Microtopographic Complexity of the Seafloor

**Summary:** Overall, the topographic relief in the study area was low, characterized by unconsolidated sediments in a depositional environment. However, a great deal of microtopographic complexity (at the scale of centimeters) was evident in the down-looking still photographs collected by the ROV. Due to the water depth at the study site (170 m) and presence of fauna, we attribute these small-scale features to the result of bioturbation in the area, created by a variety of organisms as they interact with the upper-centimeters of the sediment, rather than to bedforms formed by physical processes.

**Figure 5 - Bioturbation.** The most prominent features in the photo of bioturbated sediment is a trough in the sediment likely left by a burrowing heart urchin and numerous small holes created by burrowing organisms. Also note the head of a partially-buried flatfish in the upper left-hand corner of the image. The two red dots in the lower half of the image are the paired-lasers spaced 10 cm apart.

**Figure 6 - Low-Intensity Trawling.** The percent of the area bioturbated, as quantified from ROV still photographs, shows that control and trawled plots were similar immediately prior to trawling in Sep. '09. Post-trawl surveys indicated that control and trawled plots had diverged (* = $p < 0.05$) at two-weeks after trawling and that the difference between the two remained statistically significant at six-months and one-year post-trawling. It is interesting to note that while they diverged, both the control and trawled plots also experienced a decline in bioturbation over the course of the year.



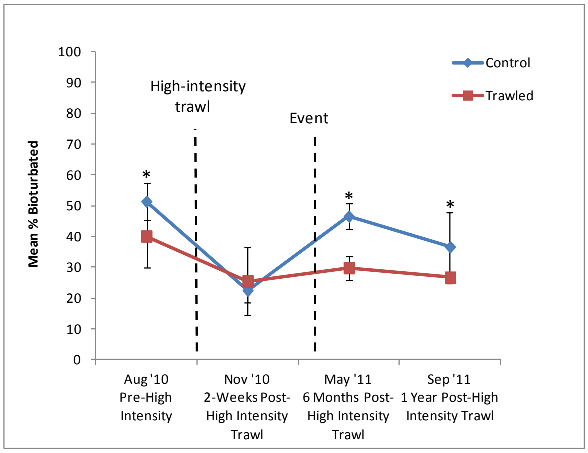


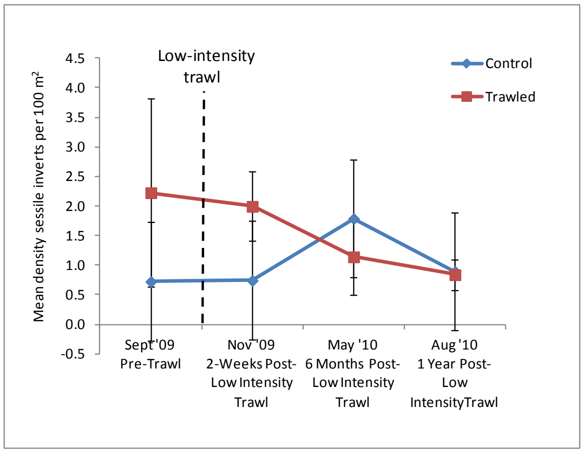
**Figure 7 - High-Intensity Trawling.** The percent-bioturbated sediment in the same study plots was quantified post-high-intensity trawling. Immediately post-high-intensity trawling, bioturbation in the control and trawled plots both declined precipitously, but did not differ from one another. At six-months post-trawl, the trawl and control plots had diverged significantly (* = $p < 0.05$). The plots converged at 1-year post trawling but remained significantly different.

## Sessile Epifaunal Macroinvertebrates

**Summary:** Sessile, erect macrofaunal invertebrates, defined here as organisms that are attached to, and extend above the plane of the seafloor (i.e. Sea whips, sea pens, anemones), provide important habitat structure for demersal fishes. In the study area, these organisms were neither diverse nor abundant (see the species list in Attachment A1). This was not unexpected as it is consistent with other research in similar habitats along the outer-continental shelf along the California coast.

**Figure 8 - Sessile inverts.** The down-looking still photograph to the left shows a sea pen as well as brittle star arms extending from the sediment. Note the flatfish in the lower portion of the image, as well as the presence of small polychaete worms on the sediment surface.

**Figure 9 - Low-Intensity Trawling**. The mean density per 100 m$^2$ for sessile epifaunal invertebrates was calculated for all trawled and control plots. Immediately prior to trawling the trawl and control plots were not significantly different from one another. Though the trajectories in the figure to the right suggest different patterns, we found no significant differences between control and trawled plots at two-weeks, six-months and one-year post-trawling.



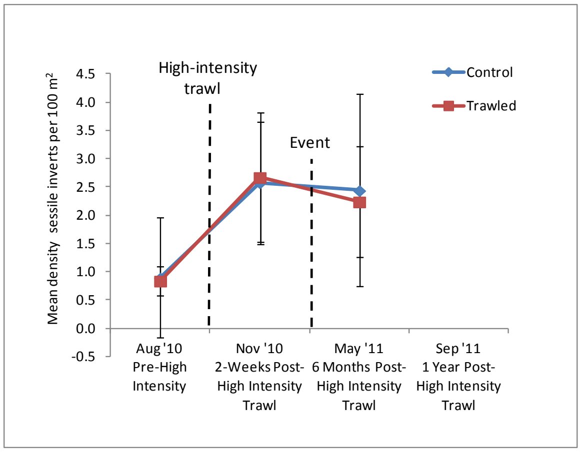


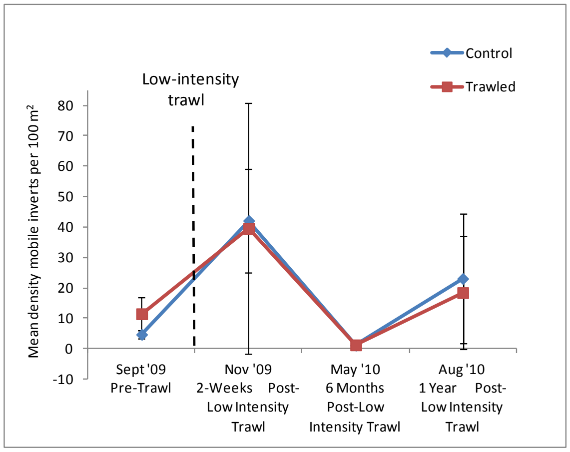
**Figure 10 - High-Intensity Trawling**. Density of sessile invertebrates in control and trawled plots were nearly identical immediately prior to the high-intensity trawling, and they remained similar (no significant difference) at two-weeks and six-months post-trawling. The data for one-year post-trawling are still being processed.

# Mobile Macro-Invertebrates

**Summary:** Mobile invertebrates observed *to-date* in the study area included a wide variety of echinoderms and molluscs, with smaller numbers of crustaceans and annelids (see species list in Attachment A1). Generally, the density of these organisms in the study area was low; however, there were very high densities of selected organisms (especially polychaete worms and brittlestars) that were patchily distributed in space and time. This was consistent with our observations of similar or related fauna at other locations along California's continental shelf.

**Figure 11 - Mobile invertebrates.** Though sea slugs (pictured left) and many larger invertebrates were recorded in the ROV still photographs and video, the polychaete worms, *Chloeia pinnata* (also pictured) were abundant in the study plots on multiple occasions over the course of four years of ROV surveys.

**Figure 12 - Low-Intensity Trawling.** Before the trawling treatment in September 2009, the density of mobile invertebrates was similar in control and trawled plots. In November 2009, immediately after low-intensity trawling, the mean density of mobile organisms increased dramatically, in both control and trawled plots, though no difference existed between the two treatments. The trajectories continued to be similar at six-months and one-year post-trawling, with no difference recorded between control and trawled plots.



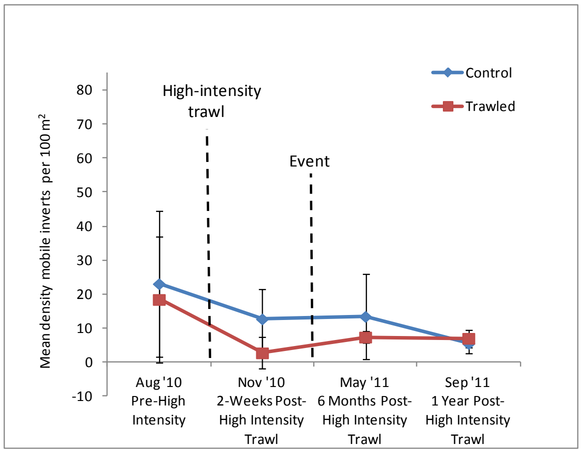


**Figure 13 - High-Intensity Trawling.** Patterns in the density of mobile invertebrates were also similar between control and trawled plots following the high-intensity trawling treatment. Overall, the variability in density was less extreme in Year 2 following high-intensity trawling, with densities declining over time in both control and trawled plots (though not significantly different).

## Infaunal Invertebrates

**Summary:** Benthic grab sampling for infaunal invertebrates was conducted before and after low-intensity trawling only. Results indicated that low-intensity trawling did not have an effect on the overall infaunal community.

Most crustaceans were identified to species level, and on average contributed to about 17-35% of the total number of individuals per infauna sample (Attachment A1). Polychaete worms were identified to family, genus, or species level as able, accounting for 50-70% of the total number of individuals per sample. Molluscs were identified to species level, and represented roughly 5-15% of the total number of individuals per sample. Echinoderms, Cnidarians, Sipunculids, Nemerteans, and other minority groups accounted for less than 5% of the total number of individuals, and were only identified to their major class or phylum in most cases. Polychaetes, crustaceans and molluscs together accounted for 97% of the total number of individuals collected from all samples, with crustaceans responsible for 22% of that total, polychaetes 65%, and mollusks 10%. The mean number of individuals per sample was ~237, with the most abundant sample containing 568 individuals, and the least abundant less than 93 individuals.

The most prolific polychaete species found throughout the samples included *Spiophanes berkeleyorum, Paraprionospio alata, Levinsenia gracilis, Cossura candida*, and *Chloeia pinnata*. The most abundant crustaceans included species such as *Protomedeia articulata, Photis* sp., *Euphilomedes producta, Diastylis* sp., *Eudorella pacifica, Gammaropsis ociosa, Metaphoxus frequens,* and *Pinnixa occidentalis* . The most frequently encountered mollusks in samples included the species *Tellina carpenteri, Rhabdus rectius, Gadila aberrans,* and *Yoldia seminuda*. One of the largest organisms found in this sample set was *Brisaster latifrons*, a burrowing heart urchin seen in all plots and on both grab sampling cruises. There were also a number of different holothuroid and ophiuroid species. Even though the abundance of echinoderms was relatively low, their contribution to the total biomass of the sample was over 50% when present.

## Demersal Fishes

To-date we have observed with the ROV or caught (with the trawl) a variety of fishes (primarily demersal) in the study area (Table 2). Analysis of fishes observed with the ROV are on-going and summaries not yet available.

**Table 2.** List of fishes encountered to-date in the study area either by ROV observation or trawl catch during directed trawling of the experimental study plots.

| Taxonomic group | Common name | *Genus species* | ROV | Trawl |
|---|---|---|---|---|
| Chondrichthyans | | | | |
| | Spotted ratfish | *Hydrolagus colliei* | X | X |
| | Torpedo ray | *Torpedo californica* | X | X |
| | Longnose skate | *Raja rhina* | X | X |
| | Big skate | *Raja binoculata* | | X |
| | Soupfin shark | *Galeorhinus galeus* | X | X |
| | Spiny dogfish | *Squalus acanthias* | X | X |
| Flatfish | | | | |
| | Dover sole | *Microstomous pacificus* | X | |
| | Petrale sole | *Eopsetta jordani* | X | X |
| | Slender sole | *Eopsetta exilis* | X | X |
| | English sole | *Parophrys vetulus* | X | X |
| | Rex sole | *Glyptocephalus zachirus* | X | X |
| | Pacific Sanddab | *Citharichthys sordidus* | X | X |
| | Curlfin sole (turbot) | *Pleuronichthys decurrens* | X | X |
| | Rock sole | *Lepidopsetta bilineatus* | | X |
| | Unk. Flatfish | | X | |
| Rockfish | | | | |
| | Striped tail rockfish | *Sebastes saxicola* | X | X |
| | Greenstriped rockfish | *Sebastes elongatus* | X | |
| | Splitnose rockfish | *Sebastes diploproa* | X | X |
| | Shortbelly rockfish | *Sebastes jordani* | X | X |
| | Chilipepper rockfish | *Sebastes goodei* | X | X |
| | Halfbanded rockfish | *Sebastes semicinctus* | X | X |
| | Blackgill rockfish | *Sebastes melanostomous* | X | |
| Other fishes | | | | |
| | Northern anchovy | *Engraulis mordax* | X | X |
| | Pacific hake | *Merluccius productus* | X | X |
| | Pacific hagfish | *Eptatretus stouti* | X | |
| | Sablefish | *Anoplopoma fimbria* | X | X |
| | Sculpin | *Icelinus sp.* | X | |
| | Bigfin eelpout | *Lycodes cortezianus* | X | |
| | Blackbelly eelpout | *Lycodes pacificus* | X | X |
| | Black eelpout | *Lycodes diapterus* | X | |
| | Bearded eelpout | *Lyconema barbatum* | X | |
| | Poacher | *Xeneretmus sp.* | X | |
| | Lingcod | *Ophiodon elongatus* | X | X |
| | Juv Lingcod | *Ophiodon elongatus* | X | X |
| | Prickleback, bluebarred | *Plectobranchus evides* | X | |
| | Plainfin midshipman | *Porichthys notatus* | X | X |
| | Cusk-eel, spotted | *Chilara taylori* | X | X |
| | Unk. Fish | | X | |

## Trawl Caught Fishes

Overall, the majority of the trawl catch from low-intensity trawling in October 2009 and high-intensity trawling in October 2010 consisted primarily of flatfishes both in terms of total number of organisms and percentage of weight caught (Figures 15 and 16 below). Roundfishes, elasmobranchs (skates and rays, sharks, and ratfish), and invertebrates also contributed substantially to the overall catch in terms of both numbers caught and weight. Other miscellaneous fish groups and rockfishes made up a minor portion of the catch. Flatfishes were most numerous, making up 43.5% of the overall catch, followed by roundfishes (lingcod and sablefish) at 20%, and all invertebrate groups combined at around 11%. The remainder of the other taxonomic groups made up <10% of total catch in terms of numbers caught. In terms of total weight, flatfishes dominated at 25.7%, followed by sharks, skates and rays, and invertebrates at 20%, 17.7%, and 15.4% respectively.

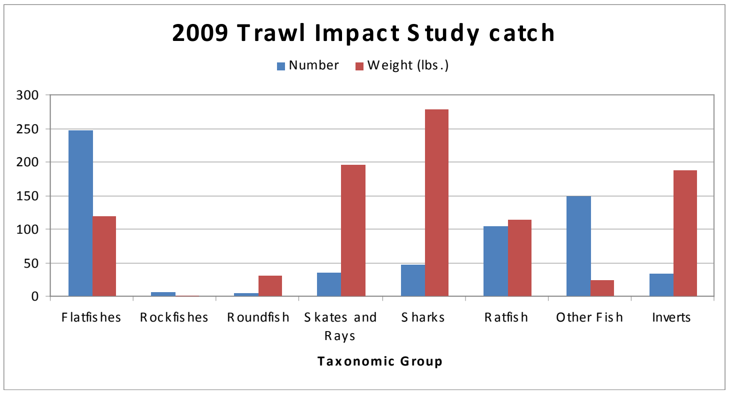


**Figure 14 - Low-Intensity Trawling.** In 2009 flatfishes, ratfish, and other miscellaneous fish groups made up most of the low-intensity trawl catch in terms of numbers caught (left). Northern anchovy (*Engraulis mordax*) was the species that contributed the highest number of fish in the miscellaneous fish group category at 118 caught.

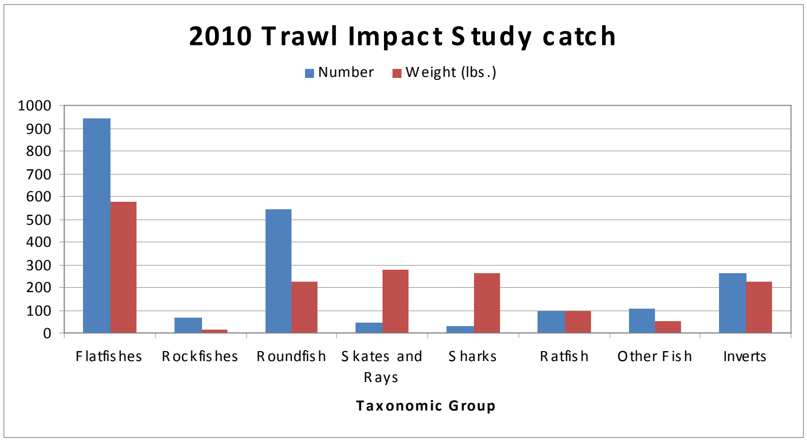


**Figure 15 - High-Intensity Trawling.** As in 2009, flatfishes were the most important taxonomic group caught in the high-intensity directed trawling in October 2010. Flatfish accounted for 44.7% of the total catch and 33% of the total weight. There were more roundfishes caught in 2010 in terms of both number of fish and weight, primarily due to a high percentage of juvenile sablefish. Ratfish and invertebrates were still important components of the catch, although fewer ratfish were caught in 2010. There were also three different species of rockfish in 2010 that were not caught in 2009, including bocaccio (*Sebastes paucispinis*), chilipepper (*S. goodei*), and shortbelly rockfish (*S. jordani*). All of these rockfishes were caught in small numbers.

# Discussion

The results of our study *to-date* offer interesting insights into the ecological effects of bottom trawling activity in the unconsolidated sediments of the outer continental shelf. Further, these interim results provide new insights into the considerable background environmental variation that is characteristic of the study area, highlighting the importance of a comprehensive analysis of all factors contributing to change in the biological communities on the deep seafloor. Here we provide some preliminary results; however, as noted previously, a more comprehensive analysis of the data is still underway and conclusions are not yet available.

### Low-Intensity and High-Intensity Trawling Reduced Micro-topographic Complexity on the Seafloor

Our results demonstrate a small but persistent difference between control and trawled study plots with respect to the percent of the seafloor that was bioturbated, a measure of micro-topographic complexity. The effect was present immediately following low-intensity trawling and had actually increased at one-year post-trawling. Similar results were recorded for high-intensity trawling, though the pattern of recovery differed somewhat (see discussion below).

However, it was also clear from the results that this effect needs to be explored in greater detail to fully-resolve the underlying explanation for any differences between trawled and control plots over time. This is important because in the relatively low-relief, sedimentary environments that characterize the majority of California's continental shelf, much of the complexity in the seafloor is the result of bioturbation. Bioturbated sediment, created as animals move around on the seafloor, is important for fishes and mobile epifaunal invertebrates in these low-relief environments as refugia from predators and bottom currents. Therefore, diminishment of bioturbated sediments, could ultimately contribute to population-level impacts on species, including some commercially-exploited fishes.

### Significant Spatiotemporal Variation in Macro-Faunal Invertebrate Densities

The results *to-date* indicate that any effect on epifaunal invertebrate communities that is attributable to low- or high-intensity bottom trawling must be considered in the context of significant background environmental variation. Small sessile invertebrates appeared to increase in density following trawling activities at both intensities, while larger sessile invertebrates (already at very low densities) appeared to decline or remain stable in the trawled plots. Mobile organisms, on the other hand, varied considerably over the course of the study, but did not differ significantly between control and trawled plots at either low- or high-intensity trawling intensities.

Our collective knowledge of the dynamics of organisms in and on the unconsolidated sediments of the outer continental shelf continues to be very limited, despite the fact unconsolidated sediments characterize upwards of 85% of the continental shelf in California. In this context, we expect the time series data on invertebrate communities (both sessile and mobile) that we are collecting as part of this project will ultimately enhance significantly our understanding of the ecology of organisms in unconsolidated sediments, including seasonal and inter-annual variability in the distribution of mobile and epibenthic invertebrates and fish, the patchiness of opportunistic organisms, and inter-annual variability in invertebrate community structure.

### Variability Present in Fish Community

An emergent property of our research *to-date* is the fact that, with a few exceptions, the ROV and the bottom trawl sampled the same fishes (see Table 1). Results to-date indicate that considerable seasonal and inter-annual variability was present in the demersal fish community with respect to abundance and spatial distribution, while community composition remained fairly constant.

### An Aperiodic 'Event' May Confound Results for Recovery Following High-intensity Trawling

We observed that the trawl door scour marks visible in November 2010, immediately after the high-intensity trawling in October 2010, were no longer visible in May 2011 and there was a noted decline in abundance of mobile invertebrates. This was in stark contrast to the persistence over a full year of the low-intensity trawl scour marks in year 1 of the study. We have hypothesized that some kind of large scale (across the whole study site or larger) event may have smoothed out the seafloor sediments. The precise nature of an aperiodic event that may have occurred in the study area between November 2010 and May 2011 will likely not be identified. There are a variety of potential explanations for the smoothing of the trawl door scour marks following the high-intensity trawling have been suggested including: strong tidal currents; a brief shoreward incursion of the California Countercurrent onto the outer continental shelf; deposition of dredge materials washed out from nearby Morro Bay; a massive gravity slide; or the tsunami resulting from the earthquake in Japan in March 2011. The absence of any oceanographic instrumentation off-shore in the study area precludes a definitive conclusion. However, circumstantial data can provide some insight into potential explanations for the bottom smoothing and relatively rapid disappearance of the trawl tracks in year 2.

Though we experienced strong currents along the seafloor when piloting the ROV on multiple occasions during each year of the study, the persistence of the trawl door scour marks from low-intensity trawling after one year suggests that the normal, mostly tidal, currents in the area are not generally sufficient to erode or bury the 10 cm deep features. Though the incursion of the Countercurrent onto the shelf has been observed far to the south of the study area along the shelf on Santa Monica Bay, there is no evidence that this has occurred as far north as our Estero Bay study site. While dredging of the harbor in Morro Bay did occur during our study period, we confirmed that the locations for the dumping of the dredge materials were several miles distant from our study site. Further, the uniform smoothing of the seafloor over our 11 km study area argues against dredge disposal or gravity slides, both of which would likely be much smaller in scope.

However, shallow-water instrumentation located in Morro Bay recorded a 2.5 m tidal wave with a 15-min period associated with the March 2011 earthquake and associated tsunami in Japan. Preliminary calculations suggest that the 2.5m tidal surge conditions could potentially have resulted in a current velocity of 30 cm/s along the bottom at our study sites. Given the grain size found at the study site, such a current could have been sufficient to erode or bury the trawl door scour marks. Analysis of this potential explanation is on-going.

Regardless of the potential explanation, the fact of the smoothing event has implications for interpretation of recovery patterns in the study area following the high-intensity trawling. We confirmed through video records that the trawl door scour was present immediately following the high-intensity trawling in October 2010, and as such, the two-week post-trawling survey is a reliable assessment of the immediate impacts of the trawling. However, the results of our analysis from May 2011 and beyond on the recovery post high-intensity trawling, are potentially confounded by the aperiodic event and it will be difficult to separate out that factor from what might be a more typical recovery pattern. As we move forward with the analysis of project data, we will be careful to place the results in the context of all potential impacts, be they anthropogenic or natural.

### Unique Research Partnership Advancing Discourse on Fisheries Management

Reform of ailing fisheries requires new, innovative models for collaboration among NGOs, scientists, regulatory agencies, and fishermen aimed at protecting ecosystems and the services they provide, including access to local, sustainable fishing opportunities (Gleason et al. 2009). One of the great benefits of this project has been the collaborative partnership that has evolved among diverse stakeholders interested in moving beyond rhetoric to a more quantitative evaluation of the impacts of bottom trawling on seafloor communities and a greater understanding of ecosystem dynamics and resilience. We have also conducted considerable outreach on this project to expand its reach (see Attachment A3) and aim to use the results to inform the ongoing dialog in the Central Coast on the role and contribution of bottom trawling to the fishery and appropriate spatial management measures.

# Next Steps

The results presented here represent our preliminary investigation of the project data to date, summarized by major categories of information. The next step in our on-going data analysis will be to further explore the data at finer scales, including

- A thorough analysis of General Linear Model results, including the significance, or lack thereof, between control and trawled plots, plots within each treatment over time, and the interaction of the two.
- A comparison of recovery trajectories following low- and high-intensity trawling for each of the metrics.
- A species-based analysis of selected invertebrates and fishes to clarify the more general patterns that we have observed.

The final research cruise of the CCTIR project funded by OPC is scheduled for early-May 2012. At that time we will be able to assess three years of study data (including data from two seasons – fall and late spring – each year) to assess the impacts of low and high-intensity trawling, recovery over one year after low-intensity trawling, and evaluate the potential confounding effect of the aperiodic event on assessing recovery post high-intensity trawling. Importantly, we will then have three years of data, with two seasons sampled per year (fall and late spring) to better understand the temporal dynamics of these communities to put the effects of trawling in a broader ecosystem context.

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## ATTACHMENT A1: List of Species Encountered *To-Date*

### *ROV Surveys*

| Invertebrates | | *Genus species* |
|---|---|---|
| Anthozoans | | |
| | Metridium | *Metridium farcimen* |
| | Burrowing anemone | *Family Halcampidae, unk sp.* |
| | Sandrose anemone | *Uticina sp.* |
| | Tube anemone | *Pachycerianthus fimbriatus* |
| | Fleshy sea pen | *Ptilosarcus gurneyi* |
| | Sea whip debris | *Possibly Disthoptilum gracilis* |
| | Red gorgonian | *Possibly Swiftia or Lophogorgia* |
| | Sea whip, live | *Halipteris sp??* |
| | White sea pen | *Stylatula or Virgularia sp.* |
| | Red sea pen | *Pennatula sp.?* |
| | Thin orange seapen | *Virgularia or Pennatula sp.* |
| Echinoderms | | |
| | Mediaster | *Mediaster aequalis* |
| | Cucumber | *Parastichopus californicus* |
| | Purple sea potato | *Mopadia intermedia* |
| | Sun star | *Rathbunaster californica* |
| | Other cucumber | *Infaunal, proboscis extending* |
| | Crinoid | *Fluorometra seratissima* |
| | Luidia | *Luidia foliolata* |
| | Brittlestar | Ophiuroid, multiple species |
| | Mud urchin | *Brisaster latifrons* |
| | Other star | |
| | Ophiuroids on surface | |
| Molluscs | | |
| | Octopus | *Octopus californicus* |
| | Gastropod | |
| | Red octopus | *Octopus rubescens* |
| | Pleurobrachia (sea slug) | *Pleurobranchia californica* |
| | Long white gastropod | |
| | Squid, Market | *Doryteuthis opalescens* |
| | Stubby squid | *Rossia pacifica* |
| | Humboldt squid | *Dosidicus gigas* |
| | Turban snail | |
| | Bivalve, small pink | |
| | Scaphopod | |
| Crustaceans | | |
| | Crab | *Cancer magister* |
| | Red rock crab | *Cancer productus* |
| | Spot Prawn | *Pandalus platyceros* |
| Annelids | | |
| | Polychaetes, surface | *Harmathoe sp. (Polynoidae)* |
| | Fan worms | *Serpulidae* |
| | Red polychaete | |

# Fish

| | | |
|---|---|---|
| Chontrichthyans | | |
| | Spotted ratfish | *Hydrolagus colliei* |
| | Torpedo ray | *Torpedo californica* |
| | Longnose skate | *Raja rhina* |
| | Big skate | *Raja binoculata* |
| | Soupfin shark | *Galeorhinus galeus* |
| | Spiny dogfish | *Squalus acanthias* |
| Flatfish | | |
| | Dover sole | *Microstomous pacificus* |
| | Petrale sole | *Eopsetta jordani* |
| | Slender sole | *Eopsetta exilis* |
| | English sole | *Parophrys vetulus* |
| | Rex sole | *Glyptocephalus zachirus* |
| | Pacific Sanddab | *Citharichthys sordidus* |
| | Curlfin sole (turbot) | *Pleuronichthys decurrens* |
| | Rock sole | *Lepidopsetta bilineatus* |
| | Unk. Flatfish | |
| Rockfish | | |
| | Striped tail rockfish | *Sebastes saxicola* |
| | Greenstriped rockfish | *Sebastes elongatus* |
| | Splitnose rockfish | *Sebastes diploproa* |
| | Shortbelly rockfish | *Sebastes jordani* |
| | Chilipepper rockfish | *Sebastes goodei* |
| | Halfbanded rockfish | *Sebastes semicinctus* |
| | Blackgill rockfish | *Sebastes melanostomous* |
| Other fishes | | |
| | Northern anchovy | *Engraulis mordax* |
| | Pacific hake | *Merluccius productus* |
| | Pacific hagfish | *Eptatretus stouti* |
| | Sablefish | *Anoplopoma fimbria* |
| | Sculpin | *Icelinus sp.?* |
| | Bigfin eelpout | *Lycodes cortezianus* |
| | Blackbelly eelpout | *Lycodes pacificus* |
| | Black eelpout | *Lycodes diapterus* |
| | Bearded eelpout | *Lyconema barbatum* |
| | Poacher | *Xeneretmus sp.* |
| | Lingcod | *Ophiodon elongatus* |
| | Juv Lingcod | *Ophiodon elongatus* |
| | Prickleback, bluebarred | *Plectobranchus evides* |
| | Plainfin midshipman | *Porichthys notatus* |
| | Cusk-eel, spotted | *Chilara taylori* |
| | Pacific sunfish | *Mola mola* |
| | Unk. Fish | |

## *Van Veen Grab Samples – Infauna*

### Polychaete (50 spp)
*Amaeana*
*Ampharetid*
*Amphinoid*
*Aphrodita spp.*
*Aricidea*
*Aricidea long*
*Capitella*
*Capitelid/Oligochaete*
*Chaetopterid*
*Cirratulid*
*Cossura*

*Eumida*
*Eteone*
*Exogone*
*Flabelligerid*
*Flabelligerid-like*
*Glycera*
*Glycinde*
*Goniadidae (Glycera-like)*
*Harmothoe*
*Hesione*
*Lumbrineris*
*Maldanid*
*Nephtys*
*Nereis*
*Nerinides-like*
*Onuphid*
*Ophelia*
*Paraonidae*
*Paraonidae long*
*Pectinaria*
*Pilargidae*
*Pista*
*P. Pista*
*Prionospio cirrifera*
*Prionospio malgrammi*
*Prionospio pinnata*
*Phyllodoce*
*Polydorid*
*Scoloplos*
*Spiophanes*
*Spionids*
*Spio-like*
*Sternaspis*
*Sternaspis-like*
*Syllidae*
*Turbonilla spp.*
*Yoldia seminude*
*Terebellidae*
*Thelenessa*
*Travisia*
Unknown

### Crustaceans (cont)

### Echinodermata (13 spp)
*Amphiodia spp.*
*Amphiura arcystata*
*Amphiura diomedeae*
*Brisaster latrifrons*
*Crinoidea spp. 1*
*Crinoidea spp. 2*
*Dougaloplus amphacanthus*
*Holothuroid spp. 1*
*Holothuroid spp. 2*
*Holothuroid spp. 3*
*Holothuroid spp. 4*
*(archival Sp #20)*
Juvenile ophiuroids
*Molpadia spp.*

### Cnidaria (8 spp)
*Anthozoan spp. 1*
*Anthozoan spp. 2*
*Anthozoal spp. 3*
*Edwardsia spp.*
*Pennatulacea spp. 1*
*Pennatulacea spp. 2*
*Pennatulacea spp. 3*
*Hydrozoans pp. 1*

### Echiura
*Echiura spp. 1*

### Nematoda
*Nemertean spp.*

### Nemertea
*Nemertean spp.*

### Sipunculida (3 spp)
*Sipunculid spp. 1*
*Sipunculid spp. 2*
*Sipunculid spp. 3*

### Oligochaete
*Oligochaete spp.*

### Mollusca (28 spp)
*Amphissa bicolor*
*Aplacophoran spp. 1*
*Aplacophoran spp. 2*
*Astyris spp.*
*Balcis*
*Cadulus tolmiei*
*Compsomyax subdiaphana*
*Cylichna diegensis*
*Eulimid*
*Eunucula tenuis*

### Mollusca (cont)
*Gadila aberrans*
*Kellia spp.*
*Lyonsia californica*
*Macoma carlottensis*
*Muricidae*
*Neptunea tabulate*
*Parvilucina tenuisculpta*
*Philine spp.*
*Rhabdus rectius*
*Rochefortia tumida*
*Saxicavella pacifica*

*Siphonodentalium quadrifissatum*

### Crustaceans (86 spp)
*Acidostoma hancocki*
*Americhelidium rectipalmum*
*Americhelidium shoemakeri*
*Ampelisca hancocki*
*Ampelisca pacifica*
*Ampelisca romigi*
*Ampelisca spp.*
*Ampelisca unsocalae*
*Anonyx liljeborgi*
*Aoroides inermis*
*Aoroides spp.*
*Bathymedon spp.*
*Bathymedon tone*
*Byblis spp.*
*Byblis veleronis*
*Bruzelia tuberculata*
*Campylaspis biplicata*
*Campylaspis spp.*
*Caprella mendax*
*Cirripedia*
*Conchoecinae*
*Cylindro leberididae*
*Diastylis crenellata*
*Diastylis glabra*
*Diastylis quadriplicata*
*Diastylis santamariensis*
*Diastylis sentosa*
*Diastylis spp.*
*Dyopedos spp.*
*Eudorella pacifica*
*Eudorellopsis longirostris*
*Euphausid*
*Euphilomedes productis*
*Flabellifera (suborder)*
*Foxiphalus cognatus*
*Foxiphalus similis*
*Gammaropsis ociosa*
*Gnathia spp.*

*Haliophasma geminatum*
*Harbansus mayeri*
*Harpiniopsis fulgens*
*Heterophoxus oculatus*
*Idarcturus allelomorphus*
*Idoteidae (Family)*
*Ilyarachna acarina*
*Isochyrocerus pelagops*
*Leptochelia dubia*
*Leptostylis calva*
*Leucon falcicosta*
*Leucon pacifica*
*Listriella diffusa*
*Listriella spp.*
*Maera simile*
*Melphisana bola*
*Metaphoxus frequens*
*Microjassa barnardi*
*Munnogonium tillerae*
*Neocrangon communis*
*Nicippe tumida*
*Opisa tridentata*
*Pachynus barnardi*
*Photis brevipes*
*Photis lacia*
*Photis macrotica*
*Photis spp.*
*Pinnixa occidentalis*
*Pleurogonium californiense*
*Pleurophoxus*
*Podocopid*
*Prochelator spp.*
*Protomedeia articulata*
*Rhachotropis spp.*
*Rutiderma lomae*
*Rutiderma sarsielloidea*
*Scleroconcha trituberculata*
*Siphonolabrum californiensis*
*Stenothoidae*
*Guernea reduncans*
*Tanaella propinquus*
*Tanaopsis cadieni*
*Tritella laevis*
*Typhlotanais williamsae*
*Westwoodilla tone*

## ATTACHMENT 2: Trawl Gear Design and Measurements

TNC, with our fisherman partners, have used a modified (small footrope) trawl gear described in these specifications on the F/V South Bay, based in Morro Bay, California. Measurements were made with local fishing partners in 2008.

## Overview*:*

A basic trawl design consists of two panels of netting that are laced together to form an elongated funnel shaped bag (Figure 1). The funnel tapers down to the cod-end where the fish are collected while the net is hauled. The mouth, or opening, of the net is held open on the top by floats along the headline rope and weighted down on the bottom by groundgear that is attached to the footrope. The net is held open on the side by wires (bridles and mudgear, aka sweeps) running from the net to the trawl doors.

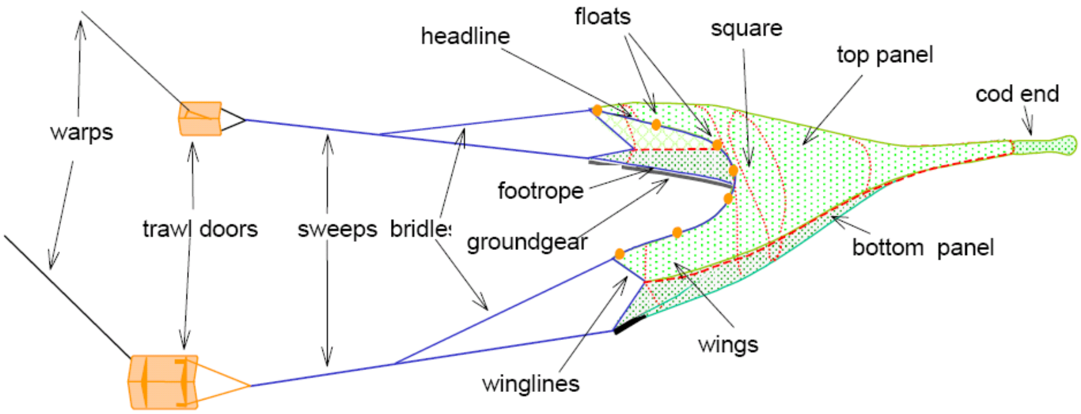

**Figure 1.** Diagram showing the basic design of bottom trawl gear.
(**Source: http://www.seafish.org/upload/b2b/file/r__d/BOTTOM%20TRAWL_5a.pdf**)

The modified trawl design consists of a two bridle trawl and the opening has a fishing circle of 300 meshes with a mesh size of 4 9/16 in. The funnel tapers down to the codend at a 2:1 cutting ratio and the mesh size at the codend is 4 ½ in.

## Headrope and Footrope Design:

The length of the headrope for the trawl is 61 ft long while the footrope is 60 ft (Figure 2). Groundgear is attached below the footrope and runs along the entire length. The groundgear keeps the net from dragging directly along bottom substrate. The footrope is attached to the groundgear, which is constructed of both 8-inch and 4-inch discs that are evenly spaced along the groundgear (Figure 3).

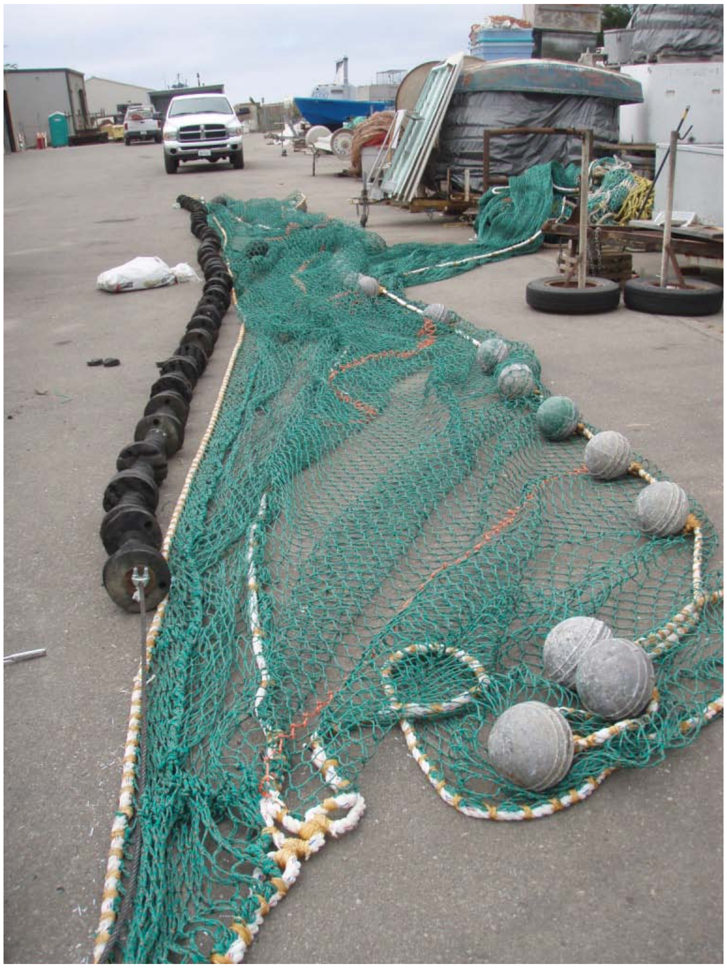

**Figure 2.** Picture showing the footrope and groundgear (left) and the hearope with attached floats (right).

**Figure 3.** Picture showing the groundgear with both 8 in. and 4 in. discs.

## Trawl Door Size:

The door size of the trawl doors, or otter boards, is 3.5 ft by 4.5 ft and each individual door weighs approximately 700 lbs.

## Opening and Dimensions:

Trawling operations on the F/V South Bay are usually conducted at a speed of 2.1 knots. Speeds slower than 2.0 knots can cause the net to dig into the bottom and results in large amounts of mud, urchins, and sea stars to become caught in the net. When the otter boards are spread open the net width is 33ft (Figure 4) and the height is 8 ft (Figure 5). The distance between the headrope and the footrope bridles is 5 ft.

**Figure 4:** Picture showing the estimated spread of the net while trawling.

**Figure 5:** Diagram showing estimated net height while trawling.

## Wire attachments:

The wings along each side to the opening of the trawl net are attached to the trawl doors by a series of two types of wires called wires and mudgear (aka sweeps). A bridle runs from the headrope and footrope along each end of the net and connects to the mud gear which is then attached to the trawl doors or otter boards. The diameter of the wire for both the bridles and the mud gear is ½ in. The length of each of the bridles is 7 fathoms and the length of the mudgear is 70-75 fathoms long. The mudgear consists of tightly packed discs, similar to the footrope materials, which are 2.5 to 3 inches in diameter.

## ATTACHMENT 3: Project Outreach

### *Oral Presentations*

Lindholm, James, Mary Gleason, Donna Kline, Dirk Rosen and Andrew De Vogelaere. Penetrating the Depths: A collaborative research effort to quantify the ecological effects of trawling activities on California's continental shelf. Second International Marine Conservation Congress, Victoria, British Columbia, Canada, May 2011.

Lindholm, James. Behind the Green Curtain: Applied Research at the Interface of Science and Policy. Monterey Bay Aquarium Research Institute, Moss Landing, California. April 2011.

The Ecological Effects of Trawling: A Collaborative Fisheries Approach. COAST Legislative Briefing in Sacramento, California. September 2010.

Recovery in Seafloor Communities Impacted by Trawling in Central California. California and the World Ocean Conference. San Francisco, California. September 2010.

The Central Coast Trawl Impact and Recovery Project. Sanctuary Advisory Council of the Monterey Bay National Marine Sanctuary. Watsonville, California. August 2010.

Habitat recovery following the cessation of trawling activities in Morro Bay. Marine Interest Group Meeting. Morro Bay, California. January 2010.

### *Poster Presentations*

Fish Associations with Small-scale Topography in Unconsolidated Sediments. Monterey Bay National Marine Sanctuary Currents Symposium, Seaside, California. April 2011. **L. Clary - Second place award in Undergraduate Student Poster section.**

The Effects of Trawling at "Low" Intensity in Unconsolidated Sediment: Year 1 of the Central Coast Trawl Impact and Recovery Project. Monterey Bay National Marine Sanctuary Currents Symposium, Seaside, California. April 2011.

Recovery in Seafloor Communities Impacted by Trawling in Central California. Monterey Bay National Marine Sanctuary Currents Symposium, Seaside, California. April 2010.

### *Student Projects*

Cortland Jordan, Devin Macrae, Joseph Platko, Lindsay Currier, Nicholas Castellon, Paul Hansen, Wendy Cooper. 2010. Distribution and Abundance of Demersal Fishes in an Area Subjected to Low-Intensity Bottom Trawling. CSUMB Group Capstone Thesis. 20 pp.