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OCTOBER 2006

MARINE MAMMAL BYCATCH AND ESTIMATED MORTALITY IN CALIFORNIA COMMERCIAL FISHERIES DURING 2005

by

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ADMINISTRATIVE REPORT LJ-06-07

Marine mammal bycatch and estimated mortality in California commercial fisheries during 2005.

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ABSTRACT

Marine mammal bycatch in 2005 is reviewed for five commercial fisheries that operate in California waters. The fisheries are the 1) swordfish and thresher shark drift gillnet fishery; 2) market squid purse seine fishery; 3) sardine purse seine fishery; 4) anchovy, mackerel and tuna purse seine fishery; and 5) halibut and angel shark set gillnet fishery. Observer coverage was 21% in the drift gillnet fishery and less than 2% in purse seine fisheries. The set gillnet fishery has not been observed since 1994 in southern California, but fisher self-reports indicate mortalities still occur. Mortality estimates do not include 2005 stranding data where a fishery interaction was implicated as the cause of death, as these data are currently unavailable.

Observed mortalities in 225 observed drift gillnet fishery sets totaled 12 short-beaked common dolphin (*Delphinus delphis*), three long-beaked common dolphin (*D. capensis*), one California sea lion (*Zalophus californianus*) and one northern elephant seal (*Mirounga angustirostris*). Additionally, one gray whale (*Eschrichtius robustus*) was released injured. Estimated drift gillnet mortality is 57 (CV = 0.30) short-beaked common dolphin; 14 (CV = 0.57) long-beaked common dolphin; 5 California sea lions (CV = 0.97); and 5 northern elephant seals (CV = 1.00).

Observed mortalities in 29 market squid purse seine trips totaled one short-beaked common dolphin and estimated mortality is 87 animals (CV = 0.98). Additionally, 43 California sea lions and three harbor seals were released alive. No mortalities were observed in the other purse seine fisheries, but 19 California sea lions, one harbor seal, and one sea otter (*Enhydra lutris*) were released alive in 42 observed trips.

Fisher self-reports of mortalities in the set gillnet fishery totaled three California sea lions and one harbor seal. Self-reports represent minimum numbers of animals killed, as they are generally underreported by fishermen. Due to a lack of recent observer coverage, total mortality cannot be estimated for this fishery. Previously estimated levels of mortality in this fishery averaged over 1,000 sea lions, 500 harbor seals, and 30 harbor porpoise annually during 1990-94, based on 2,000 to 7,000 days of fishing effort and 5-15% observer coverage.

INTRODUCTION

Fishery Classification Criteria

The National Marine Fisheries Service (NMFS) is required under section 118 of the Marine Mammal Protection Act (MMPA) to place all U.S. commercial fisheries into one of three categories based on levels of incidental serious injury and mortality of marine mammals in each fishery (16 U.S.C. 1387 (c) (1)). Each year, NMFS publishes a List of Fisheries in the Federal Register that outlines whether fishery participants are subject to registration, observer coverage, and take reduction plan requirements. Fisheries are classified as Category I, II, or III, depending on the level of incidental takes relative to the Potential Biological Removal (PBR) for each marine mammal stock. The PBR level is defined in the MMPA as the maximum number of animals (not including natural mortalities) that may be removed from a marine mammal stock while allowing that stock to reach or maintain its optimum sustainable population. Category I fisheries are defined as those where the annual level of incidental take of one or more stocks is greater than or equal to 50% of a stock's PBR. Category II fisheries are defined as those where the annual takes of one or more stocks are greater than 1% but less than 50% of PBR. Category III fisheries include those where the overall serious injury and incidental take of all marine mammal stocks, across all fisheries that interact with these stocks, is less than 10% of the stocks' PBR level. In cases where combined takes across all fisheries exceed 10% for one or more stocks, then only those fisheries with annual takes less than 1% of PBR are considered Category III.

California commercial fisheries that interact with marine mammals

In 2005, marine mammal interactions were reported and/or observed for at least five commercial fisheries operating in California waters. Numbers of mortalities and animals released alive are summarized in Table 1.

The drift gillnet fishery for swordfish and thresher shark has been observed by NMFS annually since 1990. Fishing effort has decreased from over 5,500 sets in 1993 to 1,075 sets in 2005 (Figure 1). Observer coverage ranged from 4% to 18% ($\bar{x}$ = 13%) of all sets from 1990-96 and has averaged 20% since 1997. A wide variety of cetacean, pinniped, sea turtle, and seabird species have been incidentally caught in this fishery (Julian and Beeson, 1998; Carretta *et al*., 2005). A Take Reduction Plan (TRP) was implemented in 1996 because of concerns of bycatch levels that exceeded PBR for some cetacean stocks. The TRP resulted in the use of acoustic pingers on all nets, net extenders to increase minimum fishing depth to 11 m (6 fm), and mandatory skipper education workshops. Barlow and Cameron (2003) reported on the overall decline in marine mammal bycatch resulting from the use of acoustic pingers in this fishery. A seasonal (15 August – 15 November) area closure was implemented in 2001 north of Point Sur to protect leatherback turtles in this region. An additional season/area closure in southern California is implemented during El Niño periods to protect loggerhead turtles.

Purse seine fisheries targeting market squid, sardine, anchovy, mackerel, and tuna have been monitored by NMFS at low levels since 2004. For MMPA reporting, purse seine fisheries in California are subdivided into three fisheries: 1) market squid; 2) anchovy, mackerel, and tuna; and 3) sardine. This pilot observer program has continued into 2006 and observer coverage has been less than 2% of all trips. Documented marine mammal mortalities include a short-beaked common dolphin (*Delphinus delphis*) in 2005 and a California sea lion (*Zalophus californianus*) in 2004. Most observed interactions involve California sea lions which become encircled or trapped under the purse seine and are released alive.

The set gillnet fishery for halibut and angel shark has been restricted to southern California waters since 2002, and no observer program has existed for this fishery since 1994 in southern California and since 2000 in central California. The species most commonly observed killed in this fishery included harbor porpoise (*Phocoena phocoena*), California sea lions, harbor seals (*Phoca vitulina*), and northern elephant seals (*Mirounga angustirostris*) (Julian and Beeson 1998, Forney et al. 2001). Estimated levels of annual mortality in this fishery during 1990-94 averaged over 1,000 sea lions, 500 harbor seals, and 30 harbor porpoise, based on 2,000 to 7,000 days of fishing effort (Julian and Beeson 1998). A portion of this fishery is composed of set gillnets with smaller mesh sizes (6.5 inch) that are set to catch white seabass and yellowtail. Fishing effort totaled 2,379 sets in 2004, the most recent year for which logbook data are available. Because of a lack of recent observer coverage, current estimates of bycatch and incidental mortality are unavailable. Marine mammals are still killed in this fishery, as evidenced by fisher self-reports under the Marine Mammal Authorization Program (MMAP), which are summarized in Table 1.

METHODS

Estimation of Fishing Effort

Numbers of sets fished in the California/Oregon drift gillnet fishery are determined from the vessel operators' reports to the NMFS observer contractor[4]. In this fishery, one set is equal to one day of fishing effort, as nets are set near sunset and retrieved the next morning. In general, the contractor report of fishing effort has equaled or exceeded the number of sets determined from logbook and landing receipt data provided by the California Department of Fish and Game (CDFG) in past years.

Purse seine fisheries in California are characterized by multiple sets per day (usually 2-3) over small spatial scales. One fishing 'trip' is equivalent to one 'day' of effort, although some sets may occur prior to midnight and others after. Landing receipts are available for all the purse seine fisheries, and one receipt represents a minimum of one day of effort. Logbook data exist only for the squid purse seine fishery and do not exist for purse seine fisheries targeting sardine, anchovy, mackerel, and tuna. Fishing effort in California purse seine fisheries is reported as the number of days fished, based on landing receipt data provided by the CDFG.

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Table 1. Characteristics of commerical fisheries operating out of California that recorded marine mammal, sea turtle, or seabird interactions in 2005. Species shown in ***bold italic*** represent animals ***killed***, others were released alive.

Fishery	MMPA Fishery Category	Number of active vessels	Estimated Number sets/days fished	Observed sets/days fished	Observer Coverage Rate	Species Interactions (number)
CA halibut and angel shark set gillnet	Category I	58	n/a[1]	None (fisher self-reports)	0%	***CA sea lion (3)*** ***harbor seal (1)***
CA/OR swordfish and thresher shark large-mesh drift gillnet	Category I	40	1,075[2] sets	225 sets	21%	***CA sea lion (1)*** ***northern elephant seal (1)*** ***short-beaked common dolphin (12)*** ***long-beaked common dolphin (3)*** northern fulmar (5) gray whale (1)
CA market squid purse seine fishery	Category II	65	2,448[3] days	29 days	1.1%	***short-beaked common dolphin (1)*** CA sea lion (43) Harbor seal (3)
CA anchovy, mackerel, and tuna purse seine fishery	Category II	61	1,184[3] days	16 days	1.3%	CA sea lion (5)
CA sardine purse seine fishery	Category II	61	1,510[3] days	26 days	1.7%	CA sea lion (14) Harbor seal (1) Sea otter (1)

1- n/a indicates that logbook data for 2005 were not yet available at the time this report was prepared.
2- Estimate of sets fished obtained from Carolyn Parker, Frank Orth and Associates.
3- Landing receipt totals obtained from CDFG.

Mortality Estimation

Mortality in the drift gillnet fishery is estimated with a ratio estimator (Julian and Beeson 1998, Carretta *et al*. 2005). No geographic or seasonal strata are used in estimating kill rates as differences in previous mortality estimates and coefficients of variation using both seasonal stratification and pooling of all annual data have been negligible (Carretta 2001). Yeung (1999) found that point estimates of marine mammal and sea turtle bycatch were insensitive to stratification, while pooling improved the precision of bycatch estimates. The kill rate for each species is calculated as

$$\hat{r}_s = \frac{\sum k_s}{\sum d} \qquad (1)$$

where k_s is the observed number of species *s* killed and *d* is the number of days (= sets) observed. The variance of the kill rate (σ_r^2), is estimated using a bootstrap procedure, where one trip (2 - 12 days in 2005) represents the sampling unit. Trips are resampled with replacement until each bootstrap sample contains the same number of trips as the actual observed effort level. A kill rate is then calculated from each bootstrap sample. This procedure is repeated 1,000 times, from which the bootstrap sample variance (kill rate variance) is calculated.

Annual mortality ($\hat{m}_s$) for species *s* and the variance (σ_m^2) are estimated for each species using the following formulae:

$$\hat{m}_s = \hat{D}\,\hat{r}_{s,} \qquad (2)$$

$$\sigma_m^2 = \hat{D}^2\,\sigma_r^2 \qquad (3)$$

where

$\hat{D}$ is the estimated minimum number of days (= sets) fished,
$\hat{r}_s$ is the kill rate per set for species *s* and
σ_r^2 is the bootstrap estimate of the kill rate variance.

Mortality in purse seine fisheries is estimated in a similar fashion. In California, purse seine fisheries are characterized by multiple, spatially correlated sets fished in a single day, which corresponds to one ‘trip’. All sets made during a trip are observed, thus the assumption is that trips (= days) are randomly sampled, while sets are correlated. The methods for estimating kill rate, mortality, and the bootstrap variance are the same as for the drift gillnet fishery, with the exception that the denominator of the kill rate in Equation 1 is based on trips, not sets, as in the drift gillnet fishery. No geographic or seasonal strata are used in estimating purse seine fishery mortality.

RESULTS

Drift gillnet

An estimated 1,075 sets were fished in 2005, of which 225 sets were observed from 44 vessel trips, for an observer coverage rate of 21% (Table 1). In 2005, 40 vessels were active in this fishery, though only 27 were observed. Seven vessels considered ‘observable’ were not observed and reported fishing 79 sets. Reasons given for not being observed included limited fishing effort, mechanical problems, and extra crewmembers. Six vessels that reported a total of 111 sets were considered ‘unobservable’ because they lacked berthing space for an observer.

Twelve short-beaked common dolphins, three long-beaked common dolphins, one California sea lion, and one northern elephant seal were observed killed. Mortality estimates for 2005 are 57 (CV = 0.30) short-beaked common dolphins, 14 (0.57) long-beaked common dolphins, 5 (0.97) California sea lions, and 5 (1.00) northern elephant seals. Additionally, one gray whale was entangled and released alive. The observer’s description of the gray whale interaction noted the flukes were entangled in the floatline which was cut away, after which the whale swam off. The observer noted that “*the only damage the whale incurred was cuts on tail*”. Whether these cuts were due to the net perforating the animal or a result of the release process is unknown. The description of this interaction implies that this was a non-serious injury. Mortality and interaction estimates for 2005 are summarized in Tables 2-3, respectively. The locations of all observed large-mesh drift gillnet sets in 2005 are shown in Figure 2 and the locations of entangled marine mammals are shown in Figure 3.

Purse seine

A total of 150 purse seine sets were observed in 2005 (Figure 4). By fishery, the number of sets observed was: squid purse seine (85), sardine (39), and anchovy, mackerel and tuna (25). The number of *trips* observed in the same three purse seine fisheries were 29, 26, and 16 respectively (Table 1). One short-beaked common dolphin mortality was observed in the squid purse seine fishery, resulting in a mortality estimate of 87 (0.98) short-beaked common dolphins.

Set gillnet

The set gillnet fishery for halibut and angel shark (8.5-inch mesh) has not been observed since 1994 in southern California and set gillnets have not been permitted in waters shallower than 60 fm (110 m) north of Point Arguello, California since 2002. However, fisher self-reports under the Marine Mammal Authorization Program (MMAP) indicate that marine mammal bycatch continues in this fishery. From 2000-2005, mortality totals reported under MMAP totaled 50 California sea lions, 20 harbor seals, 1 northern elephant seal, and one unidentified common dolphin. In 2005, three California sea lions and one harbor seal were reported killed.

Table 2. Summary of observed kill, kill rate, mortality estimates and statistical precision for California commercial fisheries in 2005. Fisher self-reports of animals killed in the California halibut set gillnet fishery totaled three California sea lions and one harbor seal and are not included in the estimates of mortality.

Fishery and Species	Observed kill	Kill/day	Kill rate variance	Mortality estimate (95% Lognormal Confidence Limits)	Bootstrap CV
CA/OR swordfish/thresher shark drift gillnet					
Short-beaked common dolphin	12	0.053	2.6×10^{-4}	57 (31 - 96)	0.30
Long-beaked common dolphin	3	0.013	5.6×10^{-5}	14 (4 - 35)	0.57
California sea lion	1	0.0044	1.9×10^{-5}	5 (1 - 20)	0.97
Northern elephant seal	1	0.0044	2.1×10^{-5}	5 (1 - 20)	1.00
CA squid purse seine					
Short-beaked common dolphin	1	0.035	1.3×10^{-3}	87 (13 - 300)	0.98

Table 3. Summary of number of animals that interacted with purse seine and drift gillnet fisheries and estimated numbers of animals released alive in 2005.

Fishery and Species	Observed released alive	Interactions per day	Interaction Rate variance	Released Alive Estimate (95% Lognormal Confidence Limits)	Bootstrap CV
CA/OR swordfish/thresher shark drift gillnet					
Gray whale	1	0.0044	2.1×10^{-5}	5 (1 -20)	1.06
CA squid purse seine					
California sea lion	43	1.5	1.3×10^{-2}	3,630 (2,187 – 5,658)	0.25
Harbor seal	3	0.11	3.1×10^{-3}	262 (89 - 624)	0.52
CA sardine purse seine					
California sea lion	14	0.54	0.041	813 (370 – 1,546)	0.37
Harbor seal	1	0.038	1.3×10^{-3}	58 (9 - 216)	0.99
Sea otter	1	0.038	1.4×10^{-3}	58 (8 - 200)	0.96
CA anchovy, mackerel, and tuna purse seine					
California sea lion	5	0.31	0.038	370 (115 - 875)	0.57

DISCUSSION

Fishing effort in the drift gillnet fishery for swordfish and thresher shark in 2005 is the lowest (1,075 sets) since observations began in 1990 (Figure 1). Kill rates of short-beaked common dolphin were 5.3 per 100 sets in 2005, which exceeds the average of 3.5 per 100 sets observed in pingered sets since 1996 (Figure 5). By comparison, an average of 5.9 short-beaked common dolphins were killed per 100 sets from 1990-96 in nets without pingers. The increase in common dolphin bycatch rates may be due, in part, to a shift of fishing effort into southern California waters where common dolphin densities are greatest.

Kill rates of California sea lions have been higher in the years following the use of pingers (Figure 6). Barlow and Cameron (2003) showed that there was a statistically significant *decline* in sea lion kill rates in pingered verses non-pingered nets during a 1996-1997 experiment. Since 1998 however, the average kill per set (72 killed in 2,985 sets = 0.024 per set) is more than double than that observed prior to pinger use during 1990-95 (35 killed in 3,303 sets = 0.01 per set). Barlow and Cameron (2003) noted that the initial reduction of sea lion entanglement rates in pingered nets was surprising because some predicted that pinnipeds might be attracted to pingered nets to feed on the captured fish (the "dinner bell" effect). The effects of pingers on captive sea lions was studied by Anderson (2000), who found that sea lions were startled by pingers, followed by avoidance behavior (leaving the water). A number of factors may be responsible for the recent increase in sea lion kill rates, including habituation and attraction to pingers, an increasing sea lion population, shifts in the distribution of prey into areas where gillnet activity is greater, and a 2001 area closure that shifted fishing effort into southern California waters, where sea lions are more abundant.

Marine mammal interactions with California purse seine fisheries primarily involve California sea lions that jump into and out of the purse seine and are 'released' alive. Fishery observer and stranding evidence of purse seine interactions with other species in California waters include common dolphins, Risso's dolphins, harbor seals, and California sea otters.

Marine mammal mortality continues in the set gillnet fishery for halibut and angel shark, based on fisher self-reports. NMFS began observing this fishery again in 2006.

ACKNOWLEDGMENTS

Thanks to Rand Rasmussen for maintaining the fishery observer database. Carolyn Parker at Frank Orth and Associates provided vital information on the large mesh drift gillnet observer program. Dale Sweetnam of the CDFG provided information on landing receipts and effort for the purse seine fisheries. This work could not have been done without the diligent work of NMFS biological observers and the cooperation of the California commercial fishermen. Jay Barlow, Karin Forney, and the Pacific Scientific Review Group improved this manuscript with their comments.

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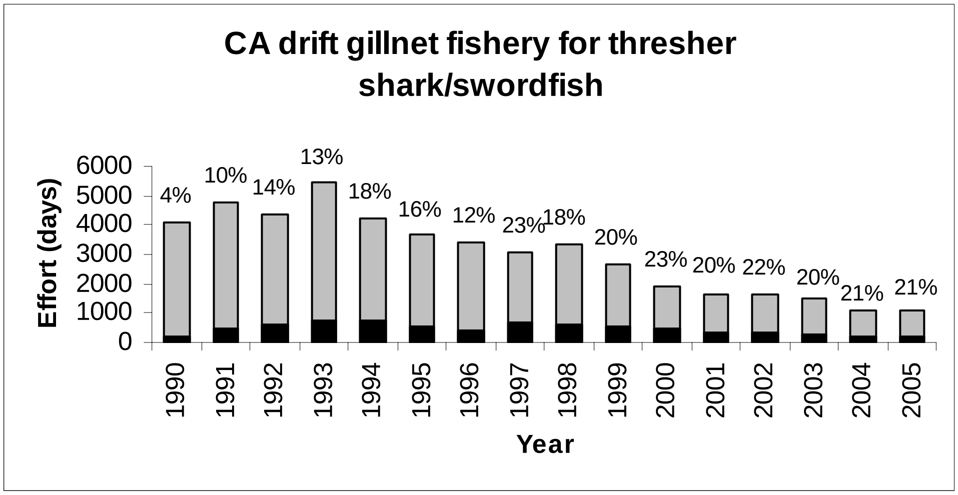


Figure 1. Estimated (gray) and observed (black) days of effort in the California swordfish and thresher shark drift gillnet fishery for 1990-2005. Percent values above bars represent the fraction of observer coverage in the fishery for a given year.

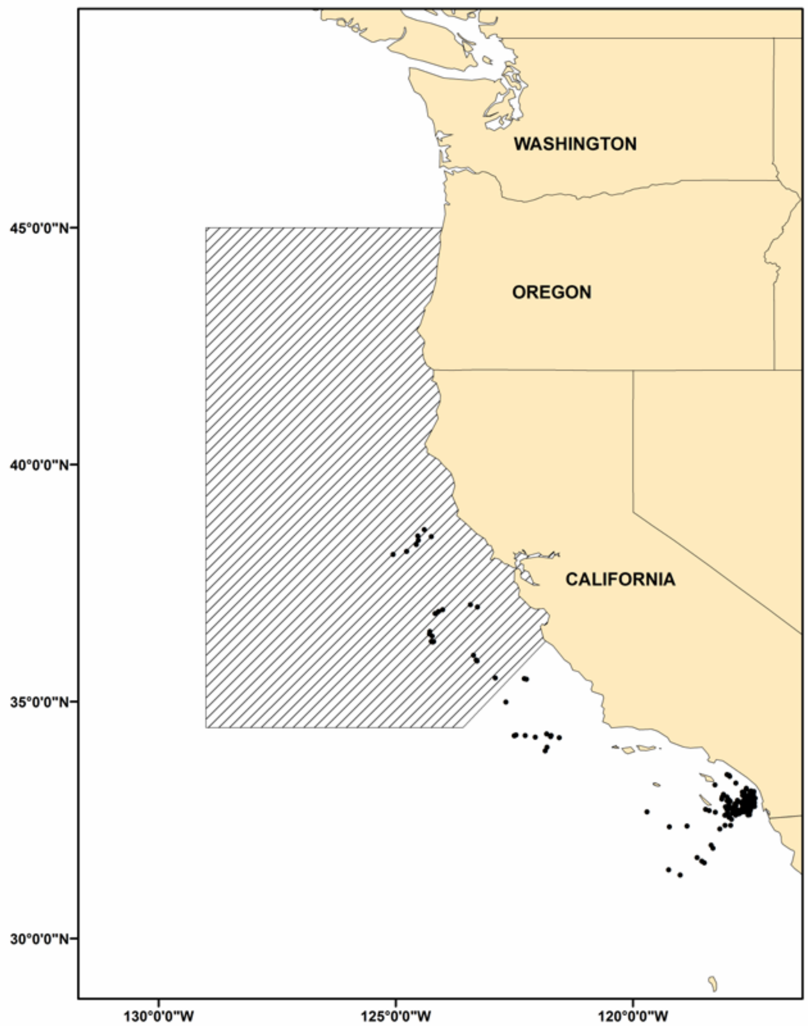


Figure 2. Locations of 225 observed sets in the large-mesh drift gillnet swordfish and thresher shark fishery in 2005. The hatched region represents the leatherback sea turtle area closed to drift gillnet fishing each year between 15 August and 15 November.

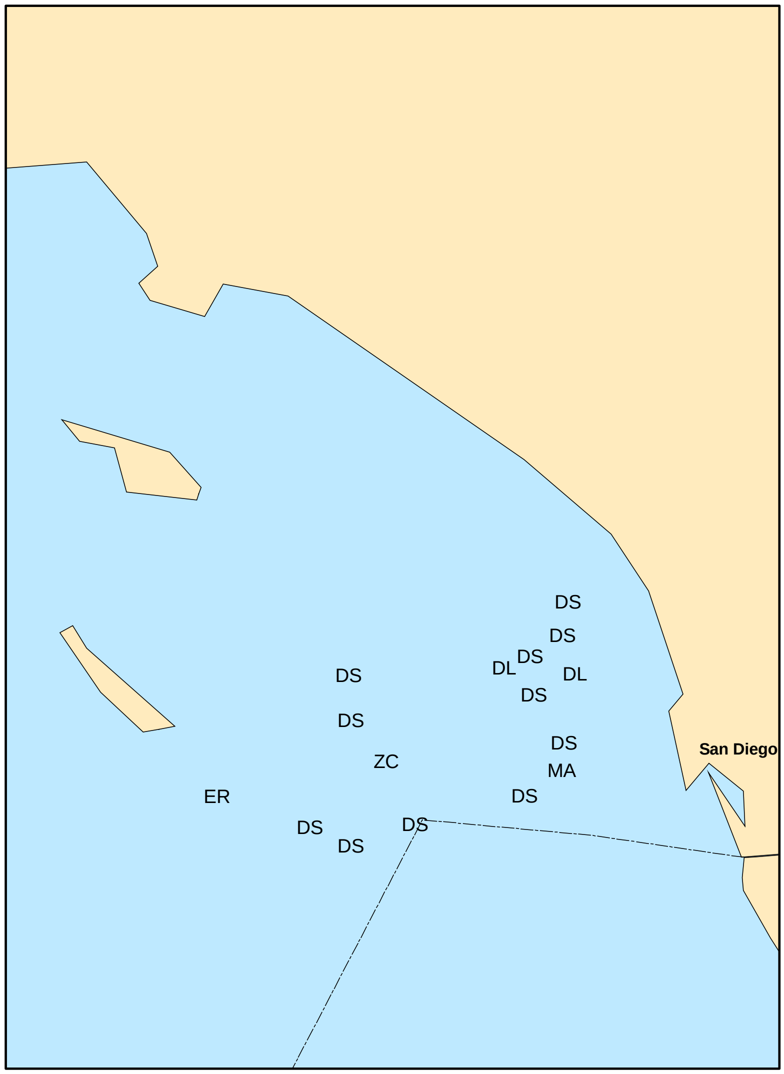
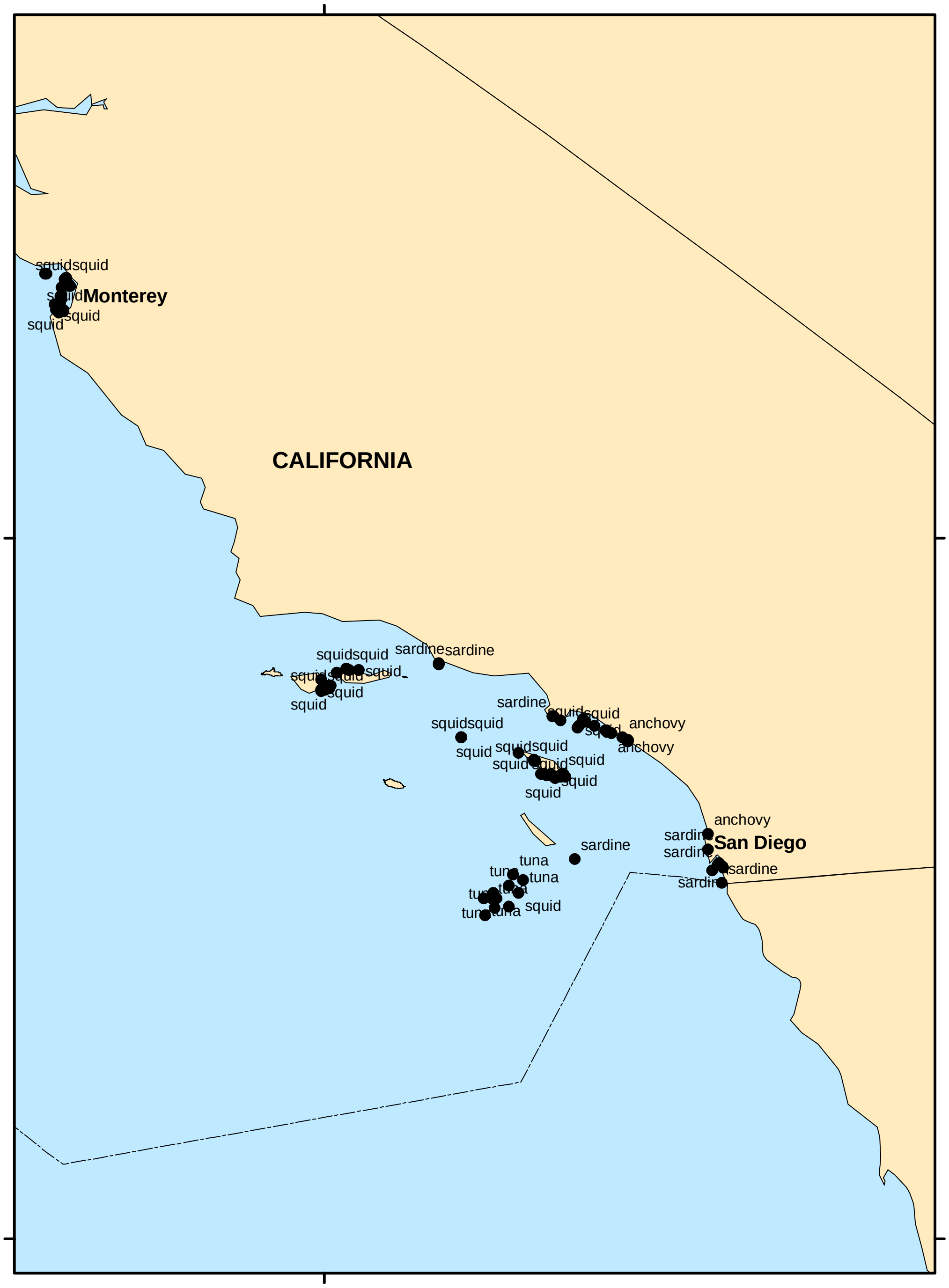


Figure 3. Locations of entangled marine mammals in the large mesh drift gillnet fishery in 2005. Key: MA = northern elephant seal; ZC = California sea lion; DL = long-beaked common dolphin; DS = short-beaked common dolphin; ER = gray whale. All animals were killed except the gray whale, which was released alive.

Figure 4. Locations of 150 observed purse seine sets in 2005, labeled by target species.



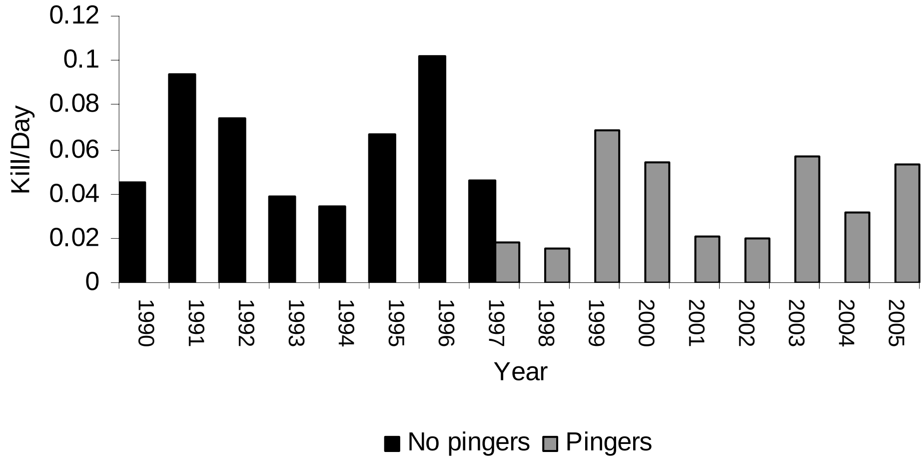


Figure 5. Kill rates of short-beaked common dolphin per set fished in the California drift gillnet fishery for swordfish and thresher shark, 1990-2005. Kill rates include observations from pingered and unpingered sets. Pingers were not used from 1990-95 and were used experimentally in 1996 and 1997. In 1996, no short-beaked common dolphins were observed killed in 146 pingered sets. For the period 1998-2005, over 99% of all observed sets utilized pingers.

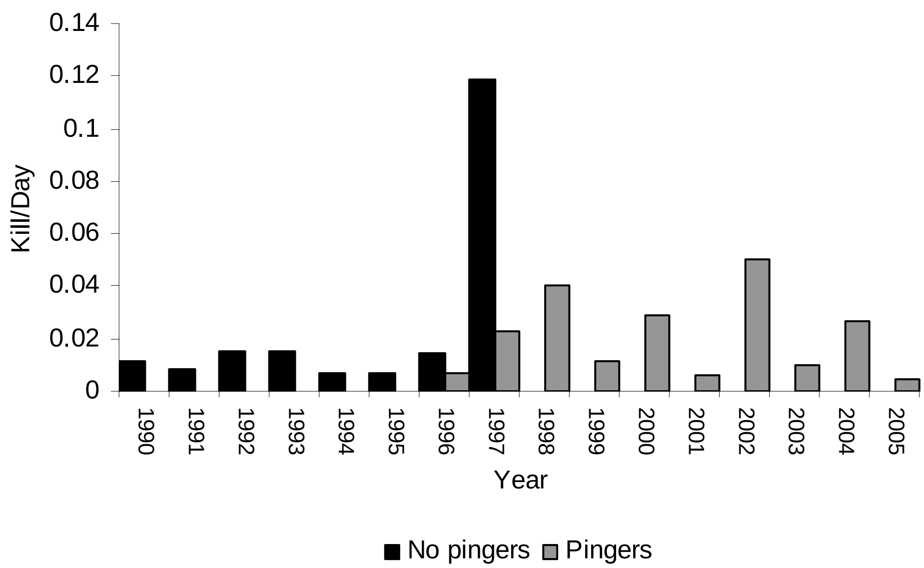


Figure 6. Kill rates of California sea lions per set fished in the California drift gillnet fishery for swordfish and thresher shark, 1990-2005. Kill rates include observations from pingered and unpingered sets. Pingers were not used from 1990-95 and were used experimentally in 1996 and 1997. For the period 1998-2005, over 99% of all observed sets utilized pingers.