CFR West 11-027 FINAL REPORT

Title: Targeting Swordfish Deep During the Day to Reduce Bycatch

Grantees: Pfleger institute of Environmental Research, PIER and the National Marine Fisheries Service, NOAA

Executive Summary

The objectives of this collaborative study were to document swordfish (*Xiphias gladius*) depth distribution and trial alternative deep-set fishing methods within the Pacific Leatherback Conservation Area (PLCA) and southern California Bight. The PLCA encompasses a >500,000 km^2 area located off the U.S. West Coast that spans from Point Sur, California to the Oregon border and out 200 nm. For over 20 years, the PLCA was a productive fishing ground for the CA drift gillnet fishery (DGN) targeting swordfish; however, the area has been seasonally restricted to DGN gear since 2001 as a conservation measure to reduce leatherback sea turtle bycatch. To better understand swordfish fine-scale movements within the PLCA and to assess potential differences in the vertical distribution of target and non-target species, this study outfitted swordfish with satellite-based archival tags scheduled for short and long-term (2-150 d) deployments. All tags were deployed on basking swordfish using traditional harpoon methods during the fall of 2012 and 2013 within the confines of the PLCA (approx. 35° 41'N/ 122° 45'W). Collectively, this work provided depth and temperature data from eleven swordfish (~90 to 150 kg) over the course of 250 days. All PLCA swordfish exhibited surface-oriented nocturnal movements (avg. 8.3 ± 1.6 m), with individuals spending ~99% of the night above the average thermocline depth (36 m) (Figure 1). Daytime depth distribution was greater and more variable (mean depth 107.1 ± 21.2 m) than nighttime movements, with fish displaying three distinct diurnal patterns: (1) surface oriented movements (basking, or <3 m of the surface) accounted for 16.7% of the collective daytime records; (2) a mixed-layer distribution (between 3 m and the thermocline) accounted for 26.8% of the daytime records; and (3) extended periods below the thermocline accounted for 56.5% of the daytime records. Daytime basking rate and thermocline depth were correlated in seven of the tracks, with several individuals exhibiting extensive basking activity in waters with a relatively shallow thermocline depth (i.e. <36 m).

In addition to the tagging studies, this project also tested the utility of deep-set gear for swordfish. The two gear types tested were deep-set buoy gear (DSBG) and deep-set longline (DSLL) gear. DSBG is an experimental gear type that has been successful in selectively targeting swordfish in the Southern California Bight but hadn't been tested in the PLCA. DSBG deployments consist of ten individual pieces of gear, each consisting of 2-3 baited hooks,

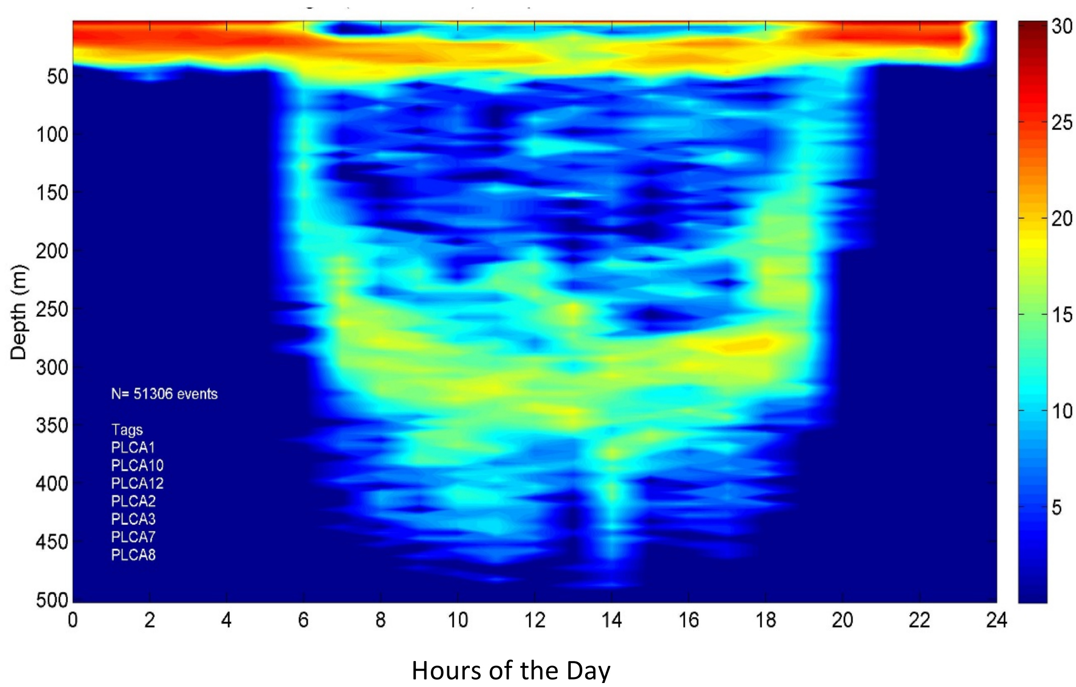

Figure 1. Collective depth distribution for seven short-term tagged swordfish plotted over one 24h day within the waters of the PLCA.

deployed consecutively in a linear set. DSBG is designed to fish at depths below the thermocline (200-400m) during the day in an attempt to selectively target swordfish and avoid species of special concern (i.e., leatherback sea turtles).

During the project period 18 sets of DSBG (180 pieces of gear) were deployed over the course of 14 days. Collectively, the PLCA deployments accounted for over 2,050 hook hours. Although the trials did not result in any interaction with species of special concern, catch rates were low for most marketable species (Table 1).

Relation to regional fisheries: The information collected in this study corroborates the high degree of nocturnal spatial overlap between swordfish and species of concern like leatherback sea turtles. Although daytime depths were variable, because more than half (56%) of the daytime swordfish depth records were below the thermocline it is possible that daytime deep-set techniques can be used to selectively target PLCA swordfish with limited risk to species of concern. The predominant depth range exhibited by the swordfish while at depth (200-450m) is within the range of depths currently used to target swordfish in southern California using DSBG, further supporting the potential use of deep-set techniques within the PLCA.

Additional findings of interest include the high degree of basking activity observed for the PLCA swordfish. Basking rates were higher than those reported for southern California and may represent an opportunity for the expansion of harpoon-based harvest methods within the PLCA. Harpoon techniques are not commonly used along central California, yet this low-impact gear type may provide additional opportunity for local fishers.

Table 1: Set and catch details for DSBG deployments within PLCA waters (2012-2013)

Number of deployment days (10 pieces/set)	Total hooks deployed in PLCA	Total hook hours	Species captured
16	480	2,050	16 blue sharks*
			3 opah**

* All individuals released alive

** Retained for biological sampling for the NOAA SWFSC.

Deep-set longline gear: DSLL gear is used in many tuna fisheries, and like DSBG targets swordfish at their daytime depths when habitat overlap with protected species is reduced. Over the course of the study the SWFSC chartered a longline vessel and conducted 4 cruises to develop methods to target the daytime depths of swordfish and to characterize catch rates (2 of these cruises were supported by this grant, see attached cruise reports Appendix III). A total of 54 sets were made with set durations ranging from 2 to 10 hrs. No protected species were caught but a range of marketable fish were landing including swordfish, opah and tuna (Table 2). The approach shows promise. Additional vessels with fewer temporal and spatial constraints are needed to further develop this method and determine whether it is a viable compliment to existing gear types for targeting swordfish off the U.S. West Coast. Another issue that will need to be addressed is the large number of blue shark caught. While the mortality of longline caught blue sharks is thought to be relatively low and more than 90% were release alive, additional efforts will focus on reducing catch rates and quantifying mortality.

Table 2: Set and catch data for DSLL deployments from 2011-2014.

Number of sets	Total hooks deployed	Set Durations	Species captured*
54	13,280	2-10 hrs	9 swordfish
			417 blue sharks**
			146 tuna (most troll caught while traveling between sets)
			97 opah
			25 king of the salmon
			29 pomfret
			5 lancet fish

*species included where catch was 5 or more

** 92% of blue sharks were released alive

This work provides the first steps towards understanding swordfish movements within the Pacific Leatherback Conservation Area. In the case of west coast swordfish, the protection of a critically endangered species has led to the underutilization of a domestic resource, economic loss and an increase in foreign imports. Understanding spatial differences in habitat utilization among target and bycatch provides the key to identifying ways to enable domestic operations to continue to exploit healthy stocks. The coupling of species specific movement patterns, biology and innovative harvest methods is necessary for developing sustainable solutions for the west coast swordfish resource. The data collected in this study provides a first step towards the development of alternative methods that enable domestic operations to continue to operate off the west coast.

Introduction

Recent stock assessments suggest that the eastern North Pacific swordfish population is healthy and that overfishing is not occurring (Brodziak and Ishimura, 2009). Despite these reports California-based landings and fishery participation have reached a historic low in recent years (PFMC, 2014). This decline can be primarily attributed to stringent bycatch mitigation measures that have severely restricted fishery operations throughout much of the California coast (Carretta et al., 2003).

The most severe restriction was initiated in 2001 when the primary west coast swordfish fishery (CA drift gillnet fishery, DGN) was restricted from over half of the California coast during the peak months of the fishery (Carretta et al. 2003). The DGN seasonal closure (Pacific Leatherback Conservation Area, PLCA) was enacted to protect the endangered leatherback sea turtle *Dermochelys coriacea* in the waters off central and northern California. Contemporary DGN operations are now seasonally restricted to the waters of the Southern California Bight (SBC), a relatively small portion of the CA coastline spanning Point Conception to the Mexican border and out 200 nm. The implementation of the PLCA has negatively influenced DGN fishery participation and west coast landings by limiting the historic fishery range and preventing fishers from tracking annual swordfish migrations into the PLCA.

The coupling of bycatch concerns and the suppressed state of the west coast swordfish fishery participation has prompted the use of vertical movement studies to identify habitat segregation between target and non-target species (Sepulveda et al., 2010; 2015; Dewar et al., 2011; Abecassis et al., 2012). Recent work in southern California suggests that daytime depth segregation may offer an opportunity to selectively target swordfish at depth while avoiding species of concern (i.e., sea turtles). Because swordfish have been shown to display regional differences in depth distribution (Carey and Robinson, 1981; Sepulveda et al., 2010; Dewar et al., 2011; Abecasis et al, 2012), regionally-specific information on depth distribution are critical for increasing gear specificity and reducing non-target interactions. The present study focused on documenting habitat characteristics, movement patterns and depth distribution of swordfish within the boundaries of the PLCA. A secondary objective was to trial the use of two southern deep-set fishing gear types, deep-set buoy and longline gear, both in the PLCA and in adjacent waters in the southern California Bight. Collectively, this study focused on understanding swordfish depth distribution within the PLCA and initiating steps towards identifying low-impact fishery options for this region.

Given the interest in developing gears to complement the existing swordfish fishery off the West Coast, an additional goal of this study was to conduct a broad comparison of economic and bycatch metric across a range of U.S. fisheries that land swordfish. The comparison included the existing DGN gear, longline gear, both deep and shallow, harpoon and DSBG used in the Atlantic and will provide the Pacific Fisheries Management Council standardized information for informed decision making (see Appendix IV).

Methods

Location and tagging activities

All swordfish tagging activities were performed within the Pacific Leatherback Conservation Area (PLCA), a region that spans from approximately Point Sur, CA northward to the Oregon border and out to the 200-nm U.S. exclusive economic zone (EEZ). Basking swordfish were spotted at the surface using stabilized binoculars or with the aid of a spotter plane and tagged from an extended (7m) bow pulpit using a modified harpoon following the protocol described by Sepulveda et al., 2010. Swordfish size estimates, tag position, and environmental conditions (i.e., sea state, water temperature and color) were documented for each tag deployment and recovery event.

Tag specifications and attachment

Three different types of tags were deployed, Wildlife Computers (WC; Redmond, Washington, USA) MK10 pop-off satellite archival tags (PSATs), WC SPLASH tags and WC MK10-AF transmitting fast-GPS tags. Seven of the tags were recovered as described in (Sepulveda et al., 2010) and provided fine-scale archived data sets. The fast-GPS tags were programmed to summarize temperature and depth data into 6-h histogram bins and were deployed for 150 days to examine larger-scale behaviors. Upon tag recovery, fine-scale archived data sets were downloaded and the tag release pin was re-fitted by the manufacturer for subsequent redeployment. For those tags that popped off outside of the recovery range or during periods of adverse weather (n=4), satellite-derived data was used to assess movements and habitat use.

Archived data analyses

For the seven PSATs that were re-acquired, fine-scale data were downloaded and summary statistics were calculated for each tag prior to conducting inter-regional comparisons. Archived depth and temperature data were analyzed to evaluate fish basking rates, vertical rates of movement, thermocline depth, dive duration (below the thermocline), dive periodicity, as well as daytime versus nighttime depth and temperature distribution statistics. All records were classified as day, night, or twilight values on the basis of the mean monthly Pacific Standard Time (PST) of sunrise, sunset, and nautical twilight at the initial tagging location from the Astronomical Applications Department of the U.S. Naval Observatory data services portal (http://aa.usno.navy.mil/data/index.php). Daytime was defined as the average monthly time of sunrise until the average time of sunset; nighttime was assigned to all values between the mean time of nautical twilight at dusk until the mean time of nautical twilight at dawn; and twilight values included all data between mean time of sunset and nautical twilight at dusk as well as from nautical twilight at dawn until mean time of sunrise for each month.

Daytime depth statistics were calculated for each swordfish as both the cumulative mean of all daytime records as well as the average time that each fish spent below the thermocline. Thermocline depth was estimated for each day of all archived data sets by calculating the maximum gradient of temperature (ΔT) between subsequent mean temperatures of 0.5 m depth bins. Thermocline values were verified through graphical inspection of depth-temperature plots for each swordfish and subsequently verified against published values for the study region (Palacios et al., 2004).

The number and duration of all dives below the thermocline as well as the descent and subsequent ascent rates were quantified for each fine-scale track. Based on daytime depth profiles and dive characteristics three distinct behavior patterns were identified and categorized into 1) basking events, 2) time spent within the mixed layer, and 3) time spent below the thermocline. Basking was defined as daytime periods spent at or near the surface (≤3m), while mixed layer activity was defined as periods when depths ranged from >3m to the thermocline. For all tagged swordfish, basking events were examined for both duration and time of occurrence (initiation) to identify any trends specific to surface-oriented activity. The percent occurrence of time spent below the thermocline was based on the duration of time the swordfish spent below the mean thermocline depth. Individual basking events were differentiated within the track records by a change in depth in which the fish traversed the thermocline (Sepulveda et al., 2010). Vertical rate of movement (VROM) was calculated for each fish as the absolute difference of all subsequent 1-min depth records (Sepulveda et al., 2011).

Satellite-derived data analyses

For tags that were not re-acquired, time-bin programming varied between tags (1-6 h) based on deployment duration. Day and night bins were separated from crepuscular periods that potentially overlapped sunrise, sunset, or twilight times for comparative analyses of pure daytime and nighttime records (Dewar et al. 2011; Abecassis et al., 2012). Subsequently, daytime periods were not equivalent to day length and daytime duration varied between tags. Minimum, maximum, and mean of the maximum values were evaluated from the time-at-depth data for day and nighttime periods. Depth bins were preset at: -1.5; 5; 25; 50; 100; 150; 200; 250; 300; 350; 400; 500; 1000; >1000. Time-at-temperature data were summarized on the basis of 14 temperature bins: 5; 7; 8; 9; 10; 11; 12; 13; 14; 15; 16; 17; 18; >18

Horizontal movements

Light data was not used for geolocation purposes due to the limited duration of the tag deployments and the lack of adequate illumination at depth. Horizontal movements were evaluated by determining the net displacement and direction of tag deployment to pop-off locations. Rate of movement (km/h) was estimated for each fish as the net-displacement distance over the deployment duration.

Statistical analysis

All values are indicated as mean ± SE. Daily depth probability plots were constructed with Matlab software vers. 6.0 [R12] (The MathWorks, Inc., Natick, MA) with depth bins of 1 h by 2 m to illustrate the cumulative probability of occurrence for each depth over a 24-h period. Sea surface temperature and chlorophyll concentration data were reviewed for both the tagging and pop-off locations of each swordfish using MODIS data obtained from Aqua and Terra EOS Satellites; processed by Terrafin Software, (www.terrafin.com).

Results

A total of thirteen swordfish were tagged with electronic tags within the waters of the PLCA in September and October of 2012 and 2013 (Figure 1 and Table 3). Of the thirteen tagged individuals, seven PSATs were reacquired for fine-scale analyses, four transmitters provided satellite-derived histogram data, one PSAT failed to report, and one individual received only a 'hitchhiker' archival tag after the PSAT release pin severed upon application. The collective dataset provided >250 days of depth, temperature and light level data.

Vertical distribution

Collectively, the mean (± SE) day and night depths of archived data sets were 107.1 ± 21.2 m and 8.3 ± 1.6 m, respectively. Average daytime depth below the thermocline (not including basking or mixed layer periods) was 234.4 ± 15.2 m, with a maximum depth of 608 m (Figure 2). Basking activity was documented for all fine-scale tags (recovered) (n=7) with a total of 58 basking events for a mean duration of 73 ± 11.9 min (range 1-362 min). Basking event duration averaged 107.7 ± 12.0 min when only basking events >3 min were considered. Basking events occurred over all portions of the day, although surface basking was rarely observed prior to 09:00 PST or after 17:30 PST. A peak in basking activity occurred between 14:00 and 15:00 PST. Vertical rate of movement increased during the daytime (4.5 ± 0.2 m/min) relative to mean nighttime VROM values (2.4 ± 0.1 m/min). Mean VROM was greatest during twilight periods (5.5 ± 0.3 m/min) when swordfish routinely spanned the water column during dawn descents and dusk ascents.

Table 3: PSAT deployment and pop-off details on swordfish within PLCA waters (2012-2013)

Swordfish #	PSAT #	Date deploy	Est. size	Deployment location	Pop-off location	Tag duration	SST
PLCA1	05A0197	10/4/2012	105 kg	35°38'N/ 122°58'W	35°34'N/123°23'W	2	16.7
PLCA2	05A0258	10/4/2012	75 kg	35°36'N/122°54'W	35°06N/123°56'W	3	16.7
PLCA3	05A0217	10/7/2012	118 kg	35°36'N/122°54'W	35°25'N/123°10'W	2	17.6
PLCA4	12A0138	10/18/2012	91 kg	36°15'N 122°49'W	Did not report	na	17.1
PLCA5	12A0102	10/18/2012	114 kg	36°10'N 122°42'W	35°35'N/127°14'W	2	16.8
PLCA6	A06052	10/18/2012	82 kg	36°12'N/122°43'W	na	na	16.8
PLCA7	05A0217_b	9/1/13	148 kg	37°19'N/123°25'W	37°05'N/123°40'W	2	18.9
PLCA8	05A0258_b	9/1/13	171 kg	37°21'N/123°25'W	37°24'N/123°37'W	2	19.2
PLCA9	05A0313	9/2/13	81 kg	37°23'N/123°28'W	36°02'N/124°38'W	20	18.5
PLCA10	12A0136	9/3/13	109 kg	37°02'N/123°38'W	37°11'N/124°48'W	20	19.0
PLCA11	11A0712	9/3/13	100 kg	37°01'N/123°38'W	31°38'N/130°52'W	25	19.6
PLCA12	05A0197_b	10/6/13	90 kg	35°41'N/122°45'W	36°00'N/123°25'W	10	16.1

Description of behavioral trends

Basking activity (> 3m) accounted for 16.7% of the daytime records. Basking rates between individuals was highly variable, ranging from 3.5 to 55.2% of the daytime records. Swordfish exhibited a mixed-layer distribution (between >3 m and the thermocline) during 26.8% of the daytime records. The mixed distribution closely matched the distribution of prey and forage on the vessel's sonar systems. Prolonged dives beneath the thermocline accounted for 56.5% of the daytime records. Dives below the thermocline ranged in depth from 68 to 479 m with a mean dive depth of 305 m.

Dive times

For all archived data sets (n=7) morning descents were initiated within 20 min PST of am civil twilight (mean = 11.8 ± 2.9 min) and evening ascents were initiated within 14 min PST of sunset (mean = 4.6 ± 1.3 min). For evening ascents, swordfish returned above the thermocline less than 20 min PST after pm civil twilight (mean = 13.1 ± 1.8 min). Daytime dives below the thermocline ranged in duration from 9 to 884 min, with a mean dive duration of 154.8 ± 25.2 min. Descent rates were greater during daytime dives (11.2 ± 0.9 m/min) than descent rates of dawn crepuscular dives (6.0 ± 0.3 m/min). Similarly, daytime ascent rates were greater (12.6 ± 1.6 m/min) than crepuscular ascents when fish returned to the mixed layer at dusk (5.7 ± 0.9 m/min). Descent rates of dawn crepuscular dives were similar to ascent rates of dusk crepuscular ascents, with mean values of 6.0 ± 0.3 m/min and 5.7 ± 0.9 m/min, respectively.

For two archived data sets with deployment durations greater than 10 days, thermocline depth estimates increased over the course of the track from a minimum of 24 m to a maximum of 63 m. For the same individuals, the rate of basking decreased over the course of the track from a maximum of 47% of the daylight hours to 0.1% of daytime activity. Maximum nighttime depth also increased over the course of track #'s 10 and 12 as individuals travelled in a westerly direction. Basking rates were greatest when daily thermocline depth was <36 m, with minimal basking activity when thermocline depth exceeded 50 m.

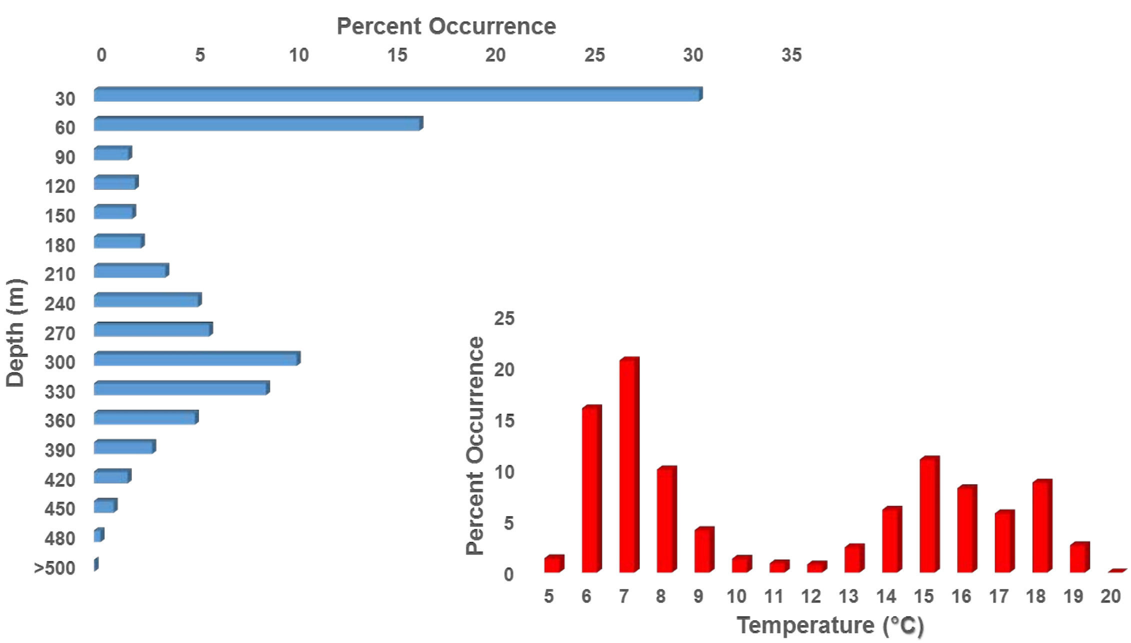

Figure 2. Collective Depth and temperature distribution for all short-term (7) PLCA swordfish

Temperature distribution

Collectively, the ambient temperatures recorded during all tracks ranged from 5.1°C at depth to 20.05°C near the surface (Figure 2). Swordfish were tagged at sea surface temperatures (SST) ranging from 16.1 to 19.6°C with an average SST of 17.7 + 0.3°C. SST values fluctuated by month and by year, with higher surface temperatures in 2013 (17.9 + 0.2°C) relative to 2012 (16.2 + 0.2°C) with a peak in SST during September of 2013. Mean SST during basking events was 17.3 + 0.5°C. Basking activity occurred over sea-surface temperatures ranging from 13.6 to 20.05°C, with peak occurrence around 18°C. The mean daily thermocline depth for the seven short-duration tracks within the PLCA was 37.5 + 1.9 m, corresponding to mean temperatures ranging from 12.4 to 15.0°C. Although temperatures as low as 5.05 °C were recorded at depth, the average temperature experienced below the mean thermocline depth was 8.3 + 0.3

Discussion

This work reports on the vertical movements of swordfish tagged within the PLCA, an area that has been seasonally restricted to California's primary swordfish fleet since 2001 (Carretta et al., 2003). Fine-scale vertical movements were analyzed to assess depth distribution trends within the PLCA and the degree to which swordfish vertical distribution overlaps with species of concern (i.e., leatherback sea turtles). These data suggest that swordfish within the PLCA are capable of exhibiting highly variable movements during the day with a consistently shallow (within the upper mixed layer) distribution at night. Although the daytime movements overlap with those described in other studies (Carey and Robison, 1981; Takahashi et al., 2003; Sepulveda et al., 2010; Dewar et al., 2011), high variability in mean daytime depth may provide challenges for directed fisheries that target swordfish during the day. The most consistent depth distribution for PLCA swordfish occurred at night, at shallow depths that overlap with the distribution of numerous other pelagic predators and protected species.

Tagging operations

All swordfish movements described in this study were obtained from fish that were tagged using harpoon-based techniques, a method that has been used extensively to tag swordfish around the globe (Carey and Robinson, 1981; Dewar et al., 2011). Harpoon techniques provide a relatively non-invasive tag attachment method that has been shown to result in minimal post-tagging mortality (Sepulveda et al., 2010). In the present study, only one swordfish tag did not report any information (tag #12A0138). Although post-tagging disposition cannot be verified, it is possible that the additional mass of the trailing archival tag may have prevented transmissions from the surface, particularly if it were to have been shed prior to the programed release date.

Although harpoon-based tagging techniques are ideal with respect to minimizing handling and tagging stress, these methods require the swordfish to be basking, a behavior not commonly observed when swordfish occur offshore (Dewar et al., 2011). Therefore, the majority of the tagging operations were performed in areas of complex bathymetry (i.e., sea mounts, canyons, bumps) as well as locations that have been historically associated with basking and harpoon activities (Monterey Bay, CA; Pers. Comm. Mike McCorkle, Santa Barbara). Thus, the data presented from the short-term deployments of this study may be more representative of swordfish when they are proximal to areas of complex bathymetry and ocean currents.

Depth distribution

Collectively, time-series data revealed consistent nocturnal movements within the upper mixed layer throughout the hours of darkness, similar to those described previously for swordfish off southern California (Sepulveda et al., 2010; Dewar et al., 2011; Sepulveda et al., 2015). The consistently shallow (>30 m) nocturnal distribution reported here supports the vulnerability of swordfish to DGN gear and the productive history of the fishery within the PLCA (Hanan et al., 1993). However, targeting swordfish above the shallow thermocline at night increases the potential for non-target interactions, a factor that led to the establishment of the PLCA and further complicates development of west coast fishery alternatives (Carretta et al., 2003; Sepulveda et al., 2015).

Within the PLCA, the primary species of concern is the leatherback sea turtle, a species that undergoes trans-Pacific movements from traditional nesting grounds on the beaches of Indonesia to forage within the productive waters of the PLCA (Benson et al., 2007). Leatherback depth distribution data for the PLCA suggests that this species spends the vast majority of the time above the thermocline both during the day and at night. Given the significant overlap between swordfish and leatherback movements at night, spatial separation is limited to the daylight hours, when swordfish are below the thermocline (in this study, 57% of the day).

In this study, swordfish daytime depths were much more variable than those previously recorded off southern California (Sepulveda et al., 2010; Dewar et al., 2011; Figure 3) and other regions within the Pacific (Abecassis et al., 2012; Evans et al., 2014). Movements oriented towards the surface, near the thermocline, and at depths well below the thermocline were present in all swordfish tracks. Collectively, the suite of movements recorded in this work have all been previously described for swordfish in the Pacific (Takahashi et al., 2003; Sepulveda et al., 2010). Heightened variability in depth distribution has been suggested to be in response to the distribution of prey, as the waters off southern California and within the PLCA are known foraging areas for swordfish. The variable swordfish depths recorded in this study were consistent with the distribution of organisms observed on the research vessel Malolo's sonar and echo-sounder systems (Furuno CH-250). Further, surface and thermocline oriented movements were more prevalent in areas more proximal to the coastline and with shallower thermocline depths. The finding of both surface and DSL-oriented movements for the same individuals may be the product of swordfish moving between productive areas along the central California coast, a region with complex bathymetry including numerous canyons and seamounts.

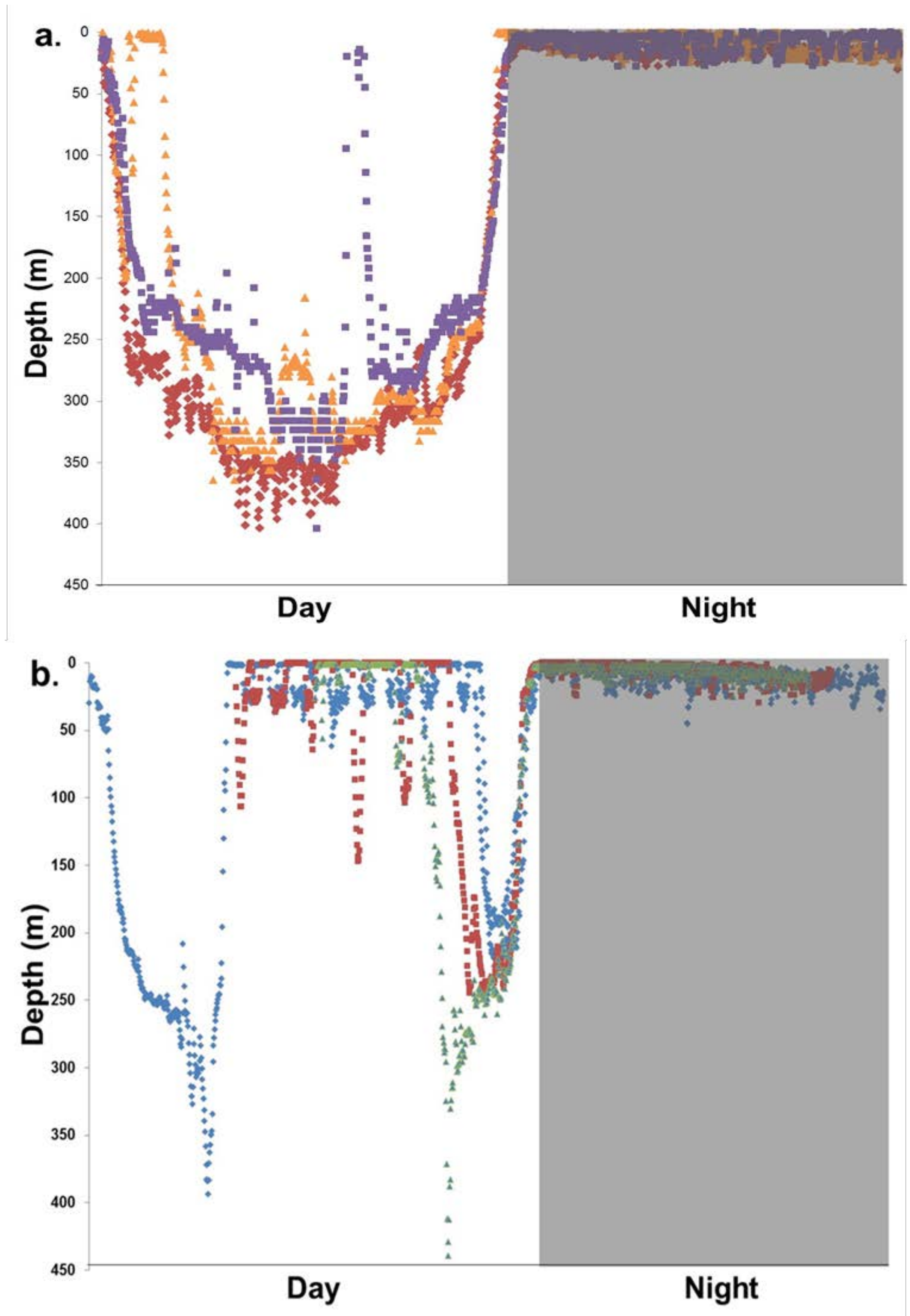

Figure 3: Overlapping depth distribution data for a 24-h period for three swordfish tagged off both (a.) southern California; and (b.) central, CA (waters of the PLCA); light sections represent daytime and shaded sections night. Southern California data included for comparison.

How these data relate to PLCA fisheries

Based on reported depth distribution, the optimal time and depth to target swordfish within the PLCA would be near the surface at night, similar to that of both DGN and traditional shallow-set longline gear (Ward et al., 2000). Support for this comes from over two decades of DGN landings from the PLCA and the slow decline of this fishery since the inception of the seasonal closure in 2001 (Carretta et al., 2003; PFMC, 2014). In the early years of the fishery the CA DGN fleet was relatively transient, with effort largely dependent upon oceanic conditions, swordfish availability and weather. In some years, the bulk of the landings occurred in waters above Point Conception (now within the PLCA boundaries), with initial efforts focused along central and northern California, progressing southward as water temperatures declined in the fall and early winter (Hanan et al., 1993). The seasonal prohibition of DGN activities within the PLCA consequently reduced the range of the fishery, preventing domestic fishers from following the resource migrations through the northern portions of California.

Given the average nocturnal depth of swordfish in this study (8m), modifications to DGN gear that reduce its threat to the leatherback sea turtles and other sensitive species are limited. Based on the swordfish vertical movements described in this study and those of leatherback sea turtles, if the minimum net depth were increased from the current 36 ft. (~11m) to 72 ft. (~22m), there would likely be a marked decrease in leatherback interactions. Results from this study indicate that if the minimum net suspender length were doubled from 36 ft to 72 ft, then target catch rates would be effectively reduced by 18%, a scenario that is not likely to be economically viable

Harpoon

All swordfish tagged in this study exhibited surface basking behaviors, indicating that swordfish are vulnerable to harpoon-based capture within the PLCA. Although harpoon operations are not currently common above Point Conception, the harpoon fishery was once a vibrant industry that exploited the west coast swordfish resource throughout the northern ports of California (Coan et al., 1998). Swordfish availability and weather, remain the primary factors associated with the success and viability of harpoon techniques. Elevated sea states, wind and large swell affect the ability to locate swordfish at the surface and also pose significant navigational and safety issues given the length of the extended bow pulpits (6 to 9m) used in harpoon operations (Coan et al., 1998).

The rate of basking observed in this study (16.7%) was greater than that reported for swordfish off southern California, further suggesting that a harpoon fishery may be viable within the PLCA (Sepulveda et al., 2010). However, factors such as market dynamics and high operational costs (i.e., slip fees, diesel, and insurance) must be considered for artisanal or non-industrial gear types to be successful. Because of the low catch per unit effort (CPUE) associated with harpoon fisheries (Bedford and Hagerman, 1983), fish must be received at a high price-point in order for operations to be financially viable. Because the harpoon fishery is open-access, has little to no bycatch and, product is received at a premium market price, harpoon-based techniques remain an option for smaller scale operations within the PLCA.

Deep-set fisheries

The use of depth to selectively target swordfish and avoid non-target species has been used in several fisheries around the world (Beverly et al., 2009). Experimental trials suggest that deep-set buoy gear and longline operations may be an option for harvesting swordfish with minimal protected species interaction (Sepulveda et al., 2015). With regards to overall bycatch across all species, the DSBG outperformed the DSLL gear which had considerable shark bycatch. Depth data from this study suggests that swordfish movements are more variable within the PLCA than within the SCB (Sepulveda et al., 2010; Dewar et al., 2011). However, given that the majority (57%) of the daytime records revealed consistent sub-thermocline movements, and that depth distribution seemed to shift to a deeper and more consistent profile upon moving offshore, deep-setting may offer a way to target swordfish within the PLCA while minimizing non-target interactions. In the present study, deep-set buoy efforts were explored during swordfish tagging cruises with limited success. The DSLL gear was deployed during research cruises that were limited temporally and spatially. Consequently, the use of deep-set techniques to selectively target swordfish within the PLCA have not yet fully been explored and will require a more robust assessment of catchability, economic return and non-target interaction. The economic and bycatch metric analyses (Appendix IV) based on these gear types from other regions show potential promise for both these fisheries.

Conclusions and long-term recommendations

This work provides the first steps towards understanding swordfish movements within the Pacific Leatherback Conservation Area. In the case of west coast swordfish, the protection of a critically endangered species has led to the underutilization of a domestic resource, economic loss and an increase in foreign imports (Rausser et al., 2009). Understanding spatial differences in habitat utilization provides the key to identifying ways to enable domestic operations to continue to exploit healthy stocks, while minimizing non-target interactions. The coupling of species specific movement patterns, biology and innovative harvest methods is necessary for developing sustainable solutions for the west coast swordfish resource. The data collected in this study, the cross fisheries comparisons and the initial work on DSLL and DSBG gear in the PLCA and off Southern California provides a first step towards identifying low-impact methods that enable domestic operations to continue to operate within the PLCA.

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Financial Report (PIER)

Project # R/OPCCFRW-4A

This project was a collaborative effort between the NOAA Southwest Fishery Science Center and the Pfleger Institute of Environmental Research (PIER). The collective cost of this work was shared among several resources including state (CFR-West Program, Ocean Protection Council), federal (Cooperative Research Program) and non-federal sources (George T. Pfleger Foundation).

The final request with associated justification is ($6,763.32) is included in Appendix I.

An itemized list of all expenses incurred during the award period is attached (Appendix II). All requested expenditures have been previously itemized with justification and grant category description in the periodic expenditure requests.

Summary of work performed in relation to the expenses listed in the original grant.

CFR-West funds were utilized to conduct field research experiments within the Pacific Leatherback Closure area during 2012 and 2013. With the submission of the final financial request (Appendix I) project R/OPCCFRW-4A has expended all of the proposed project funds. Project expenses followed closely those presented in the original budget summary, with an itemized list of funds expended presented in the Excel spreadsheet below.

Funding categories included

Salary for project staff: PI Sepulveda, Aalbers and PIER staff (Cptn. Fullam and technician Tutunjian). Additional contractual funds were included for NOAA contractor and project collaborator, H. Gjertsen.

Travel expenses included those associated with the transport of PIER staff to and from the location of the field research activities (Monterey CA) as well as conference associated costs related to the presentation of results.

Supply expenses associated with the tag deployments and gear trial exercises. These funds included tag re-fitting costs, bait and deep-set buoy gear fishing materials as well as expendable items (i.e., ice, ice chests, monofilament and batteries).

Equipment items were not purchased with any of the CFR-West/OPC funds.

Other and Special Items category included funds for spotting aircraft, outreach associated venue and hosting costs, as well as vessel costs.

Indirect Costs were charged at a reduced rate at 25%. And not included on the NOAA economist contract ($26,000). Year 2 IDC was calculated on a reduced base of $61,675 which also excluded the NOAA economist contract funds.

Collectively this project expended $151,068.73, exceeding the CFR-West proposed budget ($142,529.00) by approximately 6%. This overage was primarily in the form of salary. As noted in the original submission, the additional expenses have been covered through cooperative agreements with the George T. Pfleger Foundation. The rationale for the salary overage was due to: (1) poor fishing conditions which led to the need for additional field days to meet tagging goals; and (2) difficulties associated with analyzing and meshing the very different datasets obtained from the two research group tag types (NOAA tags were GPS-splash tags and the PIER tags were MK-10 PSATs).

Financial Report (NOAA)

This project was a collaborative effort between the NOAA Southwest Fishery Science Center and the Pfleger Institute of Environmental Research (PIER). The collective cost of this work was shared between the CFR-West Program, Ocean Protection Council and NOAA. Over the course of the project a total of 4 cruises were conducted including 40 days at sea. The current grant paid for 10 of these days while NOAA paid for the remainder.

Summary of work performed in relation to the expenses listed in the original grant.

	2012 projected	2012 used	2013 projected	2013 Used
Vessel Charter 4 days 6,500/day	26,000	26,000		
Vessel Charter 10 days 6,500/day			65,000	65,000
Technician time 1.5 months			8,436	8,436

Funding categories included

Ship Charter: The F.V. Ventura II was chartered for 10 days using funds provided by this grant. Cost was 6,500 a day.

Salary for project technician: Owyn Snodgrass 8,436 for 1.5 months including fringe benefits.

Outreach and Publications

The information collected from this work has been presented at: (1) The International Tuna Conference in Arrowhead, CA (May, 2013; May, 2014 and May, 2015), (2) The American Fisheries Society meeting (Little Rock, AR, 9/2013), (3) A regional information sharing workshop hosted by PIER and NOAA (La Jolla CA, 1/2013 & 1/2014), and (4) Pacific Fisheries Management Council and Advisory Body Meetings (HMS MT 1/2013; PFMC, Tacoma WA, 4/2013; 4/2015, Newport CA,).

Two information sharing workshops were hosted by the PIER and NOAA research groups after the 2013 & 2014 Highly Migratory Species Management Team Meetings. The outreach events included current harpoon and CA driftnet fishers and was intended to garner support for the ongoing research and also gather information from important stakeholders on the historic PLCA fishery. The event was well received due to the keen interest fishers have in re-establishing fishing operations within the PLCA.

Manuscripts in Preparation

CHUGEY A. SEPULVEDA, SCOTT A. AALBERS, CRAIG HEBERER, SUZY KOHIN and HEIDI DEWAR. In Preparation. Movements of the swordfish *Xiphias gladius* within the Pacific Leatherback Closure Area, PLCA. *Fisheries Research*.

Heidi Gjertsen, Stephen Stohs, Heidi Dewar, Chugey Sepulveda, Scott Aalbers, and Craig Heberer Comparing bycatch and economic metrics in U.S. swordfish fisheries. *Fisheries Research*

Data Handling and Availability

Project data has been continually shared with managers at the NOAA SWFSC and remains archived on the Pfleger Institute of Environmental Research tagging database. The PIER database houses information on the movements of nearly a dozen species tracked off southern California and remains accessible upon request to researchers around the world. All of the time series data are backed up on the PIER server and local network as well as cloud services provided through both Wildlife Computers (Richmond WA) and the Loggerhead Instruments data storage platform (Sarasota FL).

Summaries of the data used to calculate the bycatch metrics have been provided to the PFMC and are publically available on their website. The actual data are subject to confidentiality agreements, but much of this data can be requested directly from NOAA offices managing observer data.

Project Media

Tagging video and additional photo documentation has been uploaded to the Pacific Fisheries Management Council website

http://www.pcouncil.org/wp-content/uploads/K5b_SUP_SWFSC_PPT2_MAR2014BB.pdf, as well as the PIER website. Multi-media presentations were provided at several public venues including stakeholder workshops, PFMC management team meetings and scientific venues (International Tuna Conference).

APPENDIX 1:
FINAL REQUEST

Sepulveda CFR-West/California Sea Grant request for Reimbursement 5/2015

5. Summary of work performed in relation to the expenses listed in the invoice.

Final request: During this period PIER researchers worked with NOAA scientists on the publication of two scientific manuscripts. All data has been analyzed and the final figures are being prepared for publication.

CFR-West funds were used to purchase/pay for

1. Salary requested during this period was for manuscript preparation and data analysis for both PI Sepulveda and PIER researcher Aalbers. The total salary expenses incurred during this period were $11,747.44 . We have requested the bulk of the remaining funds ($6268.32) to cover these costs. All additional salary expenses ($5,479.12) and associated overhead will be covered through cooperative agreements with the George T. Pfleger Foundation.

2. Travel: Conference fees ($495) for presenting the final products associated with this work at the International Tuna Conference have been requested from the Travel Category. Copy of check is attached.

Check	12/30/2014	12873	Inter-American Tropical Tuna Commission		-495.00
Salary Calculation (Through March, 2015)				Hours	
Senior Researcher Time (excluding payroll burden)				56	$ 2,692.31
Payroll Burden (38.90%)					$ 1,047.31
RA Aalbers Time from (excluding payroll burden)				168	$ 5,250.00
Payroll Burden (52.530%)					$ 2,757.83
Vessel Captain Time (excluding payroll burden)				0	$ -
Payroll Burden (54.060%)					$ -
Paul Time				0	$ -
Total Payroll (excluding payroll burden)					$ 11,747.44
Vessel Use Calculation (Through March, 2015)					
Whaler				0	$ -
Malolo				0	$ -
Total Vessel Use					$ -
Indirect Burden (25%)					$ 3,060.61
Total Grant Request (Expenses plus Salary plus Vessel Use)					**$ 15,303.05**

MPA REQUEST FOR REIMBURSEMENT

Grant Number: 11-027	**Project Number: R/OPCCFRW-4A**	
Name of Grantee: Pfleger Institute of Env. Research	**Purchase Order Number:** S9000089	**Invoice Number: 6**
PROJECT TITLE: **Targeting swordfish deep during the day to reduce bycatch**	**CA Sea Grant accounting #: SEA_______ (include 4 digit number)**	
Address (include zip code): PIER: 2110 S Coast Hwy 101 Ste F Oceanside CA 92054	**Project Leader:**	**Sepulveda**
	Billing Period Covered: 9/20/14	5/7/15

Category Reimbursement *(insert rows as needed for additional budget categories)*	**Category Budget**	**Costs Incurred this Period**	**Total Cost to Date**	**Remaining Balance**
Salaries	$ 61,716.00	$ 6,268.32	$ 63,313.96	$ (1,597.96)
Benefits	$ 9,400.00		$ 9,400.00	$ -
Supplies	$ 9,146.00		$ 7,844.89	$ 1,301.11
Travel	$ 4,300.00	$ 495.00	$ 4,003.15	$ 296.85
Tuition Fee Remission				$ -
Other Costs	$ 21,600.00		$ 21,600.00	$ -
Ship Time	$ 16,000.00		$ 16,000.00	$ -
				$ -
				$ -
Indirect	$ 20,367.00		$ 20,367.00	$ -
TOTAL	$ 142,529.00	$ 6,763.32	$ 142,529.00	$ -
TOTAL AMOUNT REQUESTED		**$ 6,763.32**		

NOTE: All receipts for expenditures over $250 and all travel/mileagel expenses required.

*NOTE: Equipment/supplies over $250 require supporting documentation. Hotel, airfare and travel expense form required for all travel.

CERTIFICATION OF GRANTEE/CONTRACTOR

I hereby certify that the above costs were incurred in the performance of work required under the agreement and are consistent with the amounts evidenced by supporting documents and expenditures.

Signature	Printed Name and Title	Date
	Jennifer Thirkell Accounting	5/7/15

Email the invoice to Sea Grant and keep the original for your records.

ATTN: Rose Madson

Email: sgfiscal@ucsd.edu

	Budgeted	Billed
Year 1		
Year 2		
Year 3		

Grant #: 11-027
TITLE:
Invoice #
Project: R/OPCCFRW-4A
Institution:PIER
Lead PI: C.Sepulveda

Staff Title on Project	Number Hours	Rate	Total
PI	x	x$/hr	$
C.Sepulveda	56	48.08	2692.31
S.Aalbers	168	31.25	5250
P.Tutunjian			

Total must equal total salaries on invoice 7942.31

APPENDIX 2

TOTAL EXPENDITURES

	Type	Date	Num	Name	Memo	Amount
1.51 - CFR						
	Check	10/15/2012	11792	Get the Gaff		-625.00
	General Journal	11/05/2012	Chase		Research Supplies	-323.08
	Check	12/04/2012	11859	Wildlife Computers	Invoice #CW0908-P	-1,075.00
	General Journal	01/03/2013	Chase		Travel	-128.20
Total 1.51 - CFR						-2,151.28
TOTAL						**-2,151.28**

Salary Calculation (Through December, 2012)	Hours		
Senior Researcher Time (excluding payroll burden)		$	-
Payroll Burden (38.90%)		$	-
RA Aalbers Time from (excluding payroll burden)		$	-
Payroll Burden (52.530%)		$	-
Vessel Captain Time (excluding payroll burden)	40	$	1,170.87
Payroll Burden (54.060%)		$	632.97
Total Payroll (excluding payroll burden)		$	1,803.84
Vessel Use Calculation (Through December, 2012)			
Whaler	0	$	-
Malolo		$	-
Total Vessel Use		$	-
Indirect Burden (25%)		$	988.78
Total Grant Request (Expenses plus Salary plus Vessel Use)		**$**	**4,943.89**

Type	Date	Num	Name	Memo	Amount
General Journal	02/12/2013	Chase		Conferences	-310.50
General Journal	02/12/2013	Chase		Conferences	-229.52
General Journal	02/12/2013	Chase		Conferences	-27.61
General Journal	02/12/2013	Chase		Research Supplies	-377.32
General Journal	02/12/2013	Chase		Conferences	-133.92
Check	05/20/2013	12076	Tuna Conference	VOID:	0.00
Check	05/30/2013	12087	Tuna Conference	C.Sepulveda & S. Aalbers Conferenc	-342.00
General Journal	06/04/2013	Chase		Conference Supplies	-158.75
General Journal	06/04/2013	Chase		Field Research Supplies	-430.00
General Journal	06/04/2013	Chase		Field Research Supplies	-338.01
General Journal	06/04/2013	Chase		Field Research Supplies	-79.82
Check	06/04/2013	12094	San Diego Hydraulics		-1,261.00
General Journal	06/04/2013	Chase		Field Research Supplies	-12.82
General Journal	07/09/2013	Chase		Research Supplies	-183.74
General Journal	07/09/2013	Chase		Research Supplies	-82.73
	08/15/2013		Heidi Gjertsen	Contract Labor	-13,000.00
					-16,967.74
					-16,967.74

Salary Calculation (Through June, 2013)	Hours		
Senior Researcher Time (excluding payroll burden)	32	$	1,538.46
Payroll Burden (38.90%)		$	598.46
RA Aalbers Time from (excluding payroll burden)		$	-
Payroll Burden (52.530%)		$	-
Vessel Captain Time (excluding payroll burden)	40	$	1,170.87
Payroll Burden (54.060%)		$	632.97
Total Payroll (excluding payroll burden)		$	3,940.76
Vessel Use Calculation (Through June, 2013)			
Whaler	0	$	-
Malolo		$	-
Total Vessel Use		$	-
Indirect Burden (25%)		$	1,977.12
Total Grant Request (Expenses plus Salary plus Vessel Use)		**$**	**22,885.62**

Type	Date	Num	Name	Memo	Amount
Check	08/22/2013	12206	Andrew White	Aicraft Spotting Services	-4,000.00
General Journal	09/06/2013	Chase		Research Supplies	-160.51
General Journal	09/06/2013	Chase		Postage	-12.22
General Journal	09/06/2013	Chase		Business Meals	-292.64
General Journal	09/06/2013	Chase		Research Supplies	-77.15
General Journal	09/06/2013	Chase		Business Meals	-227.34

Check	09/09/2013	12225	Andrew White	Invoice #2	-1,547.40
Check	09/26/2013	12255	HP Welding	Field Research Supplies	-150.00
General Journal	10/05/2013	Chase		Business Meals	-31.95
General Journal	10/05/2013	Chase		Business Meals	-60.08
General Journal	10/05/2013	Chase		Research Supplies	-743.44
General Journal	10/05/2013	Chase		Travel Expense	-674.70
General Journal	10/05/2013	Chase		Auto Expense	-40.00
General Journal	10/05/2013	Chase		Business Meals	-254.34
General Journal	10/05/2013	Chase		Research Supplies	-379.27
Check	10/10/2013	12262	Andrew White	Contract Labor	-2,000.00
General Journal	11/03/2013	Chase		Business Meals	-125.53
General Journal	11/03/2013	Chase		Travel Expense	-238.10
General Journal	11/03/2013	Chase		Research Supplies	-124.28
General Journal	11/03/2013	Chase		Auto Fuel	-37.71
General Journal	11/03/2013	Chase		Business Meals	-176.58
General Journal	11/03/2013	Chase		Research Supplies	-85.61
General Journal	11/03/2013	Chase		Travel Expense	-213.49
General Journal	11/03/2013	Chase		Travel Expense	-238.15
General Journal	11/03/2013	Chase		Auto Fuel	-77.65
General Journal	11/03/2013	Chase		Business Meals	-379.69
General Journal	11/03/2013	Chase		Research Supplies	-267.70
General Journal	11/03/2013	Chase		Slip Fee	-1,000.00
					-13,615.53

Salary Calculation (Through November, 2013)	Hours	
Senior Researcher Time (excluding payroll burden)	160	$ 7,692.31
Payroll Burden (38.90%)		$ 2,992.31
RA Aalbers Time from (excluding payroll burden)	144	$ 4,500.00
Payroll Burden (52.530%)		$ 2,363.85
Vessel Captain Time (excluding payroll burden)	16	$ 468.35
Payroll Burden (54.060%)		$ 253.19
Paul Time	240	$ 4,800.00
Total Payroll (excluding payroll burden)		$ 23,070.00

Vessel Use Calculation (Through November, 2013)		
Whaler	0	$ -
Malolo	80	$ 15,000.00
Total Vessel Use		$ 15,000.00
Indirect Burden (25%)		$ 12,921.38
Total Grant Request (Expenses plus Salary plus Vessel Use)		**$ 64,606.91**

General Journal	12/08/2013	Chase		Research Supplies	-256.19
Check	12/30/2013	12356	Wildlife Computers	Invoice #DW1153-P	-800.00
Check	01/16/2014	12370	Tuna Conference		-485.00
Check	01/16/2014	12369	Tuna Conference		-485.00
Check	02/06/2014	12401	Justin Stopa	Contract Labor	-300.00
General Journal	03/04/2014	Chase		Travel Expense	-312.00
Check	04/03/2014	12471	Heidi Gjertsen	Contract Labor	-13,000.00
					-15,638.19

Salary Calculation (Through March, 2014)	Hours		Requested
Senior Researcher Time (excluding payroll burden)	112	$ 5,384.62	$ 5,384.96
Payroll Burden (38.90%)		$ 2,094.62	$ 1,155.08
RA Aalbers Time from (excluding payroll burden)	96	$ 3,000.00	$ 3,000.00
Payroll Burden (52.530%)		$ 1,575.90	$ 771.18
Vessel Captain Time (excluding payroll burden)	0	$ -	
Payroll Burden (54.060%)		$ -	
Paul Time	16	$ 320.00	$ 320.00
Total Payroll (excluding payroll burden)		$ 12,375.13	$ 10,631.22

Vessel Use Calculation (Through March, 2014)			
Whaler	0	$ -	
Malolo	0	$ -	
Total Vessel Use		$ -	
Indirect Burden (25%)		$ 3,093.78	$ 2,657.80
Total Grant Request (Expenses plus Salary plus Vessel Use)		**$ 31,107.10**	$ 28,927.21
		Actual	**Requested**

Check	08/25/2014 12695	Heidi Gjertsen	Invoice dated 8/20/2014			-6,500.00	
Check	09/15/2014 12738	Heidi Gjertsen				-6,500.00	
						-13,000.00	$ 11,580.30

Salary Calculation (Through August, 2014)	Hours		
Senior Researcher Time (excluding payroll burden)	0	$ -	
Payroll Burden (38.90%)		$ -	
RA Aalbers Time from (excluding payroll burden)	32	$ 1,000.00	$ 1,000.00
Payroll Burden (52.530%)		$ 525.30	
Vessel Captain Time (excluding payroll burden)	0	$ -	
Payroll Burden (54.060%)		$ -	
Paul Time	0	$ -	
Total Payroll (excluding payroll burden)		$ 1,525.30	$ 1,000.00
Vessel Use Calculation (Through August, 2014)			
Whaler	0	$ -	
Malolo	0	$ -	
Total Vessel Use		$ -	
Indirect Burden (25%)		$ 3,631.33	$ 1,821.92
Total Grant Request (Expenses plus Salary plus Vessel Use)		**$ 18,156.63**	$ 14,402.22

				Actual	**Requested**
Check	12/30/2014 12873	Inter-American Tropical Tuna Commission		-495.00	$ 495.00

Salary Calculation (Through March, 2015)	Hours		
Senior Researcher Time (excluding payroll burden)	56	$ 2,692.31	
Payroll Burden (38.90%)		$ 1,047.31	
RA Aalbers Time from (excluding payroll burden)	168	$ 5,250.00	
Payroll Burden (52.530%)		$ 2,757.83	
Vessel Captain Time (excluding payroll burden)	0	$ -	
Payroll Burden (54.060%)		$ -	
Paul Time	0	$ -	
Total Payroll (excluding payroll burden)		$ 11,747.44	$ 6,268.32
Vessel Use Calculation (Through March, 2015)			
Whaler	0	$ -	
Malolo	0	$ -	
Total Vessel Use		$ -	
Indirect Burden (25%)		$ 3,060.61	
Total Grant Request (Expenses plus Salary plus Vessel Use)		**$ 15,303.05**	$ 6,763.32

Appendix III:
NOAA Cruise Reports 2012 and 2013

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
SOUTHWEST FISHERIES SCIENCE CENTER
8604 LA JOLLA SHORES DR.
LA JOLLA, CA 92037-1508

CRUISE REPORT

VESSEL: F/V *Ventura II*

CRUISE NUMBER: SWO-DSLL-2012

CRUISE DATES: October 23, 2012 – November 7, 2012

PROJECT: Swordfish Deep-set Longline 2012

ITINERARY
Leg 1: Vessel departed Ventura on October 23, 2012 and proceeded to fishing grounds offshore of Central California, north of 34N and west of Point Conception (Figure 1). Deep-set longline operations were conducted targeting the daytime depths of swordfish. Opportunistic trolling for tuna and tuna like species was conducted between sets. Vessel returned to Ventura on October 30, 2012 to exchange personnel and resupply.

Leg 2: Vessel departed Ventura on October 31, 2012. Deep-set longlining operations remained west of Point Conception and were focused on areas both north and south of 34N based on oceanographic conditions and prior swordfish catch data. Opportunistic trolling for tuna and tuna like species was conducted between sets. Vessel returned to Ventura on November 7, 2012.

OBJECTIVES
1) Target swordfish off California deep during the day using longline gear to test the feasibility of this approach in the California Current.
2) Catch swordfish, opah and albacore to characterize catch of major marketable species
3) Release healthy swordfish, sharks, opah and albacore with a combination of conventional, satellite and archival tags for studies of migrations and essential habitat.
4) Collect biological samples opportunistically including otoliths, fin spines, scales, gonads, muscle, heart, reproductive tissue, stomach contents, and whole specimens.
5) Conduct oceanographic measurements in the fishing areas using CTD deployments and monitoring acoustic backscatter.
6) Document all animals to determine catch depth and characterize species composition and distribution

LONGLINE SET AND TROLLING METHODS
During all fishing operations, backscatter within the water column between the surface and 750 m was recorded using a 50/200 kHz echo sounder and data logging.
Longline sets targeting swordfish were conducted during the daytime. For each set, approximately 12 miles of monofilament mainline was set with an average of 288 branchlines, 36 feet in length. 18/0 C style hooks were baited with whole mackerel or sardine. Time-depth recorders were used to document hook depth across all sets and hook numbers. Fishing depths ranged from 107 m to 460 m. with an average depth of 235 +/- 12 m.

Trolling for albacore occurred opportunistically during transit, soak time or between longline sets during daytime hours. Trolling gear was either handlines, commercial outrigger trolling lines or rod and reel lines with surface lures. Albacore are an additional marketable species occurring in the California Current.

RESULTS

Seventeen longline sets and approximately 35 hours of trolling were completed. A total of 4899 hooks were deployed and 260 animals were caught and documented (Table 1). Most animals were brought on board and measured, tagged and sampled for DNA before being released. One swordfish (*Xiphias gladius*) and 42 albacore (*Thunnus alalunga*) were caught during both longline and troll operations; two of the albacore were released and the remaining animals did not survive. The swordfish was in bad condition and was retained for samples. The two species that composed the majority of the longline catch were blue sharks (*Prionace glauca*) and opah (*Lampris guttatus*). Ten blue sharks and 29 opah were kept for sampling. 138 blues sharks and three opah were tagged and released. Two of the tagged opah were released with mk10-PAT pop-off archival tags and the third with a conventional billfish tag. A number of uncommon deep water species including the pomfret (*Taractes rubescens*), lancetfish (*Alepisaurus ferox*) and the king of the salmon (*Trachipterus altivelis*) were also caught. No interactions with marine mammals, seabirds or sea turtles occurred.

Table 1. Catch summary for the swordfish deep-set longline research cruise. Longline (LL) catch during sets, Trolling, DNA collected, and number of conventional and electronic tags deployed by species.

Species	LL	Trolling	Total	DNA	Conv. Tag	Elect. Tag
Alepisaurus ferox	2	0	2	1	0	0
Coryphaena hippurus	1	0	1	1	0	0
Isurus oxyrinchus	1	0	1	1	1	0
Lampris guttatus	37	0	37	32	1	2
Prionace glauca	157	0	157	147	138	0
Ruvettus pretiosus	1	0	1	0	0	0
Taractes rubescens	9	0	9	8	0	0
Thunnus alalunga	2	40	42	39	0	0
Trachipterus altivelis	9	0	9	7	0	0
Xiphias gladius	1	0	1	1	0	0
Total	**220**	**40**	**260**	**237**	**140**	**2**

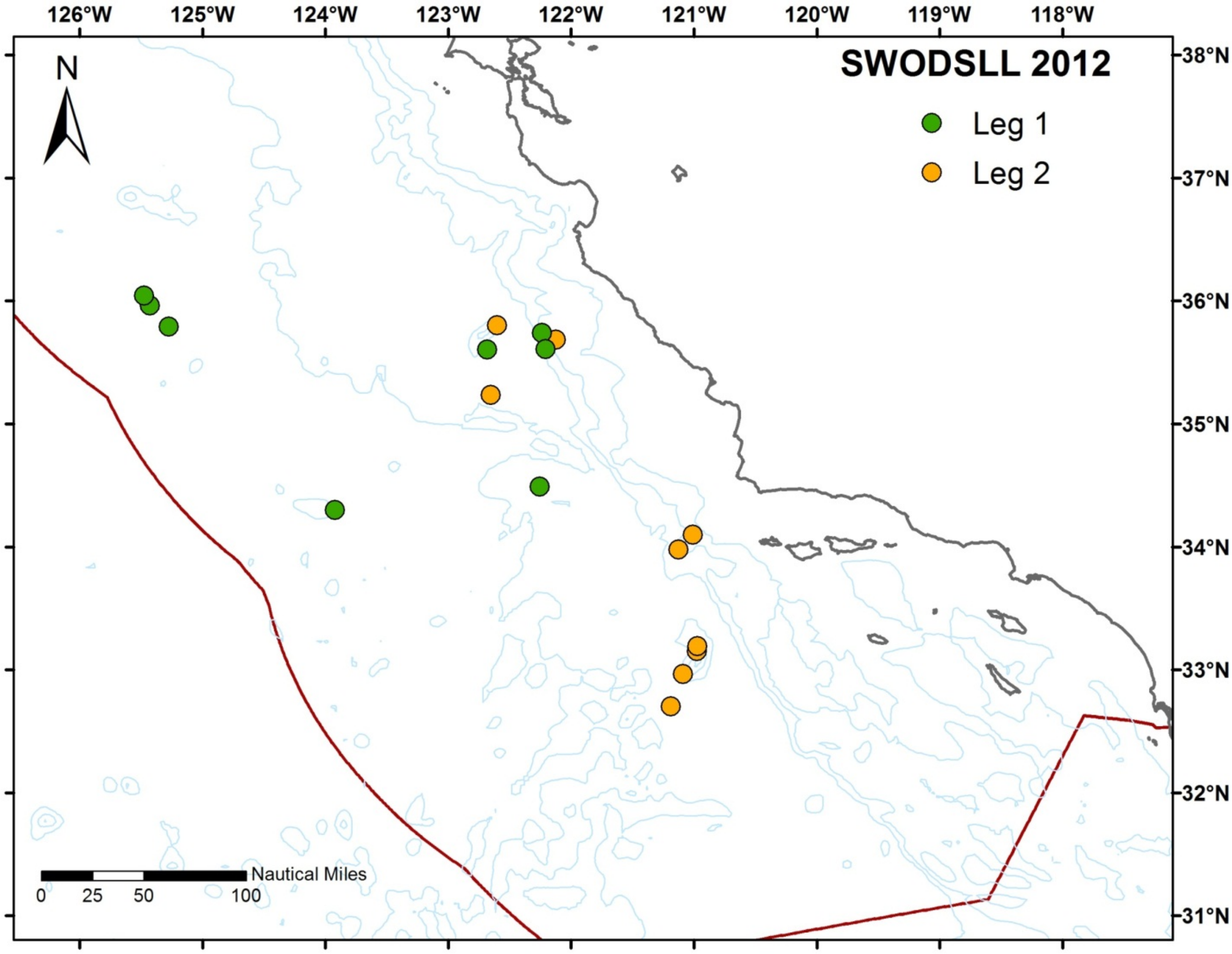

Figure 1. Set locations of the swordfish deep-set longline cruise during October and November 2012.

MISCELLANEOUS

1) The disposal of fish caught was in accordance with NOAA Administrative order 202-735B dated January 25, 1989.

2) The cruise leaders held a pre-cruise meeting aboard the vessel with the ship's crew before departure and a post-cruise meeting upon termination of the cruise. The charter captain and crew were well experienced and knowledgeable and all operations proceeded smoothly.

PERSONNEL

Leg 1:	Suzanne Kohin – cruise leader	SWFSC
	James Wraith	SWFSC
	Owyn Snodgrass	SWFSC
	Nick Wegner	SWFSC
	Kevin Lewand	Monterey Bay Aquarium
	Diego Cardenosa	Columbia
Leg 2:	Heidi Dewar – cruise leader	SWFSC
	John Hyde	SWFSC
	Owyn Snodgrass	SWFSC
	Emily Bell	U.C. Berkley
	Helena Aryafar	SWFSC
	Dave Holts	SWFSC

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
SOUTHWEST FISHERIES SCIENCE CENTER
8901 LA JOLLA SHORES DR.
LA JOLLA, CA 92037-1508

CRUISE REPORT

VESSEL: F/V *Ventura II*

CRUISE NUMBER: SWO-DSLL-2013

CRUISE DATES: October 14, 2013 – November 3, 2013

PROJECT: Swordfish Deep-set Longline 2013

ITINERARY

Leg 1: Vessel departed Monterey on October 14, 2013 with only Monterey Bay Aquarium staff onboard. Trolling fishing operations were conducted targeting tuna and tuna like species to examine potential for live retention. After the conclusion of the government shutdown, SWFSC staff and volunteers met the boat in Ventura on October 18 and proceeded to fishing grounds. Deep-set longline operations were conducted targeting the daytime depths of swordfish. Opportunistic trolling for tuna and tuna like species was done during the day while the vessel was transiting between longline fishing locations. Vessel returned to Monterey on October 22, 2013 to exchange personnel.

Leg 2: Vessel departed Monterey on October 23, 2013. As in Leg 1, deep-set longline operations were conducted targeting the daytime depths of swordfish. Opportunistic trolling for tuna and tuna like species was done during the day while the vessel was transiting between longline fishing locations. Vessel returned to Ventura on November 3, 2013.

OBJECTIVES

1) Target swordfish deep during the day using a deep-set longline deployed at target depths of > 200 m.
2) Troll for albacore opportunistically.
3) Target swordfish, opah and albacore for biological and oceanographic studies.
4) Release healthy swordfish, sharks and opah with a combination of conventional and satellite tags for studies of migrations and essential habitat.
5) From all species, collect biological samples opportunistically including otoliths, fin spines, scales, gonads, muscle, heart, reproductive tissue, stomach contents, and whole specimens.
6) Conduct oceanographic measurements in the fishing areas using CTD or TDR deployments.
7) Document all animals caught on either longline or troll gear to determine species, sex and size distribution by area.

LONGLINE SET AND TROLLING METHODS

Longline sets targeting swordfish were done during the daytime. At set locations, document temperature depth profiles and when possible also conductivity and oxygen profiles. For each of the sets, approximately 10 nautical miles of monofilament mainline was set with an average of 208 branchlines, 36 feet in length. 18/0 C style hooks were baited with whole mackerel or sardine. Time-depth recorders were used to document hook depth across all sets and hook numbers. The average fishing depth, determined by the average depth of all hook recorded was 247 m. No interactions with marine mammals, seabirds or sea turtles occurred.

Trolling occurred opportunistically during daytime transit and during longline soak periods. Trolling gear was a combination of handlines, commercial outrigger trolling lines and rod and reel lines with surface lures. Two to eight lines were set during trolling operation. Barbless hooks were used when targeting albacore for archival tagging. No interactions with marine mammals, seabirds or sea turtles occurred.

RESULTS

Nineteen longline sets and over 50 hours of trolling were completed. A total of 3919 hooks were deployed and 167 animals were caught and documented (Table 1). Most animals were brought onboard and measured, tagged and sampled for DNA before being released. A total of four swordfish (*Xiphias gladius*) were caught during deep-set longline operations. The two species that composed the majority of the longline catch were blue sharks (*Prionace glauca*) and opah (*Lampris guttatus*). Troll catch was exclusively skipjack (*Katsuwonus pelamis*) and albacore tuna (*Thunnus alalunga*). Neither of these two species were caught on longline. A total of fifty blue sharks were tagged and released with conventional tags for movement and migration studies. In addition, electronic tags were deployed on some fish. One swordfish and one opah were released with mk10-PAT pop-off archival tags. In addition, two opah were released with pop-off temperature loggers that simultaneously measured and recorded ambient water temperature and the internal muscle temperature of the fish. Lastly, one blue shark was released with a satellite positioning (SPOT) tag.

Biological samples and measurements were conducted during the cruise in support of ongoing studies (Table 1). DNA samples were collected from 120 fish (nine different species); the majority of dna samples were collected from blue sharks, albacore, and opah. Internal temperature measurements of the swimming musculature, eye muscle, heart, and viscera were made on several opah to examine potential adaptations to cold water. Detailed morphometric information and biological samples were collected from dead animals collected during all fishing events. Stomachs and reproductive tracts were collected to examine feeding habits and food web relationships. Tissue biopsies were collected from sharks, albacore, swordfish and opah in support of studies conducted at Stoney Brook University investigating niche overlap and separation using isotope analysis.

Table 1. Catch, collection and tag summary for the swordfish deep-set longline research cruise. Catch includes longline (LL) catch troll. Number of individuals samples for DNA and number of conventional and electronic tags deployed by species.

Species	LL	Troll	Total	DNA	Conv. Tag	Elect. Tag
Thunnus orientalis	4	0	4	4	0	0
Isurus oxyrinchus	1	0	1	1	0	0
Lampris guttatus	20	0	20	17	0	3
Prionace glauca	66	0	66	51	50	1
Brama japonica	10	0	10	10	0	0
Katsuwonus pelamis	0	30	30	5	0	0
Thunnus alalunga	0	28	28	28	0	0
Trachipterus altivelis	4	0	4	1	0	0
Xiphias gladius	4	0	4	3	0	1
Total	**109**	**58**	**167**	**120**	**50**	**5**

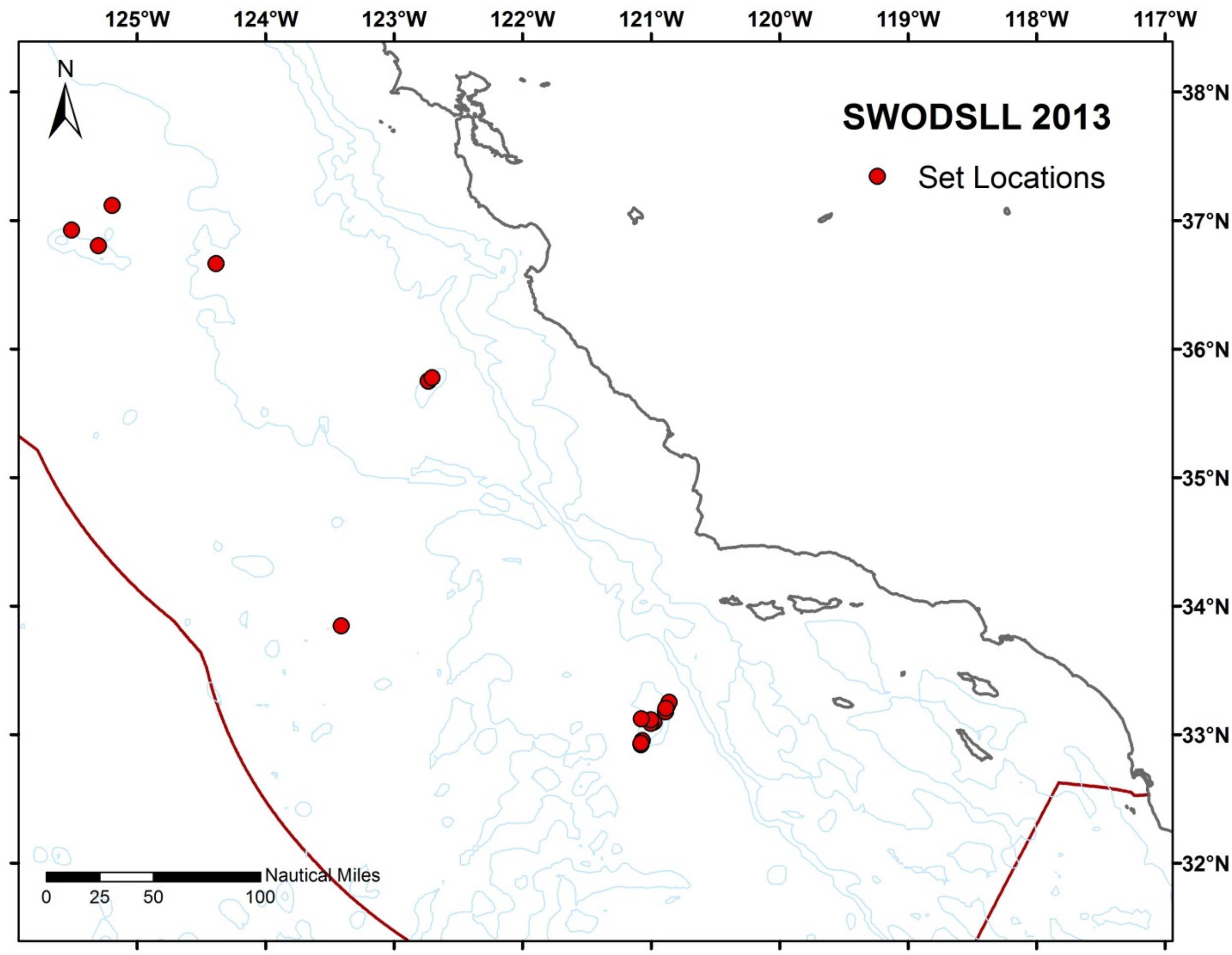

Figure 1. Set locations of the swordfish deep-set longline cruise.

MISCELLANEOUS

1) The disposal of fish caught was in accordance with NOAA Administrative order 202-735B dated January 25, 1989.

2) The cruise leaders held a pre-cruise meeting aboard the vessel with the ship's crew before departure and a post-cruise meeting upon termination of the cruise. The charter captain and crew were well experienced and knowledgeable and all operations proceeded smoothly.

PERSONNEL

Suzanne Kohin – cruise leader Leg 2	SWFSC
Heidi Dewar – cruise leader Leg 1	SWFSC
Owyn Snodgrass	SWFSC
Nick Wegner	SWFSC
John Hyde	SWFSC
Helena Aryafar	SWFSC
Nathan Mertz	SWFSC
Megan Ouyang	SWFSC
Kevin Lewand	Monterey Bay Aquarium
Billy Perry	Monterey Bay Aquarium

Appendix IV: Final Report: A comparison of bycatch and economic metrics across U.S. Fisheries targeting or retaining swordfish.

Prepared by: Heidi Gjertsen, Stephen Stohs, Heidi Dewar, Chugey Sepulveda, Scott Albers and Craig Heberer

1. Background

Due to concerns about the reduction in vessels and landings by the CA drift gillnet (DGN) swordfish fishery and the continuing interest in both reducing bycatch and revitalizing west coast swordfish fisheries, a number of research projects on alternative gear options to target swordfish are underway, including those on deep-set buoy gear (DSBG) and deep-set longlines (DSLL). The goals are to find gear configurations that are effective at catching swordfish while maintaining low bycatch rates of turtles and other species. The development of an economically feasible/low bycatch gear for swordfish fishing along the U.S. West Coast was identified in the 2010 HMS SAFE Report as a high priority research need (PFMC 2011).

In addition to field trials of the two gear types, a second important component of this research is to examine the two experimental gears in the broader context of all U.S. fisheries that land swordfish. The specific focus is on U.S. fisheries with available, high quality data on bycatch, landings, costs and revenues. There are a number of specific motivations for this research.

1) Create standardized metrics for bycatch and economic measures that will allow for broad comparisons across diverse fisheries using different gear types.
2) Check frequently made claims that DGN is a high-bycatch fishery through direct comparison with other HMS fisheries.
3) Address PFMC request for research on alternate gear options as complements to DGN, with the understanding that bycatch and economic considerations are important to any decisions made about alternative gears.
4) Include all U.S. fisheries that land swordfish, including deep-set methods where the main target is tunas, since the two gears being tested currently both involve deep day-time sets.
5) Build upon previous work that focuses solely on turtle bycatch by examining all protected species bycatch as well as blue sharks that are caught in relatively large numbers.

This approach provides a way to evaluate the possible roles of diverse methods in a revitalized west coast swordfish fishery by gauging their potential for increasing swordfish landings while limiting bycatch.

2. Fisheries

All U.S. commercial fisheries that commonly catch swordfish as a primary or secondary target were included. While a comparison to international fisheries also is ultimately of interest, few nations have observer programs of comparable quality and scope to those of the U.S. By contrast, U.S. programs generally have complete landings data and at least some observer coverage, though the percentage of observed effort varies across all fisheries. This first step makes use of the high quality bycatch and landings data for U.S. fisheries to make comparisons across commercial fishing methods, gear types, time periods and geographic regions.

Fisheries under comparison include CA DGN^{S}, California deep-set longline (CA DSLL^{T}), California harpoon (CA HPN^{S}), Hawaii shallow-set longline (HI SSLL^{S}), Hawaii deep-set longline (HI DSLL^{T}), Atlantic pelagic longline (ATL LL^{S,T}), and Atlantic buoy (ATL BG^{S}); superscripts indicate the main target(s) of the fishery with "S" for swordfish and "T" for tuna. We also examine the California shallow-set longline fishery (CA SSLL^{S}) for a historical comparison to shallow-set longline swordfish fishery bycatch levels prior to the implementation of requirements to use circle hooks and finfish bait. The CA and HI DSLL^{T} fisheries primarily target tuna, but are included because of their relevance to considering deep-set longline for targeting swordfish.

Data used to compute metrics were selected for periods of time when the management regime relating either to gear or time area closures was consistent. For example, the HI SSLL^{S} fishery analysis only uses data collected after 2004 when circle hooks and finfish bait were required, and CA DGN^{S} fishery analysis only includes data from the period after 2001. By contrast, for the CA SSLL^{S} fishery, the bycatch and landings data used in the analysis are from the pre-2005 period when J-hooks and squid bait were utilized, as shallow-set longline gear was not authorized when the HMS FMP was implemented in 2004, effectively closing the fishery. These data are included as a historical example because they provide the only swordfish longline data for California waters.

3. Methods

Data Sources and Limitations

Data sources include landings receipt databases (e.g. PacFIN), observer data for catch and bycatch counts, and cost-earnings studies for costs and profits. Logbook data are used where needed to supplement observer and landings data, for instance to quantify Hawaii non-swordfish catch.

The data are subject to a number of limitations:

- Levels of observer coverage vary across fisheries from no coverage to full coverage;
- Profit and cost metrics may not be representative due to short data windows or differences in data collection methodology.
- Profit metrics are linked to the differences in dollar value of different species landed.
- Fisheries operate on different scales and have operated over different periods, which can impact both profit metrics and bycatch. However scale and effort are normalized by looking at the takes relative to landings.
- Bycatch species populations and bycatch rates from different areas are not necessarily directly comparable. The composition and gear vulnerability of bycatch species can vary in the different regions fished. For example, leatherback populations are much more depleted in the Pacific than they are in the Atlantic, suggesting that given level of leatherback bycatch is less problematic in the Atlantic than the Pacific. Also, the species

composition differs between where the HI DSLL^{T} fishery operates, the California Current, and the Atlantic.

These differences highlight the need to conduct experimental fisheries when considering gear modifications or operating in new areas and to conduct standardized economic studies across fisheries.

Bycatch Metrics

Three main categories of bycatch were considered (Table 3). The first is “high priority” protected species (HPPS). These species are either listed under the Endangered Species Act or designated as a strategic stock under the Marine Mammal Protection Act. HPPS are highlighted in dark grey in Table 3 to indicate protected species considered to be at higher risk than others (e.g. ESA listed or closer to Potential Biological Removal (PBR) limits). Unidentified individuals of a species group (e.g. whales, turtles…) were included in the high priority category if others of the same species group were in this category.

The second category is “other protected species” (highlighted in light gray). The third category is non-protected species that are not marketable (20% or less retained) caught in relatively high numbers (the catch in number is 5% or greater) with high dead discards (dead discard to live discard ratio greater than or equal to 0.25). Blue shark is included as an example which fits these criteria, but there may be additional species to include.

The bycatch metrics for this report are metric tons of swordfish landings and total marketable species landings per take for the three species categories described above (L/B ratios). The unit of bycatch is number of individuals taken. A “take” is defined as an interaction from observer data, regardless of whether the animal was released alive, injured or dead. The number of annual takes is estimated using the expected number of annual takes, defined as the ratio of observed annual takes to annual percent of observer coverage (bycatch per unit of effort, or BPUE). The L/B ratio is calculated as the ratio of landings in metric tons summed over included years to estimated takes summed over all included years. There are alternative methods for estimating “actual” takes, but as they are still under review, this simple, straightforward estimation method is used. Total marketable species landings are included since for a number of the fisheries under comparison (CA and HI DSLL^{T} and ATL LL^{S,T}), landings of marketable species other than swordfish make up a significant portion of total landings and are economically important.

Economic Metrics

Economic metrics are summarized in Table 2. They include measures of variable costs, revenues, and profits based on recent prices and market species landings standardized by metric tons landings catch for comparison to bycatch rates. All revenues, prices, and costs are converted to 2012 dollars using the U.S. Bureau of Economic Analysis Implicit Price Deflator for Gross Domestic Product.

Data from cost-earnings surveys are used to estimate the variable cost per metric ton of swordfish landings and total landings. Variable costs are those that vary by fishing trip and include fuel, oil, bait, ice, communications, provisions, gear, labor, and maintenance/repairs. Most cost-earnings surveys are only conducted over one or two years; thus the period covered by cost data is generally shorter for the fisheries in the study than are the landings or observer data series. Some years may be more costly than others (e.g. high fuel prices) or fishing may be particularly bad, which adds a degree of uncertainty to comparisons across fisheries; however, the general economic results of interest can still be determined.

Landings and market price data (or revenue data, where available) from landing receipts data collection programs such as PacFIN are used to estimate the revenue per metric ton of swordfish landings and/or total landings for each fishery. Since revenue is equal to landings multiplied by ex-vessel price, swordfish revenue per metric ton of swordfish landings can be interpreted as a weighted average price per metric ton of landings. The average price per pound of swordfish over the period is also reported. Revenue from swordfish only and total revenue from all landings are presented. Subtracting costs from revenues provides estimates of the profit per metric ton of swordfish landings and/or total landings.

<u>Commercial Volume Metrics</u>

In addition to the economic and bycatch measures we included metrics of commercial volume for comparison across fisheries, as a relevant indicator of the potential total and per-vessel production from a given fishery. Four commercial volume metrics are provided, including average annual swordfish landings at the (1) fleet and (2) vessel levels, and average annual total landings (mt) at the (3) fleet and (4) vessel levels (Table 2).

4. Results

We discuss results for each category of metrics in the following sections. Figures provide visual comparisons across the fisheries in our study.

<u>Bycatch Metrics Results</u>

1. The CA HPN^{S} and ATL BG^{S} have no documented protected species takes (Table 1).

2. The CA DSLL^{T} fishery had the highest production per number of protected species takes. Landings per individual protected species take were more than twice that of the next highest (HI DSLL^{T}) and more than an order of magnitude higher than the historic CA SSLL^{S} fishery (Figure 1). As a reminder, the CA SSLL fishery used J hooks and squid bait. It should be further noted that the CA DSLL^{S} fishery includes only one vessel and thus ignores inter-vessel variability in bycatch rates. Consequently, results for a larger fleet may differ.

3. All the Pacific-based longline fisheries show higher total production (all landings) relative to bycatch than occurred in the pre-2005 CA SSLL^{S} fishery (Figure 1). This is likely linked to the mandatory use of circle hooks and mackerel bait since 2004 which resulted in a ~90% decline in the bycatch of loggerheads and lower but significant declines in leatherback bycatch as well (Watson et al. 2005, Gilman et al. 2007). Area fished or temporary conditions in the fishery that changed over time could also have affected this comparison. Differences in species compositions, protected species population size and area fished likely contributed to the difference between the ATL LL^{S,T} fisheries and the current Pacific-based longline fisheries.

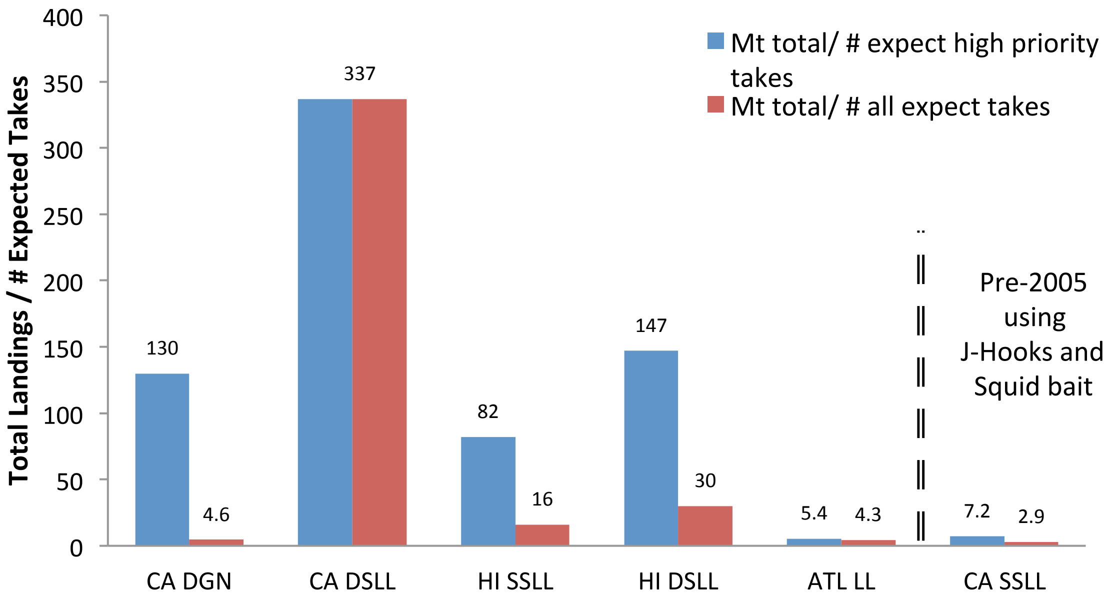

Figure 1. Comparative bycatch metrics for fisheries with protected species interactions. Metric tons (Mt) of all market species landings per high priority protected species takes by numbers (blue / left bars) and all high priority and other protected species combined by number (red / right bars). Note that there were no "other" protected species takes for the CA DSLL fishery; hence the two values are the same. Harpoon and ATL BG did not have any protected species interactions.

4. Total market species landings per expected HPPS take for the CA DGN^{S} is at a comparable level as for the HI DSLL^{T} fishery, and higher than in the HI SSLL^{S} fishery (Figure 1).

5. Comparisons of swordfish landings alone to bycatch may be misleadingly low for fisheries which land a significant amount of other market species besides swordfish (e.g. CA DGN^{S}, HI DSLL^{T}, and ATL LL^{S,T}). Comparisons of total landings to bycatch are a more relevant measure for these fisheries (Table 1).

6. Since blue shark is a species with some commercial landings which is neither endangered nor protected, a more relevant metric for comparison to swordfish or market species landings would be based on landed weights rather than catch counts. Regardless, the buoy gear fishery (ATL BG^{S}) showed far larger amounts of commercial landings relative to blue shark catch (Table 1) than other fisheries under comparison. It should be noted that blue sharks are not abundant where the DSBG^{S} operates and use of this gear in other areas may result in higher bycatch rates. Among other gears, swordfish and all market species landings per blue shark catch count were highest for CA DGN^{S}, indicating lower relative bycatch of blue sharks in this fishery.

7. Most takes in CA DGN are marine mammals (not high priority) (Figure 2).

8. Turtles and/or sea birds comprise most takes in other fisheries (Figure 2).

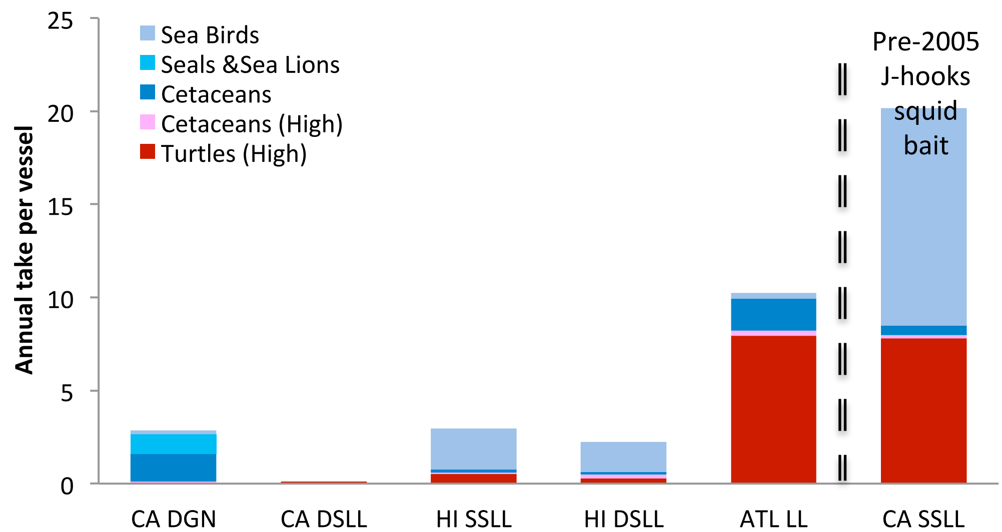

Figure 2. Comparative catch composition for fisheries with protected species interactions. Average annual takes per vessel of different protected species categories.

Economic Metrics Results

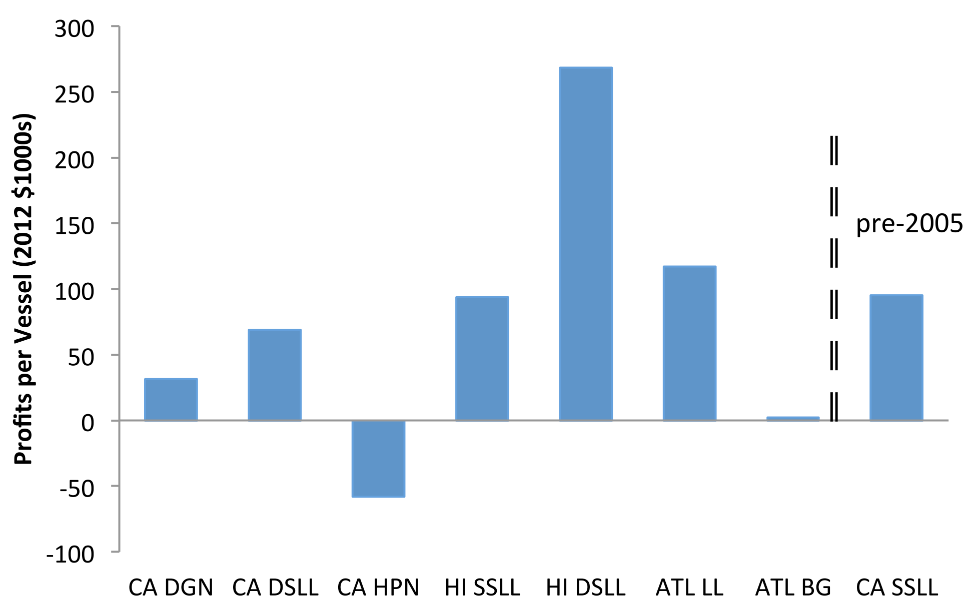

Figure 3. Average annual profit (2012 $1000s) per vessel. Values were calculated by dividing estimated average annual profits for the fleet by the average annual numbers of vessels fishing during the study period. Due to the limited period for which cost data were collected for some of the fisheries, profit estimates may vary from long-run averages.

1. Longline fisheries produced higher profits per vessel than other methods under comparison (Figure 3). These vessels tend to be larger than those used in the other fisheries compared although vessel size is accounted for by calculating profits relative to total landings (Figure 4).

2. Average price per pound of swordfish was higher for CA HPN^{S} and ATL BG^{S} than for the high volume methods (Table 2).

3. The CA HPN^{S} fishery, over the years studied, is negative for the three profit metrics (Figure 3, 4 Table 2). This may result from 1) the short periods over which economic metrics were measured, 2) the boats that responded to the economic survey may not be representative of the overall fleet and 3) that years with very low catch rates were included in this study (2008-2010). The oceanographic conditions during the time of year when harpooners typically operate were unusual over this time period. While swordfish landings over the same period for the CA DGN^{S} fishery were also lower than is typical, this fishery remained profitable over the same period indicating the added challenges of fishing for swordfish using a harpoon.

4. Profit per metric ton of total landings (Figure 4) provides a measure of the net value of output per unit weight of the resource stock, resulting in an indicator of economic viability which does not intrinsically favor larger vessels with more hold capacity. All gears except for CA HPN^{S} showed positive profitability by this metric, with profits on the range from $2000 to $3000 per metric ton of total landings for CA DGN^{S}, HI DSLL^{T}, ATL LL^{S,T}, ATL BG^{S} and the pre-2005 CA SSLL^{S} fishery. At $2900 per metric ton of total landings, ATL BG^{S} was most profitable by this metric.

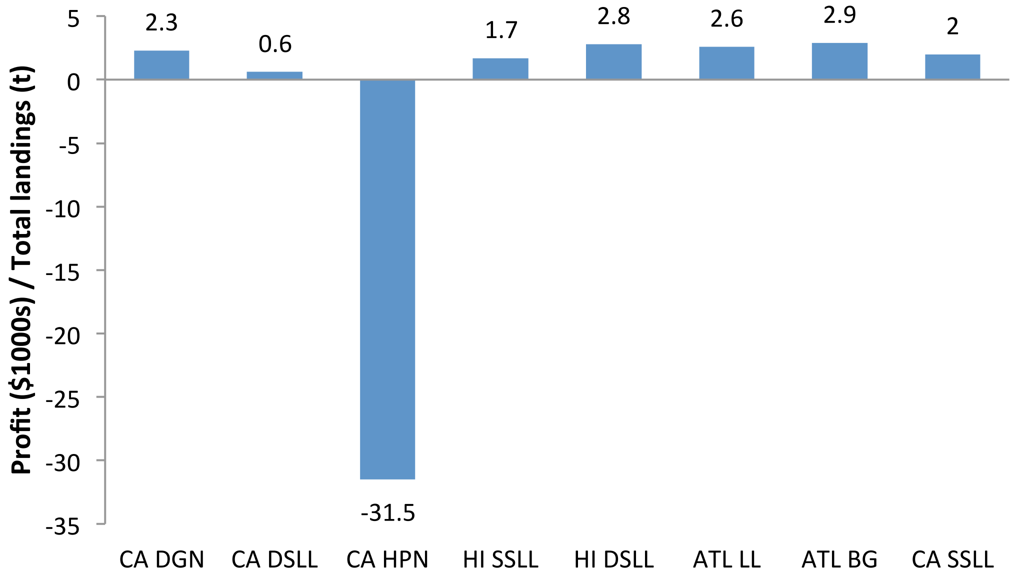

Figure 4. Profit per total landings. Values were calculated by dividing the total profits by the total landings.

<u>Commercial Volume Metrics Results</u>

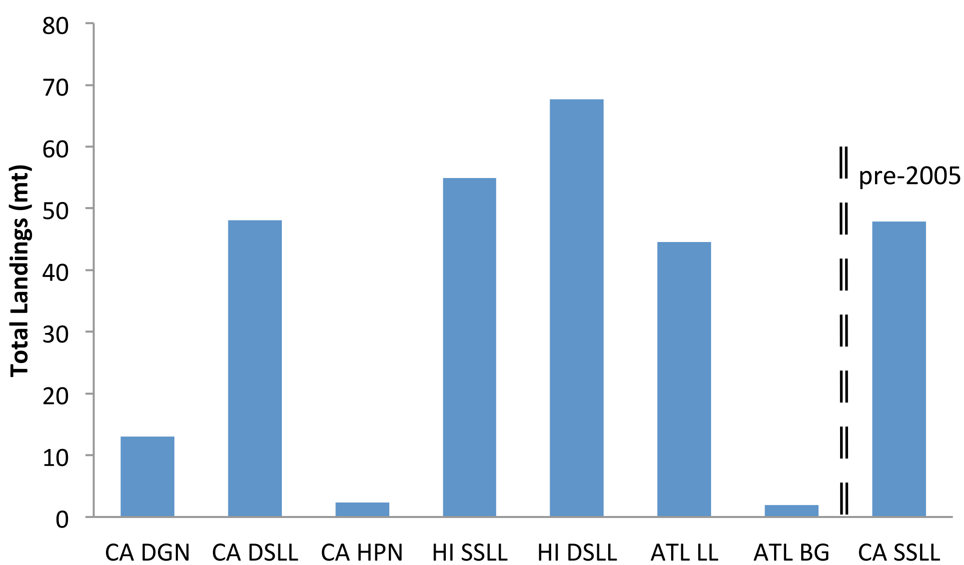

Figure 5. Comparison of commercial volume metrics across fisheries. Average annual total landings (mt) per vessel during period of analyses.

1. Longline fisheries provided by far the highest commercial volumes of production, both on a fleet and a vessel-level basis (Figure 3). CA DGN^{S} was an intermediate case, while CA HPN^{S} and ATL BG^{S} produced low commercial volumes. Again, longline vessels

tend to be larger than those used in the other fisheries, increasing their potential to produce a commercial volume of landings.

2. The comparison of production volumes across methods is confounded by the areas where the fisheries operate, as longline fisheries typically occur on the high seas while the other three gear types operate inside the 200 mile EEZ limits.

General Conclusions

1. Buoy gear appears promising due to high market prices and lower costs, making it a low-bycatch gear that is economically viable. At $2900 per metric ton of total landings, ATL BG^{S} had the highest profit per metric ton of total landings among fisheries we compared. It could be a valuable component of a west coast swordfish fishery, though it is unlikely on its own to supply a large commercial volume of swordfish to the market. Additional research is on-going to determine the potential volume of fish that could be supplied using this method.

2. Harpoon is an attractive gear in terms of bycatch, but in the last 20 years it has not appeared capable of supplying commercial volumes of swordfish. Also profitability is likely variable over time, with unprofitable results in years with poor fishing conditions. Given intermittent economic viability, harpoon can be a useful component of a portfolio type approach to targeting swordfish, while not viable as a stand-alone fishery on a large scale and continuous basis.

3. The CA DGN^{S} fishery does not appear to be a high-bycatch fishery compared to HI $DSLL^{T}$ and HI $SSLL^{S}$ fisheries or the ATL $LL^{S,T}$ fishery, which is Marine Stewardship Council certified.

4. Pacific longline fisheries rank high in terms of volume of swordfish (SSLL) and all commercial species (DSLL) landings relative to high priority bycatch species, economic measures of revenue and profitability, and production of commercial volumes of landings.

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