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A review of sperm whale (*Physeter macrocephalus*) bycatch in the California swordfish and thresher shark drift gillnet fishery

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Summary

Bycatch of sperm whales (*Physeter macrocephalus*) in the California swordfish drift gillnet fishery ('the fishery') has rarely been documented since the inception of the observer program in 1990. The fishery was observed every year since 1990 and through 2012, a total of 8,365 drift gillnet sets have been observed. Ten sperm whales have been observed entangled during six different observed sets, yielding a bycatch rate of approximately 1.1 sperm whales per 1,000 observed sets. All of the entanglements occurred during October through December in waters deeper than 1,500 meters (820 fathoms), in proximity to steep continental shelf bathymetry. Recent bycatch of sperm whales in the fishery has exceeded allowable potential biological removal (PBR) levels set under the Marine Mammal Protection Act (MMPA) (Carretta et al. 2012). Given the rarity of sperm whale entanglements, the effectiveness of current NMFS Take Reduction Plan measures (including the use of acoustic pingers) designed to reduce bycatch of this species is unknown. This summary reviews information regarding the bycatch of sperm whales in the fishery, current distribution of fishing effort, and the known distribution of sperm whales in the region. The review may provide insights for reducing the future risk of sperm whale entanglements.

Background and Data

The NMFS federal observer program for this fishery began in 1990 and the fishery has been observed annually since that time, with an average of ~15% of all fishing effort observed (Carretta and Barlow 2011). Between 1990 and 2012, a total of 8,365 fishing sets were observed (Figure 1). Mandatory regulatory changes to the fishery occurred in 1997, including the use of acoustic pingers, minimum extender lengths, and other gear modifications designed to reduce marine mammal bycatch (Barlow and Cameron 2003). During the same period, a total of 10 sperm whales were observed entangled during six fishing sets (Figure 1, Table 1). Five whales were dead, two injured, and three released alive. Previous bycatch estimates extrapolated to the entire fishery based on observed entanglements have been summarized by Julian and Beeson (1998), Carretta et al. (2004), and Carretta and Enriquez (2012). The current annual estimate of bycatch in the fishery is 3.2 animals over the 5-year period 2006-2010 (this holds true through 2012), based on observed entanglements of 2 animals in 2010 and a resulting bycatch estimate of 16 (CV=0.95) animals, resulting from low observer coverage (~12%) in the fishery that year (Carretta and Enriquez 2012). The potential biological removal (PBR) level for this stock of sperm whales is 1.5 animals (Carretta et al. 2013). The rarity of sperm whale takes in the fishery (approximately one whale per 1,000 sets observed) makes an analysis of contributing factors to the bycatch of this species difficult. Prior to the use of acoustic pingers in this fishery, there were six sperm whales observed entangled during 3,900 observed fishing sets (approximately 1.5 whales per 1,000 observed sets). Following the introduction of pingers into the fishery in 1996, there have been four sperm whales observed entangled in 4,465 observed sets through 2012 (approximately 0.8 whales per 1,000 sets observed). Although bycatch rates of sperm whales are lower in sets with pingers, entanglements are too rare to draw the conclusion that pingers are effective at reducing bycatch of this species (Carretta and Barlow 2011, Carretta et al. 2013). Acoustic pingers currently used in the fishery emit frequencies of 10-12 kHz (Barlow and Cameron 2003), which have been shown to significantly reduce the bycatch of common dolphins (*Delphinus* spp.) and beaked whales (Barlow and Cameron 2003, Carretta et al. 2008, Carretta and Barlow 2011). Watkins and Schevill (1975) found that sperm whales reacted to acoustic pingers, but the primary behavioral response appeared to be cessation of sound production and not avoidance. Sperm whales appear to be unaffected by other anthropogenic sound sources, such as detonators (Madsen and Møhl 2000).

The six sperm whale bycatch events in the fishery (totaling 10 whales) all occurred during the period late October through December, in waters deeper than 1,500 meters (820 fathoms), in close proximity to the continental shelf edge (Table 1, Figure 1). This is consistent with findings that sperm whales may associate with areas of steep bathymetry, such as shelf edges, seamounts, and submarine canyons (Jacquet and Whitehead 1996). However, sperm whales are found throughout the world's oceans wherever deep water occurs. While it is tempting to identify a seasonal pattern of bycatch in the fishery, this temptation should be avoided, as there are only six events contributing to that 'pattern'.

A better predictor of potential sperm whale bycatch in this fishery is water depth and proximity to the shelf edge, combined with the known distribution of sperm whales in this region derived from systematic research vessel survey data collected by SWFSC over the past 25 years (Hamilton et al. 2009, Barlow 2010, Becker et al. 2012, Figure 2). Research vessel sightings in the fishery area show that approximately 95% of all sperm whale sightings were detected in waters deeper than 1,000 meters (547 fathoms), even though survey effort occurred in coastal waters right up to the mainland (Hamilton et al. 2009, Barlow 2010, Figure 4). Approximately 90% of all sperm whale sightings in this region occurred in waters deeper than 2,000 meters (1,094 fathoms) (Figure 4). For comparative purposes, the sighting locations of the humpback whale (*Megaptera novaeangliae*), a species which is known to prefer coastal shelf waters, are shown along with sperm whale sighting locations in Figure 3. Habitat models of sperm whale density were developed from SWFSC sightings data, in combination with remotely-sensed and fixed oceanographic variables, such as depth (Becker et al. 2012). Models predict the lowest sperm whale densities inshore of the shelf edge south of Point Conception. The largest predicted sperm whale group sizes are associated with proximity to the 2,000 m (1,094 fathoms) isobath. North of Point Conception, predicted sperm whale densities are considerably higher closer to shore than they are in the southern California Bight. This likely reflects the narrower shelf edge in this region, in combination with the presence of submarine canyons that provide suitable sperm whale habitat close to the mainland.

Fishing effort in the fishery has largely been conducted south of Point Conception, California, since the leatherback conservation closure area to the north was implemented in 2001. Approximately half of all observed sets south of Point Conception were retrieved in waters deeper than 1,000 m (547 fathoms) between 2001 and 2012, with approximately 10% of all sets retrieved in waters deeper than 2,000 m (1,094 fathoms) (Figure 5a). In contrast, observed sets fished north of Point Conception generally occur in deeper waters. Approximately 85% of all observed sets were retrieved in waters deeper than 1,000 m (547 fathoms) and 65% of sets were retrieved in waters deeper than 2,000 m (1,094 fathoms) (Figure 5b). Strategies to reduce the bycatch of sperm whales may impact fishing effort, based on the observed distributions of historical fishing effort.

Conclusions

Although sperm whales may be sighted in any water depths within the California Current, they appear to have a clear preference for waters deeper than 1,000 to 2,000 meters (547 to 1,094 fathoms). Habitat models of sperm whale abundance that combine sightings and environmental data yield predictions of the highest sperm whale densities found seaward of the 1,000 to 2,000 meter (547 to 1,094 fathom) isobaths and the largest group sizes found in proximity to the 2,000 meter (1,094 fathom) isobath (Becker et al. 2012). The response of sperm whales to acoustic pingers currently used in the fishery to reduce bycatch is undetermined. Sperm whale bycatch in this fishery appears to be driven by the spatial overlap of fishing effort and preferred sperm whale habitat.

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Figure 1. Locations of observed fishing sets (white dots, n=8,365) and sperm whale bycatch events (red triangles, n=6, totaling 10 animals) in the California swordfish drift gillnet fishery, 1990-2012. The transition area between light blue and dark blue water represents the continental shelf edge, approximately 1,000 to 2,000 meters (547 to 1,094 fathoms) in depth.

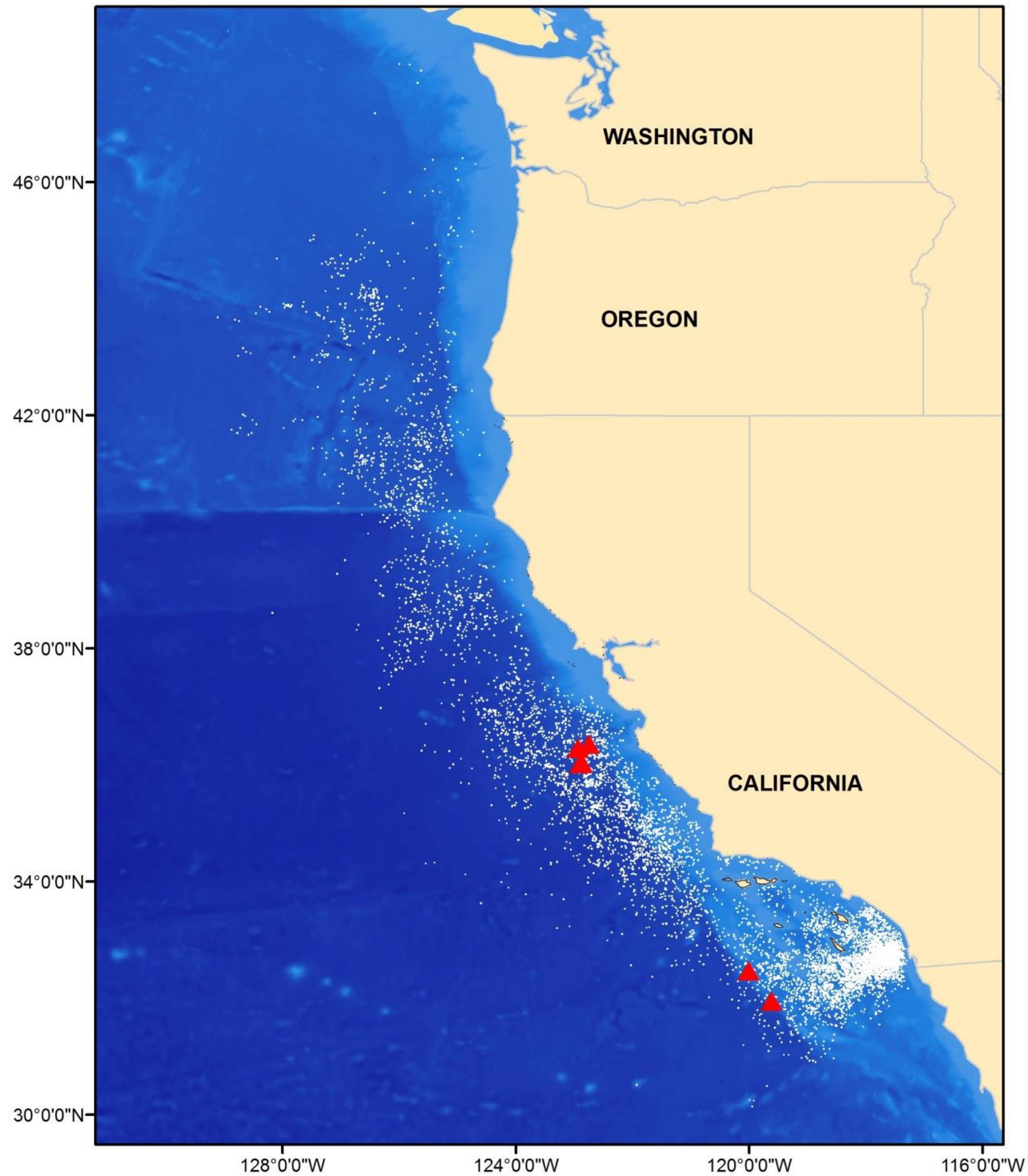

Figure 2. Systematic research vessel line-transect survey effort (gray lines) and sperm whale sightings (white circles, n=135) during SWFSC abundance surveys in the California Current, 1986-2010. The transition area between light blue and dark blue water represents the continental shelf edge, approximately 1,000 to 2,000 meters (547 to 1,094 fathoms) in depth.

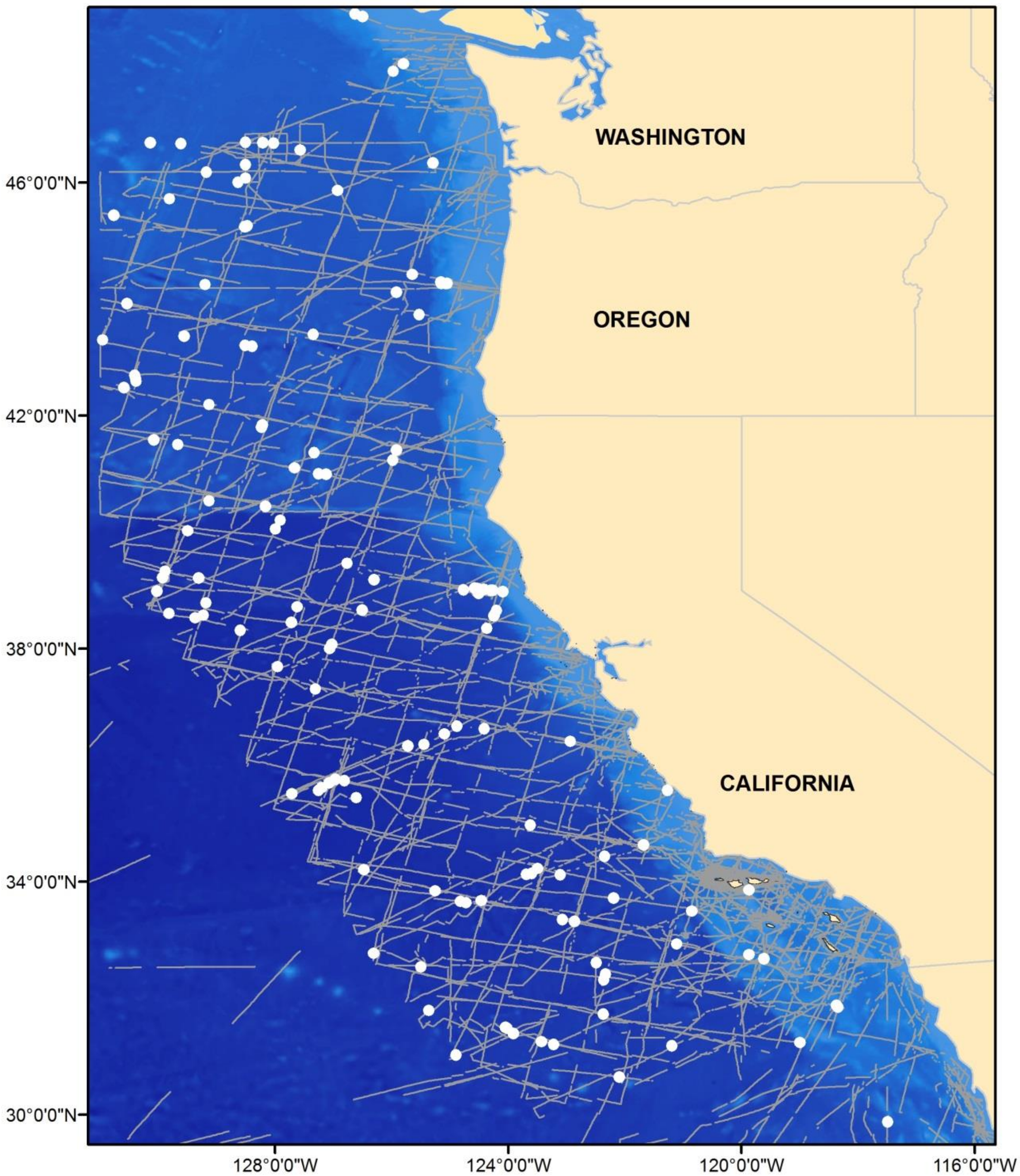

Figure 3. Comparison of systematic research vessel sightings of humpback whales (orange circles) and sperm whales (white circles) during SWFSC abundance surveys in the California Current, 1986-2010. The transition area between light blue and dark blue water represents the continental shelf edge, approximately 1,000 to 2,000 meters (547 to 1,094 fathoms) in depth.

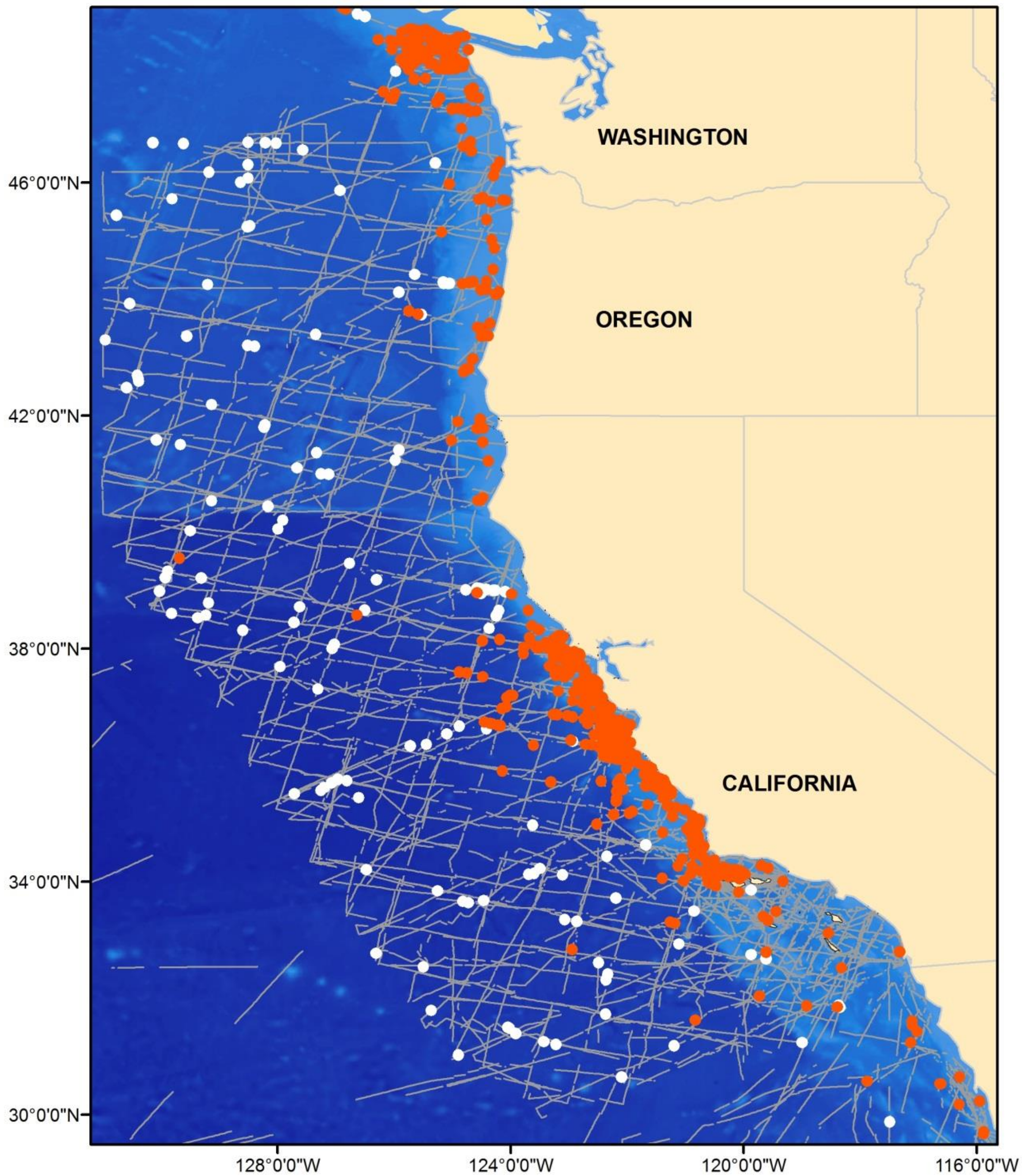

Figure 4. Depth distribution of sperm whales sighted during SWFSC research vessel (RV) surveys conducted between 1986 and 2010 in the north Pacific (top panel). The bottom panel shows the depth distribution of sperm whales from the same surveys, but limited to the geographic area off the U.S. west coast shown in Figure 2. In the fishery area off the U.S. west coast (bottom panel), approximately 95% of systematic research vessel sightings have occurred in waters deeper than 1,000 m (547 fathoms) and approximately 90% of sightings have occurred in waters deeper than 2,000 m (1,094 fathoms).

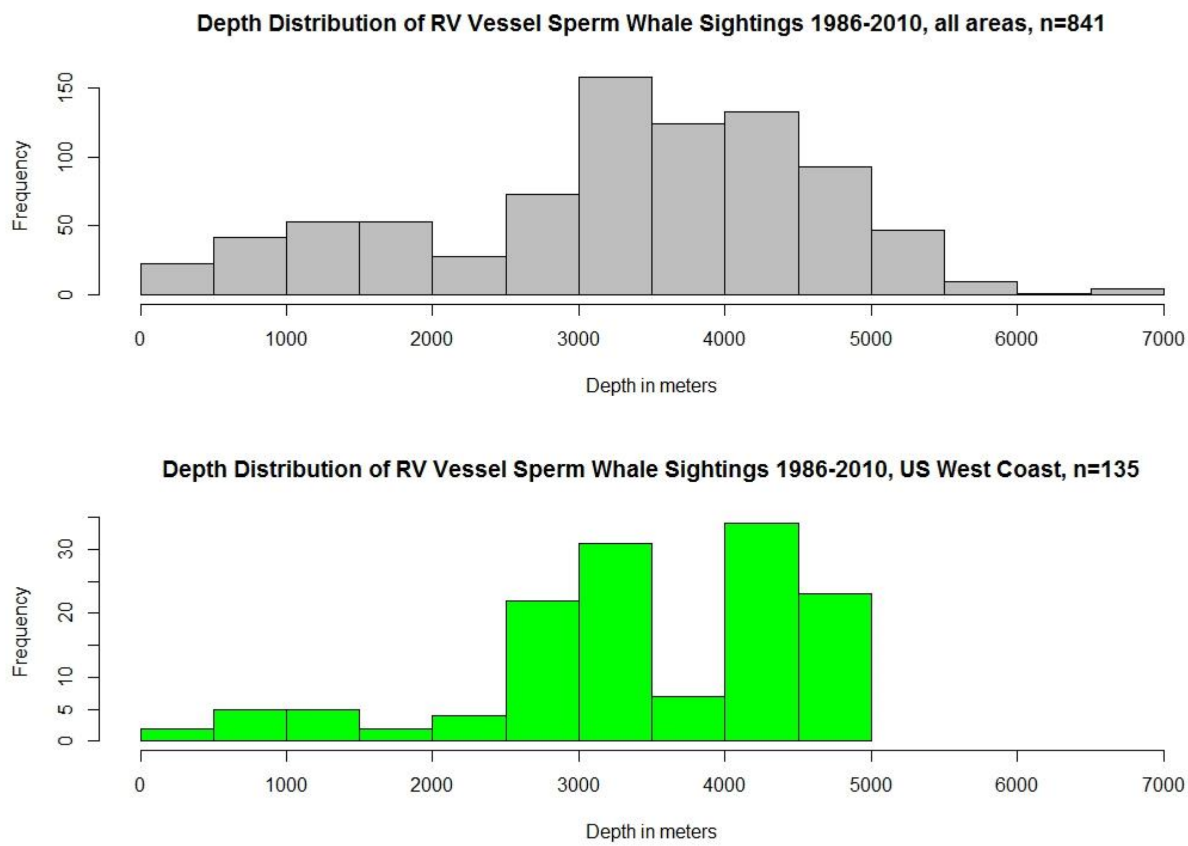

Figure 5. Distribution of net retrieval depths for observed sets in the swordfish drift gillnet fishery, 2001 to 2012. Separate histograms are shown for regions north and south of Point Conception, California, respectively. Scales for depth are identical for the two histograms, but sample sizes of observed sets are much higher for the area south of Point Conception. Approximately 65% of all sets in the northern area were observed fished in waters deeper than 2,000 meters (1,094 fathoms), while approximately 10% of all sets in the southern area were observed fished in waters deeper than 2,000 meters (1,094 fathoms).

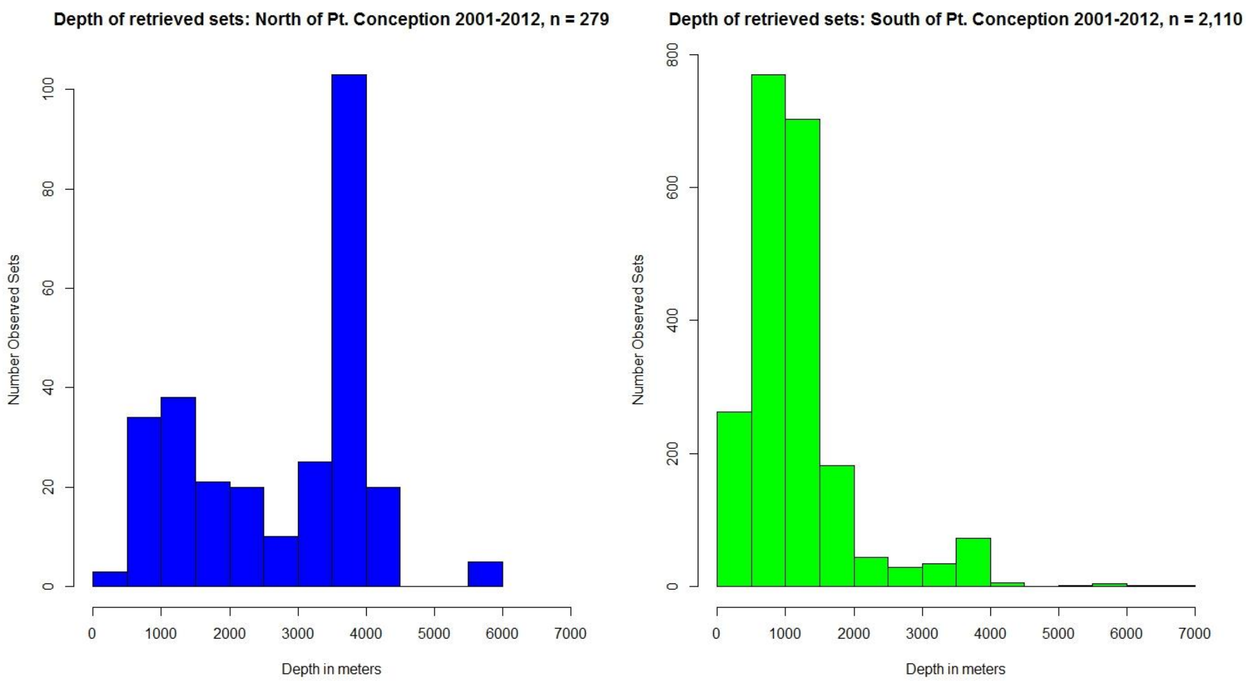

Table 1. Fishing sets in which sperm whale bycatch was observed in the California swordfish drift gillnet fishery during 1990-2012. Sets fished in 1992 and 1993 predated the use of acoustic pingers in the fishery.

latitude	longitude	Date	Depth (meters)	Depth (fathoms)	Number Acoustic Pingers	Extender Length (feet)	Number of whales entangled
36.35	-122.74	11/13/1992	3,299	1,803	0	36	3
36.28	-122.93	10/26/1993	3,089	1,690	0	36	1
32.47	-120.00	12/20/1993	1,645	899	0	46	2
36.02	-122.89	12/10/1996	2,944	1,610	33	36	1
36.03	-122.85	11/17/1998	3,290	1,799	28	36	1
31.95	-119.60	12/05/2010	2,924	1,599	40	37	2