Central Coast Trawl Impact and Recovery Study: 2009-2010 Summary Report

(State Coastal Conservancy Grant #08-119 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 year of a five-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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- California Ocean Protection Council (OPC) – Skyli McAfee, Executive Director of the Ocean Science Trust.
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- Morro Bay Harbor - Rick Algert

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Executive Summary

This report summarizes accomplishments and results for the period from June 1, 2009 to November 30, 2010 which cover the first year (and part of the second year) of a five-year study to assess the impacts of bottom trawling on seafloor habitats and associated biological communities. The Central Coast Trawl Impact and Recovery Study, focused on the continental shelf off Morro Bay, California, is funded by the California Ocean Protection Council through a State Coastal Conservancy grant (#08-119) to The Nature Conservancy and by private funders. This is a collaborative research project 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 the distributions of seafloor microhabitats and associated species 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 do seafloor microhabitat, 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. otter trawl net 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 has been apportioned into eight treatment plots, each measuring 1000 m x 300 m at a water depth of approximately 170 meters in soft-bottom habitat on the continental shelf off Morro Bay, California. Four of the plots were selected to be trawled at known levels of intensity (based on historical effort data), while the remaining four plots are serving as non-trawled control plots against which changes in the trawled plots can be evaluated over time. The study began with pre-trawling baseline surveys in the fall of 2009, followed by directed trawling of low-moderate intensity (2x per plot). Post-trawling surveys to assess impacts and recovery occurred at two-weeks, six months, and one year after the directed trawling effort.

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. Specifically, our results demonstrate a small but persistent difference between control and trawled study plots with respect to the percent of the seafloor that is bioturbated (a measure of microtopographic complexity created by organisms on the seafloor). The effect was present immediately following low-intensity trawling and increased at one-year post-trawling.

Further, these initial results provide new insight 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 seafloor. Small sessile invertebrates appeared to increase in density following trawling activities, while larger sessile invertebrates declined significantly in the trawled plots. Mobile organisms, on the other hand, varied considerably over the course of the year, but did not differ significantly between control and trawled plots.

In October 2010 additional directed trawling effort at a higher intensity (5x per plot) was conducted in the “trawl” plots and a post-trawling survey with the ROV was conducted within 1-2 weeks after directed trawling. Results and additional post-trawling surveys are pending and will be provided in a following summary report. The OPC has funded Years 2 and 3 of this five-year research project.

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 (see National Research Council [NRC] 2002). However, it is thought, based on limited evidence, that soft-bottom habitats tend to recover more quickly than rocky habitats. Currently, flatfish — which are an important component of the groundfish fishery in central California and generally found in soft-bottom habitats — can be caught in commercially-viable quantities only by using 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 are working with local fishermen and other key partners to implement a five-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 be more economically and environmentally viable. The goal of this 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.

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 knowledge platform 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 in these habitats or the impact of fishing gear on the habitat and its associated species. One of the defining characteristics of this project is that we can experimentally control the trawling effort applied to the study plots in partnership with local fishermen. The vast majority of studies worldwide, and all of the studies on the west coast (including studies 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 are not available.

The research questions being addressed by this study include:

- How do seafloor microhabitat, 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 being 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 OPC science 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 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.
- **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 just offshore from the town of Morro Bay, California. This site was selected based on site-prospecting and baseline surveys conducted aboard the NOAA RV *Fulmar* using the ROV in September 2008 and in consultation with some members of the commercial fishing community in Morro Bay. This is a relatively productive area just shoreward of the Rockfish Conservation Area and the shelf-slope break. It is an area that was historically trawled for flatfish (Petrale sole, Dover sole) but 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 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. The study plots includes four control plots and four treatment plots that were subjected to directed trawling of known intensity for this experiment.

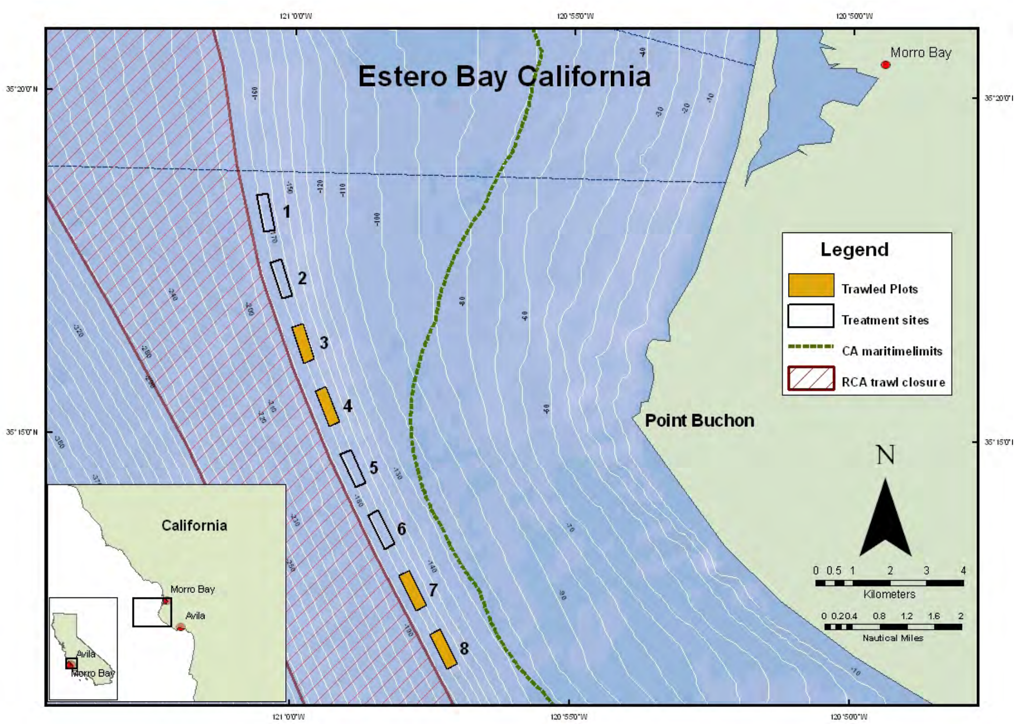

Figure 1. Map of Estero Bay study area including trawled (yellow) and control (black) plots. The hatched area immediately seaward of the plots is the Rockfish Conservation Area.

Research Objectives
The research objectives of this project are to compare the distributions of seafloor microhabitats[1] and associated fauna across a gradient of bottom trawling effort from no recent trawling (control) to low intensity trawling to higher intensity trawling. More specifically, we aim to quantify the relative abundance of seafloor microhabitats, epifaunal macro-invertebrates, infaunal macro-invertebrates, and fish species in study plots subject to a known level of trawling compared to untrawled (control) plots over time. This study incorporates 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

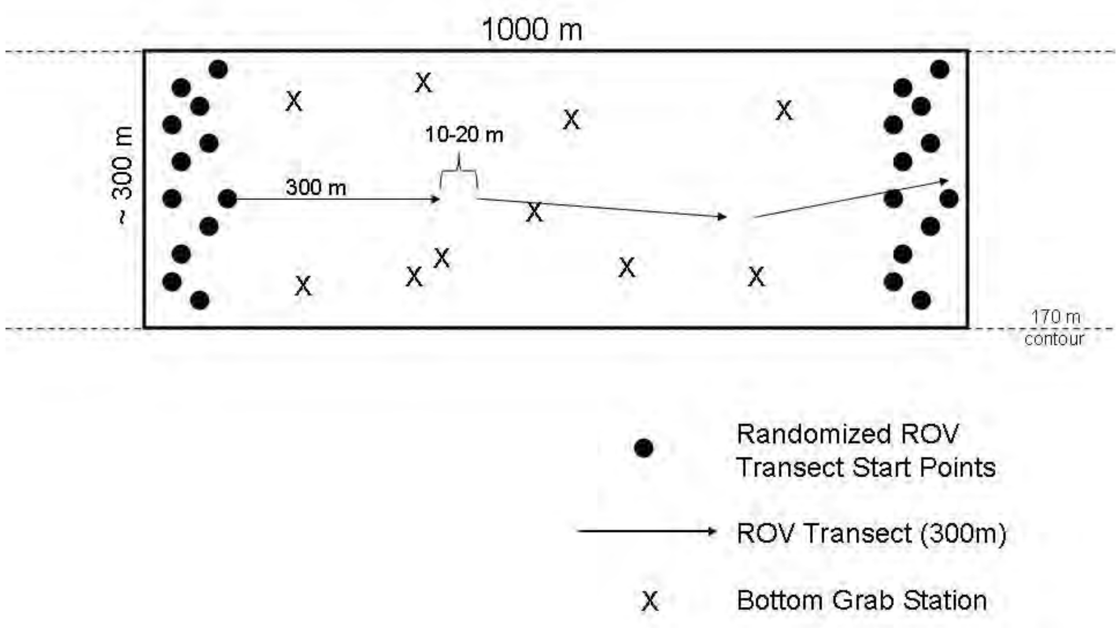

Figure 2: Idealized schematic depicting 1) a set of randomized ROV transect start points, 2) ROV transects, and 3) randomized bottom grab sample locations for each control and trawled treatment plot.

[1] Microhabitat 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-owned ROV, the "Beagle", is 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. The ROV is equipped with an altimeter and is "flown" at an altitude of approximately 0.6 – 0.8 m above the seafloor.

Each ROV transect is ~300 m in length (approximately 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 are 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 depends on local conditions (winds, currents, etc.) at the time of the dive.

Each ROV transect consists of continuous video and digital-still photographs recorded on DVD and digital tape. Each video transect is 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 is approximately 0.15 m^2. Still photographs are taken at approximately 1-minute intervals along each transect for a minimum of 20 photographs. Each still photograph covers an area of approximately 0.40 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 the survey transects are used to assess:

- relative density and percent-area covered for selected seafloor microhabitats
- relative abundance and density of epifaunal macro-invertebrates
- relative abundance of benthic fishes

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

Seafloor Microhabitats: Digital-still photographs are used to assess the spatial extent of bioturbation in each of the eight study plots. Bioturbation in this context refers to micro-topographic complexity in 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). The percent area bioturbated is quantified for each still photo using a digitally rendered 5 cm grid that is superimposed over each photo.

Epifaunal Macro-Invertebrates: Digital-still photographs are 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 selected anemones) provide habitat structure for fishes and mobile invertebrates in the study area. Counts (and ultimately densities) are made of each identifiable organism in a photograph (identified to the lowest taxonomic level possible). Sessile organisms are currently binned according to size categories (> 10 cm and < 10 cm) using the paired 10 cm lasers on the ROV. Densities are estimated based on an area of 0.40 m^2 per photograph.

Fishes: Though this is primarily a study of fish habitat rather than of fishes themselves, we are collecting information on all fishes observed in still photographs (and to some extent video imagery). Individuals of all observed fishes are identified to the lowest taxonomic level possible and are measured when possible.

Van Veen Bottom 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 in northern California and the Gulf of Maine (Grannis 2001; de Marignac 2009). 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. The grab sampling was conducted from a different vessel than the 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.

Total organic carbon (TOC), median particle size (Phi), sorting coefficient, and % moisture were measured by sub-sampling from an additional 5 bottom grab samples in each treatment and control plot. The surface layer of sediment was removed from the grab with a scoop, placed in a bowl, and mixed. A TOC sub-sample was then removed from the homogenized sample and placed in a 125-mL plastic jar with lid and stored frozen. 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. TOC and grain-size samples were processed using protocols modified from Plumb (1981). Infaunal invertebrate samples were collected from each grab and subsequently identified to the lowest taxonomic level possible.

Directed trawling

The directed bottom trawling efforts were 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 and is described in detail in Attachment A2.

The trawl treatment plots were first trawled at a 2x level of intensity in October 2009 and again at a 5x level of intensity in October 2010. These levels of effort were determined based on meetings with NMFS staff and their review of historical trawl effort aggregated by fishing block along the Central Coast. 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. The plots were trawled at the low intensity (2x; Figure 3) in the first year and we monitored recovery over a year. The same trawl treatment plots were trawled at a higher intensity the second year and recovery will be followed over a 2-3 year time frame.

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.

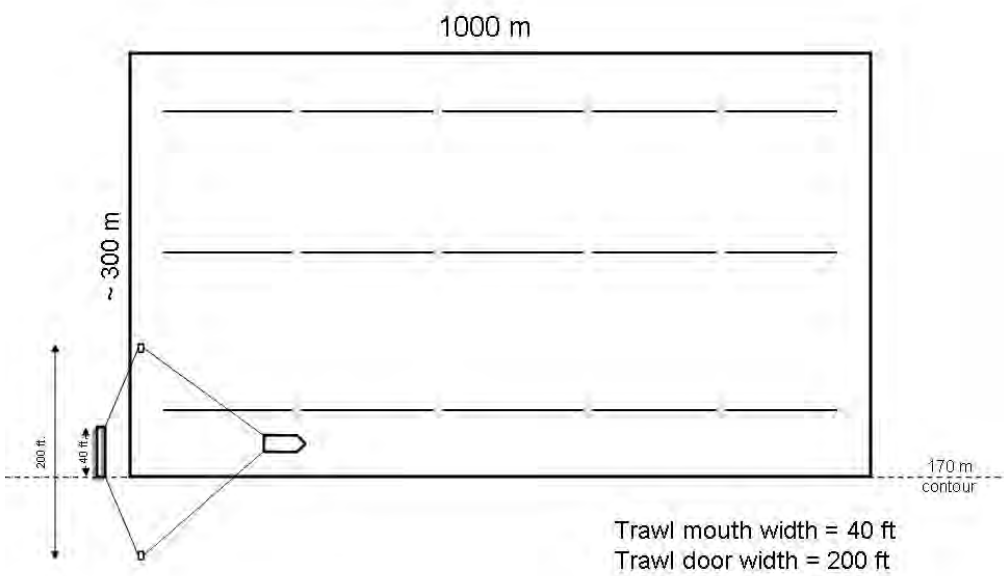

Figure 3. Idealized schematic depicting the planned distribution of bottom trawling effort.

Data Analyses
This study incorporates a “Before-After-Control-Impact” (BACI) design. Multiple measures are being used to compare trawled and control plots to test for differences between metrics in Year 1 (before) and to track the trajectories of communities at each location over time (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, will be tested statistically using ANOVA or ANCOVA and identified using SIMPER. Mixed effects modeling techniques will be 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 is designed as a five-year project (Figure 4). This report summarizes results from the first year (through September 2010) and describes operations for part of the second year (through November 2010). Table 1 summarizes the research cruises conducted to date.

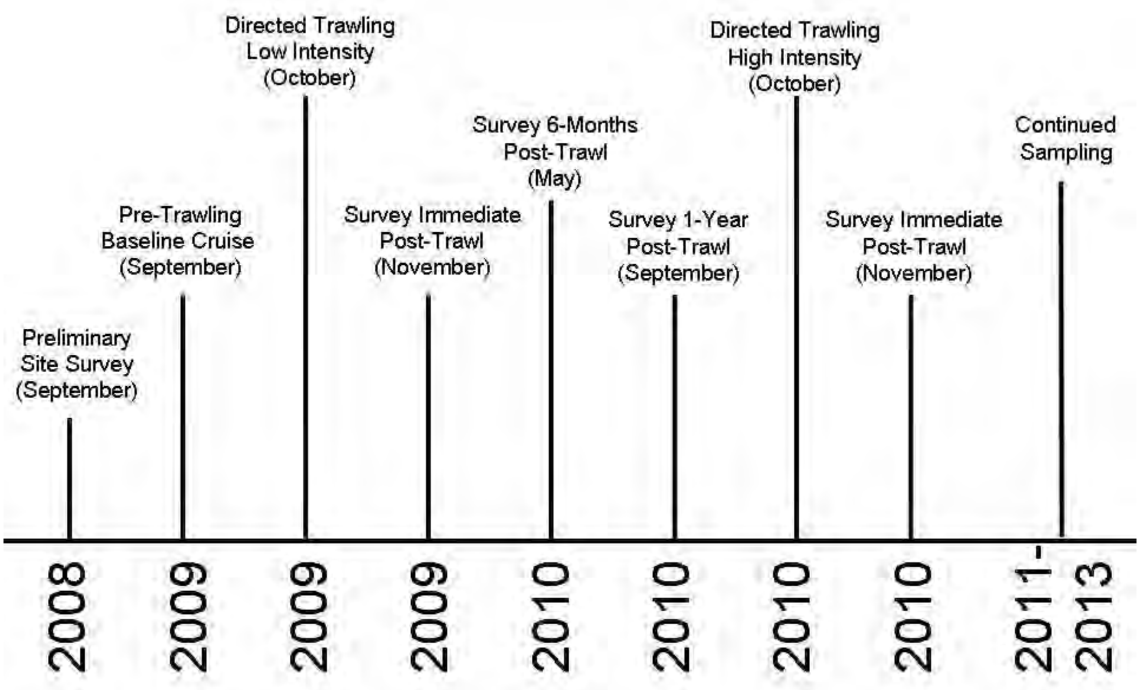

Figure 4. Project timeline

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.

Cruise	Vessel	Description	# ROV transects	# Benthic samples	# Trawl tows
Sep '08	*RV Fulmar*	Preliminary survey of study area	10		
Sep '09	*RV Fulmar*	Pre-trawling baseline	18		
Sep '09	*FV Rita G*	Pre-trawling baseline		80	
Oct '09	*FV South Bay*	Directed trawling (low intensity)			16
Nov '10	*FV Donna Kathleen*	Immediate post-trawling (low intensity)	46		
Nov '10	*FV Bonnie Marietta*	Immediate post-trawling (low intensity)		80	
May '10	*FV Donna Kathleen*	6-months post-trawling	48		
Sep '10	*RV Fulmar*	1-year post-trawling	29		
Sep '10	*FV Bonnie Marietta*	1-year post-trawling		80	
Oct '10	*FV South Bay*	Directed trawling (high intensity)			40
Nov '10	*FV Donna Kathleen*	Immediate post-trawling (high intensity)	48		

Results

Here we provide the summary of our analyses *to-date;* as such this is an interim report in what is intended to be a five-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 our five years of data collected and analyzed, will the results from any particular year be able to be placed in the context of the entire study.

Analysis of Sediment Grain Size

A total of 16 grab samples were collected across the eight study plots in September 2009 to sample the sediment grain size (Table 1). These samples were collected in addition to the infaunal samples. Each grab sample was sub-sampled three times to evaluate any discontinuities within individual grab samples. However, preliminary analyses of the sediment data (nested ANOVA) indicated no significant differences among the subsamples for each grab sample and the subsamples were subsequently pooled for further analysis. A one-way ANOVA comparing the pooled sediment grain size data across study plots (Figure 5) indicated significant differences (p-value = 0.008) between study plots 1, 3, and 8.

There are a number of potential explanations for the variability across the study plots, including differences in the dominant current patterns in the vicinity of the plots and/or relict deposits of sediment from episodic, though infrequent, oceanographic, geological, or anthropogenic events. The implications of any differences in sediment type across the study plots will depend on the organisms and habitat attributes of interest. We know a number of invertebrates, both infaunal and epifaunal, select for particular grain sizes. As such, if the differences in sediment size among the three plots occur at a scale that is relevant for the distributions of associated organisms, we may be able to attribute any differences we observe in their distribution to differences in grain size. Pending analyses of these data, including a characterization of grain size across plots at two weeks and one year post-trawling, should yield important insights into sediment dynamics in the study area.

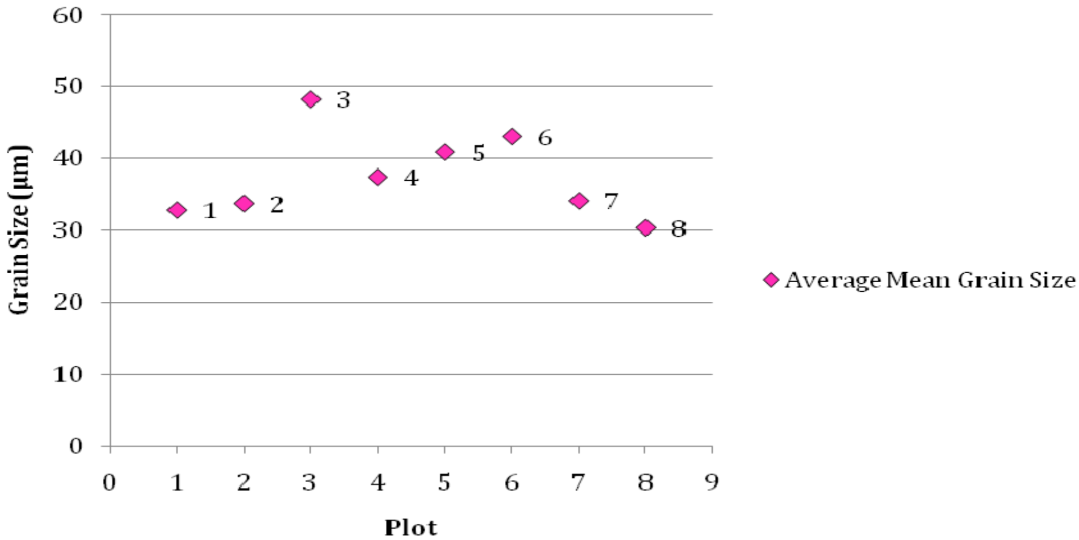

Figure 5: Average mean grain size for sediment in each plot based on the average of all quantifiable stations and subsamples per grab.

Analysis of Seafloor Microhabitats

Overall, the topographic relief in the study area was low, characterized by unconsolidated sediments in a depositional environment. However, a great deal of micro-topographic complexity (at the scale of centimeters) was evident in the down-looking still photographs collected by the ROV. 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 (Figure 6).

Figure 6. Down-looking still photograph of bioturbated sediment. 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-laser impacts on the sediment. Lasers are spaced 10 cm apart.

Figure 7 depicts the change in the percent of the viewable area bioturbated in both the control and trawled study plots from immediately prior to the low-intensity directed trawling to one-year following the trawling activity. There was no significant difference between the control and trawled plots with respect to mean percent-bioturbated immediately prior to trawling in September 2009 (based on a General Linear Model or GLM). This was expected as the area had not been impacted by trawling activities for more than a decade. Immediately following the low-intensity directed trawling, bioturbation in the trawled plots dropped considerably and was statistically different from the control plots. It is interesting to note that the percent bioturbated also declined in the control plots, though not as much in the trawled plots. In May 2010, at six-months post-trawling, the decline in bioturbated sediment abated, but the difference between control and trawled plots persisted. In August 2010, the percent bioturbated dropped precipitously again in both control and trawled plots, while the difference between control and trawled plots continued to be significant. The fact that the control and trawled plots differed statistically from one another over time in the GLM ($p < 0.001$) is suggestive of an impact from trawling. However, interaction terms inserted into the GLM to quantify the effect of any interaction between individual study plots and the two treatments and the plots vs. time were also significant, suggesting that subsequent analyses will be necessary to fully understand the dynamics in the study area with respect to bioturbation.

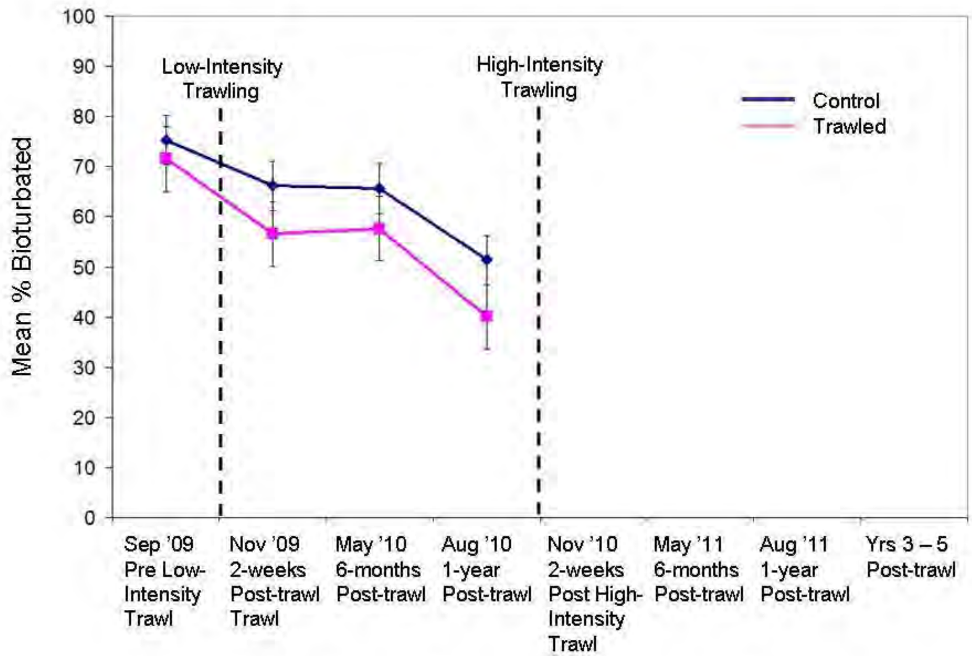

Figure 7. Changes in the mean % bioturbated in control and trawl plots for Year 1 as measured in ROV still photographs. Error bars represent ±1 standard error.

Analysis of Epifaunal Macroinvertebrates

Sessile, erect macro-faunal invertebrates, defined here as organisms that are attached to, and extend above the plane of, the seafloor, provide habitat structure that demersal fishes and mobile invertebrates from a variety of taxonomic groups use as refugia from predation and bottom currents. 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 our experience in similar habitats along the outer-continental shelf at other locations along the California coast. Common organisms in the area included several species of Anthozoa, including anemones, sea pens (Figure 8), and sea whips (Figure 9) as well as at least one species of fan worm (Annelida). Due to the significant variation in height of these species, their densities are reported here for small (< 10 cm) and large (> 10 cm) organisms.

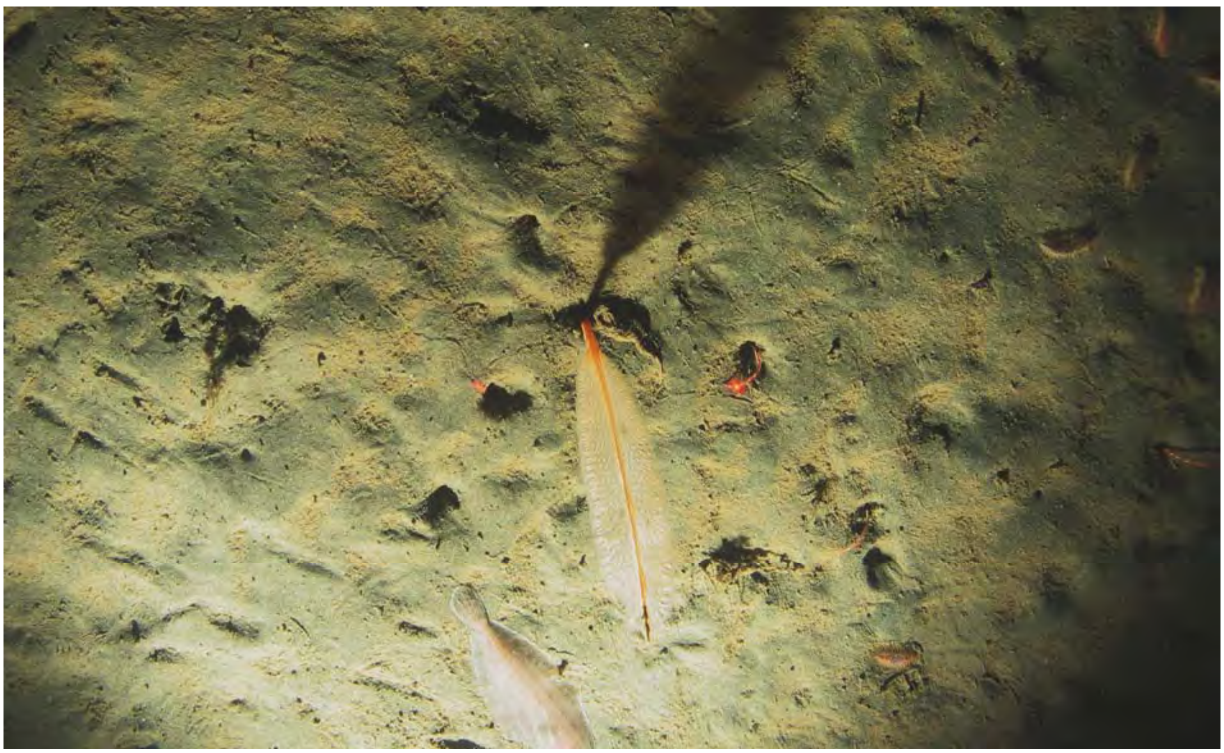

Figure 8. Down-looking still photograph of a sea pen. Note the flatfish in the lower portion of the image, as well as the presence of small polychaete worms on the sediment surface and brittle star arms extending from holes in the sediment.

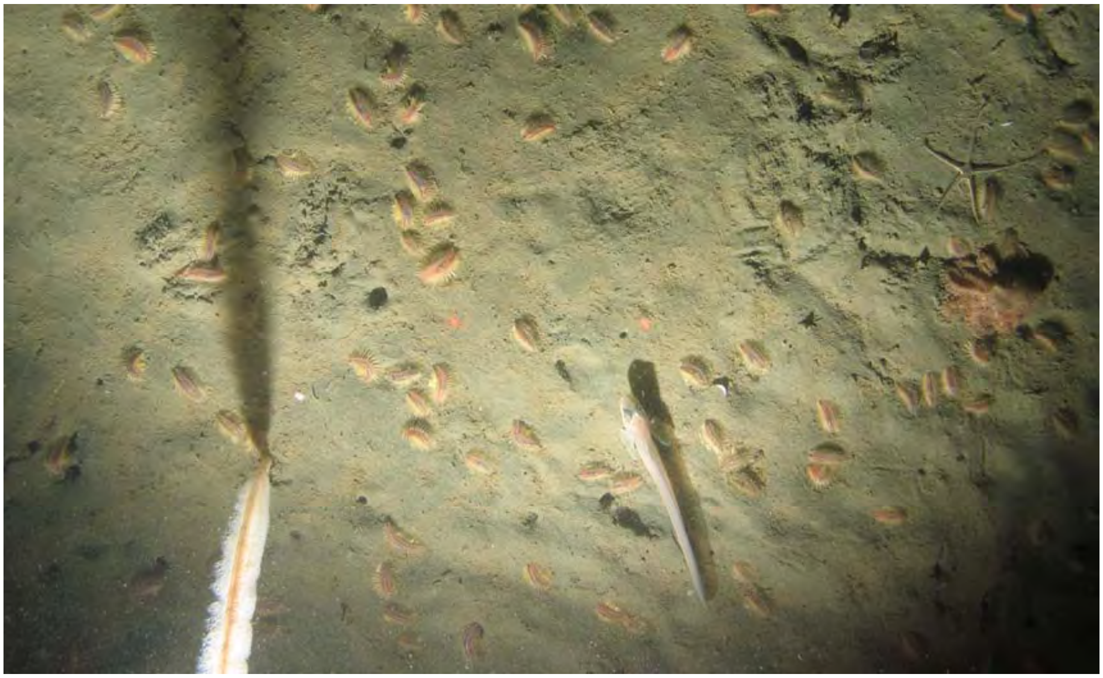

Figure 9. Down-looking still photograph of a sea whip. Also note the presence of an eel pout, an octopus, a brittle star, and multiple polychaete worms in the image.

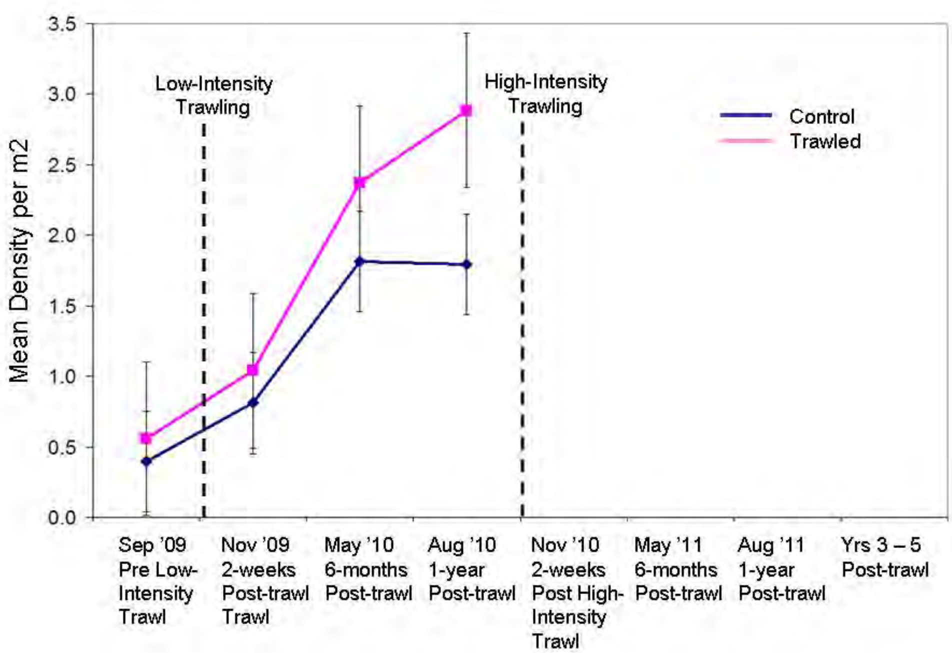

Figure 10. Mean density per m^2 for small (<10 cm) sessile epifauna. Error bars represent $\pm$1 standard error.

Results of a GLM indicated that small (< 10 cm) epifauna (including anemones and sea pens) were not different between the control and trawled sites in September 2009 before the directed trawling was conducted. Immediately following trawling (in November 2009) the mean density of small organisms increased in both trawled and control plots, though the difference between the two was not significant. Interestingly, the mean density of small epifauna continued to increase substantially at six-months and one-year post trawling, particularly in the trawled plots. By May 2010 the mean density in trawled plots was significantly higher than in the control plots, and by August 2010 the difference between plots had grown even further. Indeed by the end of Year 1 the mean density of small sessile organisms in the trawled plots had increased five times. The fact that the control and trawled plots differed statistically from one another over time in the GLM ($p < 0.001$) is suggestive of an impact from trawling. However, interaction terms inserted into the GLM to quantify the effect of any interaction between individual study plots and the two treatments and the plots vs. time were also significant, suggesting that subsequent analyses will be necessary to fully understand the dynamics in the study area with respect to small sessile epifauna.

The mean density of large (> 10 cm) sessile epifauna (primarily sea whips) in the study area was very low in September 2009 immediately prior to trawling activity and continued to be low throughout Year 1 (note the values for the y-axis in Figure 11 below). A GLM indicated no significant differences with respect to control and trawled treatments over time. Density within the trawled plots declined somewhat immediately after trawling, while in the control plots it remained level. By May 2010 the density in trawled plots had declined, while control plots experienced a dramatic increase in density, resulting in higher densities in the control plots. However, by August 2010 the densities of trawled and control plots had converged again.

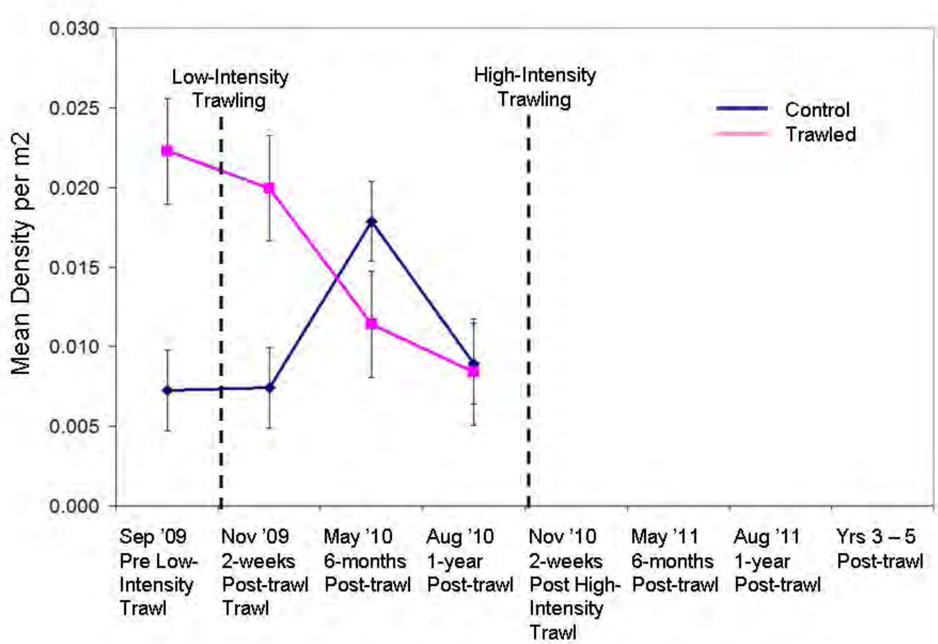

Figure 11. Mean density per m^2 for larger (> 10 cm) sessile epifaunal invertebrates. Error bars represent $\pm$1 standard error.

Analysis of Mobile Invertebrates

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). Overall, the density of these organisms was low in the study area, but was consistent with our observations of similar or related fauna at other locations along California's continental shelf.

Figure 12. Down-looking still photograph of a sea slug and multiple polychaete worms.

A GLM indicated that the mean density of mobile organisms did not differ significantly between control and study plots in September 2009 immediately prior to trawling activities or at any other point in Year 1. However, the results of the GLM indicated that densities did vary significantly over time. In November 2009, immediately after trawling, the mean density of these organisms increased dramatically in both control and trawled plots, though no difference existed between the two treatments. In May 2010, at six-months post-trawling, the density of mobile invertebrates had declined to near zero in both control and trawled plots. However, in August 2010 the density had increased again in both treatments, though no statistical difference was evident between the two. Complicating the interpretation of these results is the fact that the interaction terms for study plots vs. time, plots vs. treatments, and plots vs. time vs. treatment were all significant, suggesting that further analyses will be required to fully understand the dynamics of mobile invertebrates in the study area.

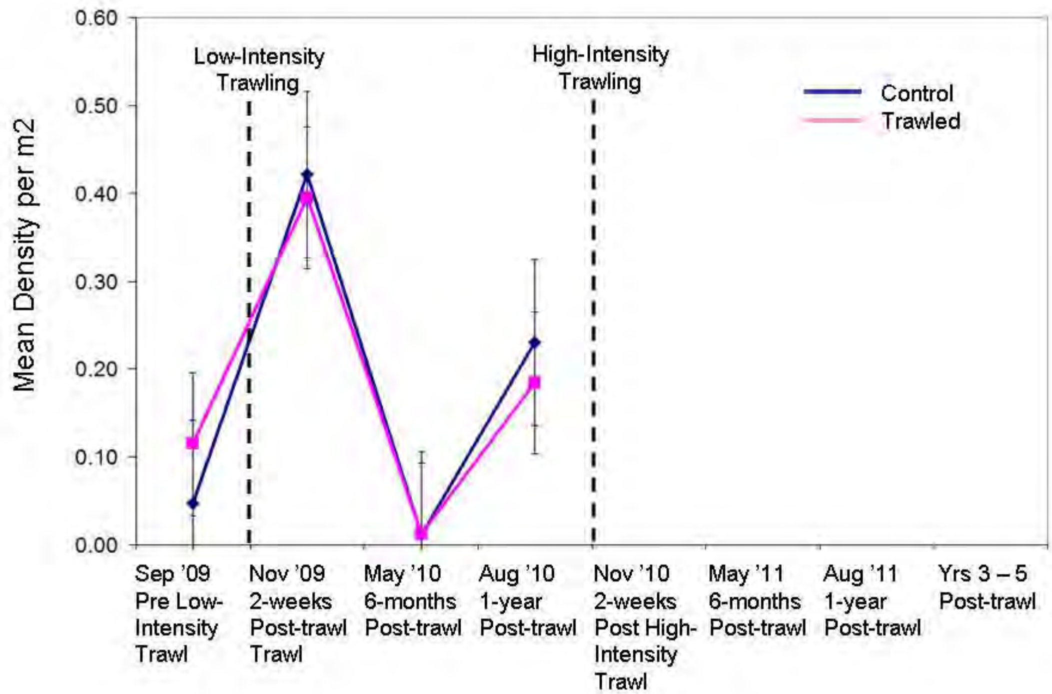

Figure 13. Mean density per m^2 for mobile invertebrates. Error bars represent $\pm$1 standard error.

Analysis of Infaunal Invertebrates

The inventory and analysis of infaunal invertebrates collected by the bottom grab is on-going and very time-intensive; results are too preliminary to present at this time. A preliminary species list of taxa collected in the infauna samples is provided in Attachment A1.

Analysis of Fishes

To-date we have either observed with the ROV or caught (with the trawl) a variety of fishes (primarily demersal) in the study area. A list of species is provided in Table 2 below.

Table 2. List of fishes encountered to-date in the study area either by ROV observation or trawl catch.

Taxonomic group	Common name	Genus species	ROV	Trawl
Chondrichthyans				
	Spotted ratfish	*Hydrolagus colliei*	X	X
	Pacific electric 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	*Lyopsetta 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
	Southern rock sole	*Lepidopsetta bilineata*		X
	Unk. Flatfish		X	
Rockfish				
	Striped tail rockfish	*Sebastes saxicola*	X	X
	Greenstriped rockfish	*Sebastes elongates*	X	
	Splitnose rockfish	*Sebastes diploproa*	X	X
	Shortbelly rockfish	*Sebastes jordani*	X	X
	Chilipepper rockfish	*Sebastes goodie*	X	X
	Halfbanded rockfish	*Sebastes semicinctus*	X	X
	Blackgill rockfish	*Sebastes melanostomous*	X	
Other fishes				
	Northern anchovey	*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
	Bearded eelpout	*Lycodes diapterus*	X	
	Poacher	*Lyconema barbatum*	X	
	Lingcod	*Xeneretmus sp.*	X	X
	Juv. Lingcod	*Ophiodon elongatus*	X	X
	Prickleback, bluebarred	*Ophiodon elongates*	X	
	Plainfin midshipman	*Porichthys notatus*	X	X
	Spotted cusk-eel	*Chilara taylori*	X	X
	Unk. Fish		X	

Trawl catch

Overall, the majority of the trawl catch (from 2009 and 2010) consisted primarily of flatfishes both in terms of total number of organisms and percentage of weight caught (Figures 14 and 15 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, while 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.

Year 1 Low-Intensity Trawling:

In 2009 flatfishes, ratfish, and other miscellaneous fish groups made up most of the catch in terms of numbers caught. Northern anchovy (*Engraulis mordax*) was the species that contributed the highest number of fish in the miscellaneous fish group category at 118 caught. Although sharks and skates and rays were fewer in number when compared to the flatfishes, ratfish, and other fish groups they contributed substantially to the overall weight at 29.3 and 20.6 % respectively. Invertebrates and flatfishes were also important in terms of weight at 19.7 and 12.6% respectively of the total weight in 2009 for these species groups.

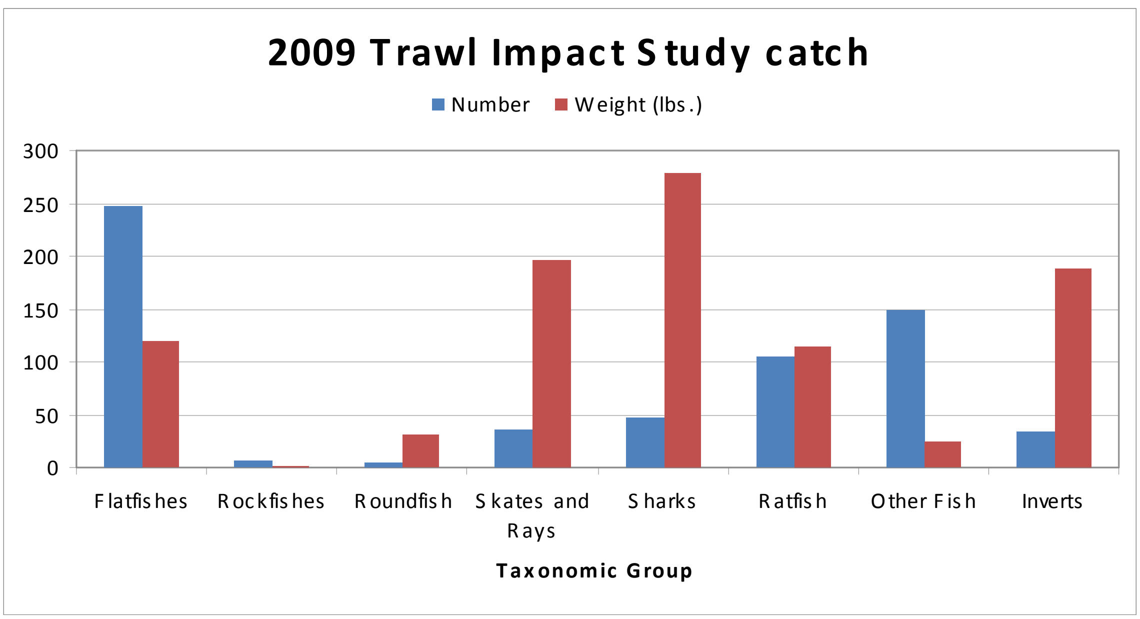

Figure 14. Number and weight of fishes captured in directed trawling efforts in 2009.

Year 2 High-Intensity Trawling:

In 2010, the higher intensity directed trawl catch was also dominated by flatfishes in terms of both numbers caught (at 44.7% of the total catch) and weight (at around 33%). For roundfishes, there was a substantial jump in both number of fish caught and weight primarily due to a high percentage of juvenile sablefish caught. Ratfish and invertebrates were still important components of the catch, although ratfish dropped in importance for both numbers and weight. Sharks, skates and rays were still lower in numbers when compared to other taxonomic groups, but still high for weight at 15.3% of the total overall weight for sharks and at around 16% for skates and rays. There were no anchovies in the catch for 2010, but there was an increase in number for Plainfin Midshipmen (*Porichthys notatus*) and Pacific Hake (*Merluccius productus*) for the miscellaneous other fish group compared to 2009. There was also the addition of 3 new rockfish species in 2010 that weren't caught in 2009, including bocaccio (*Sebastes paucispinis*), chilipepper (*S. goodei*), and shortbelly rockfish (*S. jordani*). All of these rockfishes were caught in small numbers.

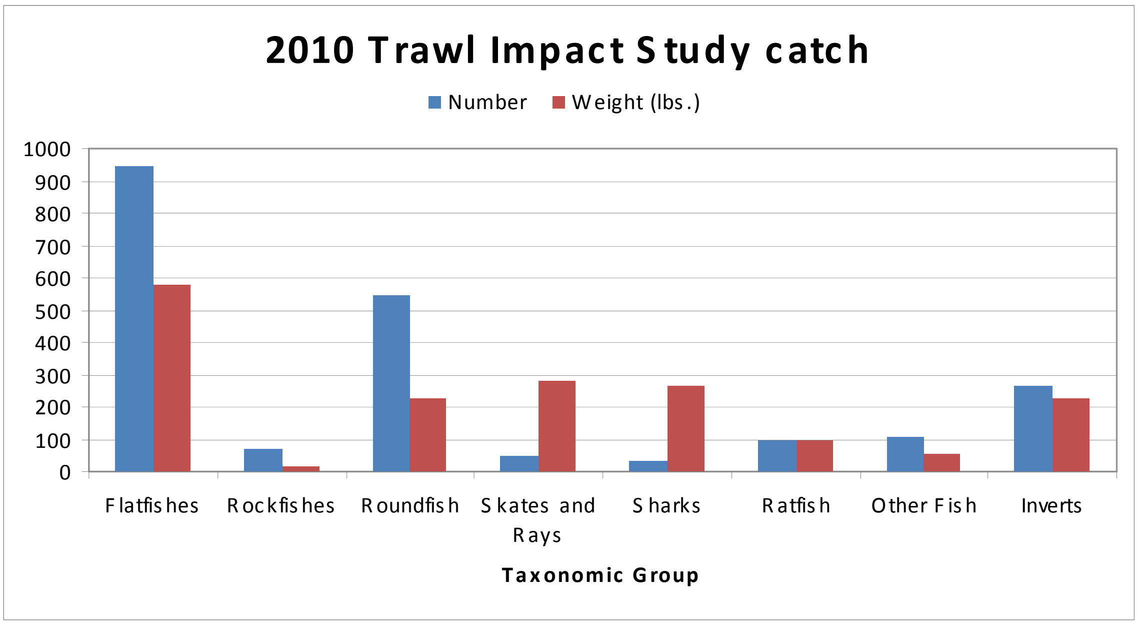

Figure 15. Number and weight of fishes captured in directed trawling efforts in 2010.

Discussion and Next Steps

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 initial results provide new insight 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 seafloor.

Low-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 is bioturbated. The effect was present immediately following low-intensity trawling and had actually increased at one-year post-trawling. 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. Diminishment of bioturbated sediments, therefore, may 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-intensity bottom trawling must be considered in the context of significant environmental variation. Small sessile invertebrates appeared to increase in density following trawling activities, while larger sessile invertebrates (already at very low densities) appeared to decline in the trawled plots. Mobile organisms, on the other hand, varied considerably over the course of the year, but did not differ significantly between control and trawled plots. 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 five-year time series data on invertebrate communities (both sessile and mobile) that we are collecting in this project will ultimately enhance significantly our understanding of the ecology of organisms in unconsolidated sediments, including seasonality in the distribution of mobile invertebrates and epibenthic predators, the areal extent of ephemeral patches 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. Results 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.

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. As part of this project, we have also conducted considerable outreach on the work to date to expand its reach (see Attachment A3).

Next Steps- The critical second year of the project is already underway with the high-intensity trawling completed in October 2010. While the insights derived from the low-intensity trawling to-date are interesting in an absolute sense, it is the comparison of data across a gradient of low-to-high intensity trawling that will ultimately offer the most insights for management. While we have endeavored to make the two trawling treatments reflective of actual effort applied either currently or historically in the vicinity of the study, it is the relative impact of high and low intensity trawling that will provide managers with the insight necessary to ensure sound and sustainable trawling practices along our coast.

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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

<u>Polychaete (50 spp)</u>
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

<u>Echinodermata (13 spp)</u>
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.

<u>Cnidaria (8 spp)</u>
Anthozoan spp. 1
Anthozoan spp. 2
Anthozoal spp. 3
Edwardsia spp.
Pennatulacea spp. 1
Pennatulacea spp. 2
Pennatulacea spp. 3
Hydrozoans pp. 1

<u>Echiura</u>
Echiura spp. 1

<u>Nematoda</u>
Nemertean spp.

<u>Nemertea</u>
Nemertean spp.

<u>Sipunculida (3 spp)</u>
Sipunculid spp. 1
Sipunculid spp. 2
Sipunculid spp. 3

<u>Oligochaete</u>
Oligochaete spp.

<u>Mollusca (28 spp)</u>
Amphissa bicolor
Aplacophoran spp. 1
Aplacophoran spp. 2
Astyris spp.
Balcis
Cadulus tolmiei
Compsomyax subdiaphana
Cylichna diegensis
Eulimid
Eunucula tenuis

<u>Mollusca (cont)</u>
Gadila aberrans
Kellia spp.
Lyonsia californica
Macoma carlottensis
Muricidae
Neptunea tabulate
Parvilucina tenuisculpta
Philine spp.
Rhabdus rectius
Rochefortia tumida
Saxicavella pacifica
Siphonodentalium quadrifissatum

<u>Crustaceans (86 spp)</u>
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.

Crustaceans (cont)

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.

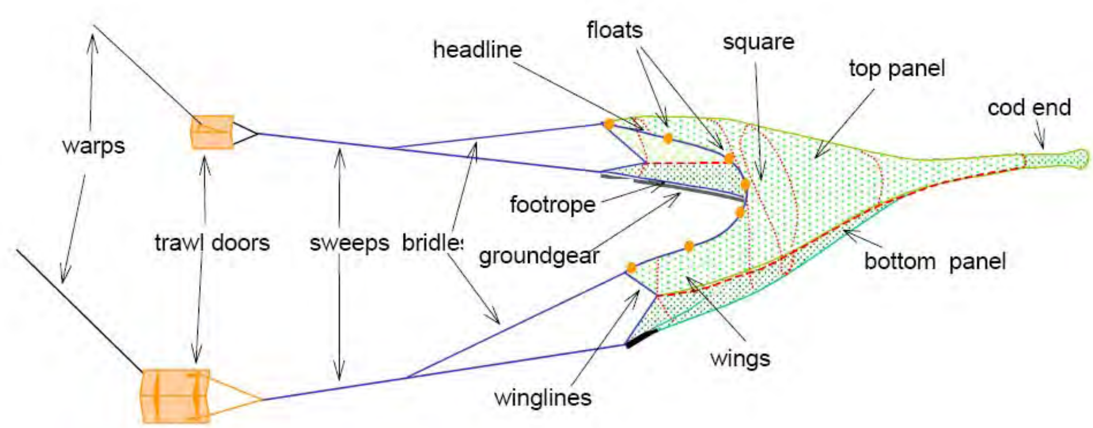

Figure 1. Diagram showing the basic design of bottom trawl gear.
(**Source: http://www.seafish.org/upload/b2b/file/r__d/BOTTOM%20TRAWL_5a.pdf**)

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

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.

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.