Estimates of Marine Mammal, Sea Turtle, and Seabird Mortality in the California Drift Gillnet Fishery for Swordfish and Thresher Shark, 1996–2002

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ABSTRACT—Estimates of incidental marine mammal, sea turtle, and seabird mortality in the California drift gillnet fishery for broadbill swordfish, Xiphias gladius, *and common thresher shark,* Alopias vulpinus, *are summarized for the 7-year period, 1996 to 2002. Fishery observer coverage was 19% over the period (3,369 days observed/17,649 days fished). An experiment to test the effectiveness of acoustic pingers on reducing marine mammal entanglements in this fishery began in 1996 and resulted in statistically significant reductions in marine mammal bycatch. The most commonly entangled marine mammal species were the short-beaked common dolphin,* Delphinus delphis*; California sea lion,* Zalophus californianus*; and northern right whale dolphin,* Lissodelphis borealis. *Estimated mortality by species (CV and observed mortality in parentheses) from 1996 to 2002 is 861 (0.11, 133) short-beaked common dolphins; 553 (0.16, 103) California sea lions; 151 (0.25, 31) northern right whale dolphins; 150 (0.21, 27) northern elephant seals,* Mirounga angustirostris*; 54 (0.41, 10) long-beaked common dolphins,* Delphinus capensis*; 44 (0.53, 6) Dall's porpoise,* Phocoenoides dalli*; 19 (0.60, 5) Risso's dolphins,* Grampus griseus*; 11 (0.71, 2) gray whales,* Eschrichtius robustus*; 7 (0.83, 2) sperm whales,* Physeter macrocephalus*; 7 (0.96, 1) short-finned pilot whales,* Globicephala macrorhychus*; 12 (1.06, 1) minke whales,* Balaenoptera acutorostrata*; 5 (1.05, 1) fin whales,* Balaenoptera physalus*; 11 (0.68, 2) unidentified pinnipeds; 33 (0.52, 4) leatherback turtles,* Dermochelys coriacea*; 18 (0.57, 3) loggerhead turtles,* Caretta caretta*; 13 (0.73, 3) northern fulmars,* Fulmarus glacialis*; and 6 (0.86, 2) unidentified birds.*

Introduction

The California drift gillnet fishery for broadbill swordfish, *Xiphias gladius*, and common thresher shark, *Alopias vulpinus*, developed in the late 1970's when incidental catches of pelagic sharks in small-mesh coastal drift gillnets targeting barracuda, *Sphyraena argentea*, and white seabass, *Atractoscion nobilis*, motivated fishermen to experiment with large-mesh nets targeting thresher shark.[1] In 1979, 40 vessels participated in the fishery, and by the 1981–82 fishing season, over 6,000 sets were made by about 200 active permit holders (Herrick and Hanan, 1988; Hanan et al., 1993; Holts et al., 1998). Fishing effort peaked at over 10,000 sets in the 1982–83 and 1986–87 fishing seasons, after which effort declined, largely due to a combination of a limited entry system, net length restrictions, and a series of time/area closures (Hanan et al., 1993; Holts et al., 1998). NOAA's National Marine Fisheries Service (NMFS) began placing observers on drift gillnet vessels in 1990 to monitor marine mammal bycatch. Fishing effort at that time was about 4000–5000 sets. Effort had declined to about 1,700 sets by 60 vessels by 2002.

In the early to mid 1990's, the fishery was responsible for taking a number of marine mammal species at levels where estimated mortality exceeded potential biological removal (PBR) limits set under the Marine Mammal Protection Act (MMPA) (Barlow et al., 1997; Julian and Beeson, 1998). At that time, the fishery was considered to be a MMPA Category I fishery, where incidental mortality and serious injury of marine mammals is frequent and annual mortality and serious injury for a given stock or stocks exceeds 50% of PBR. A Take Reduction Team (TRT) was convened in 1996 with the goal of reducing marine mammal interactions with the fishery. The TRT recommended the experimental use of acoustic warning devices or "pingers," to test their effectiveness in reducing marine mammal bycatch. Experimental results demonstrated that entanglement rates of short-beaked common dolphins, *Delphinus delphis,* and California sea lions, *Zalophus californianus*, were significantly reduced in pingered nets (Barlow and Cameron, 2003). The effectiveness of acoustic pingers in this fishery led to their mandatory use in late 1997 (U.S. Dep. Commer., 1997).

Typical gear used in this fishery is an 1,800 m (1,000 fm) gillnet with a stretched mesh size ranging from 46 to 56 cm (18 to 22 in), with a required 36 cm (14 in) minimum. The net is attached to one end of the vessel, set at dusk, and allowed to drift during the night for 12 to 14 h. In the 1997–98 fishing season,

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[1] Fishery Management Plan and Environmental Impact Statement for U.S. West Coast Fisheries for Highly Migratory Species. Pacific Fishery Management Council (PFMC), Aug. 2003.

a net extender length of 11 m (36 ft, the minimum depth at which the top of the net may be fished) became mandatory. Vessel trips usually range from 5 to 18 days, depending on the area to be fished, weather, and fish availability. Effort in this fishery is highly seasonal, with > 70% of sets occurring between October and December. Season-area closures for this fishery require that effort must be further than 200 nautical miles (n.mi.) from shore from 1 February to 30 April; inclusive, and that effort must be further than 75 n.mi. from shore from 1 May to 14 August. Since August 2001, a season/area closure to protect leatherback turtles prohibits drift gillnet fishing from 15 August through 15 November in the area bounded by straight lines from Point Sur, Calif., (lat. 36°17′N) to lat. 34°27′N, long. 123°35′W, west to long. 129°W, north to lat. 45°N, then east to the Oregon coast (Fig. 1). Due to current season/area closures, fishing effort is concentrated in southern California waters (Fig. 2). An additional season-area closure south of Point Conception, Calif., and east of long. 120ºW is effective during the months of June, July, and August during El Niño years to protect loggerhead turtles, *Caretta caretta*.

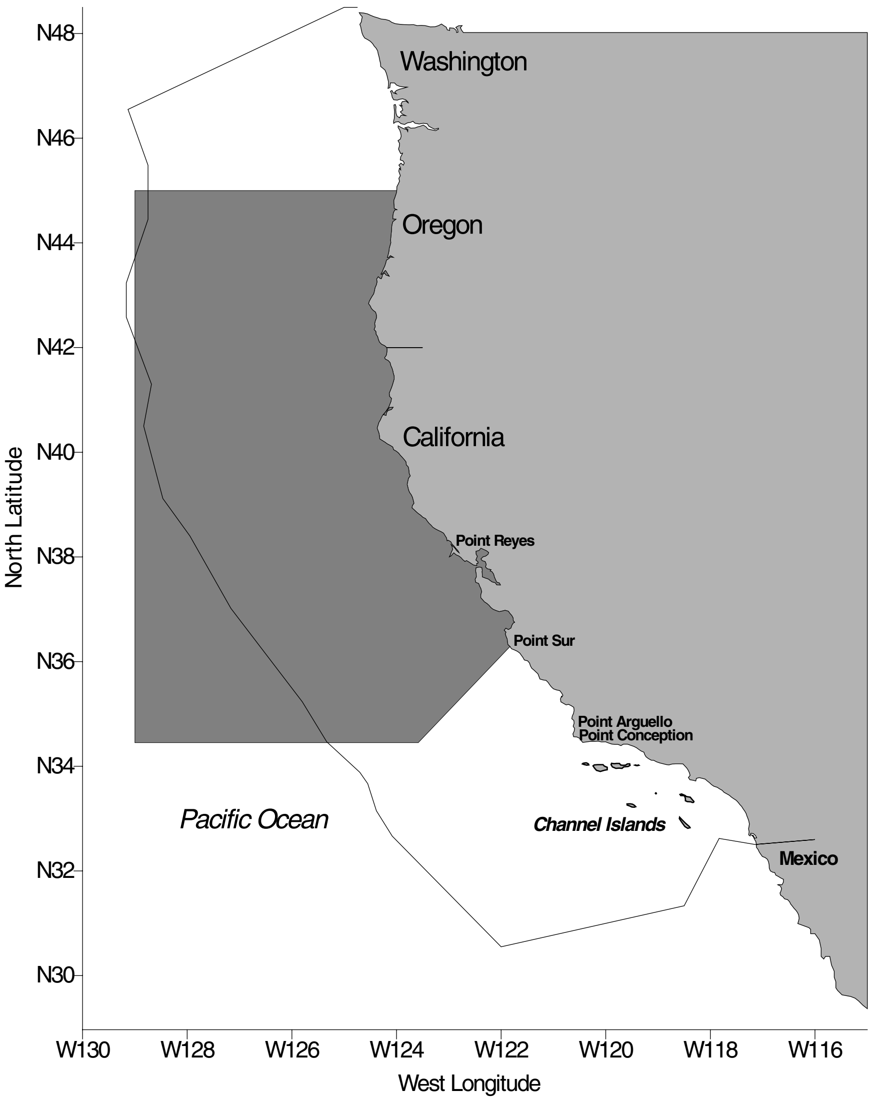

Figure 1.—Area fished by the California swordfish and thresher shark drift gillnet fishery. The solid line represents the U.S. Exclusive Economic Zone (EEZ). Dark gray region has been closed to fishing from 15 Aug. to 15 Nov. each year since 2001 to protect leatherback turtles.

Marine mammal, seabird, and sea turtle mortality in this fishery has been described for the period 1990–95 by Julian and Beeson (1998). Those authors reported estimates of 400–650 cetaceans and 100–200 pinnipeds killed annually, based on annual observer coverage that ranged from 4% to 18%. This paper summarizes the number of marine mammals, seabirds, and sea turtles observed killed annually in the California drift gillnet fishery for swordfish and thresher shark from 1996 to 2002, annual estimates of mortality, and total estimated mortality for the whole period.

Materials and Methods

Data Collection

Data on incidental entanglement and mortality of protected species is collected by observers that are placed on board drift gillnet fishing vessels. An attempt is made to sample at least every fifth vessel trip, with an overall goal of 20% observer coverage for the fishery. Not all vessels are observed, because smaller vessels have no berthing spaces to accommodate observers. During the 2002 fishing season, at least 13 vessels were unobserved, which were responsible for a minimum of 550 days of fishing effort (NMFS Southwest Regional Office, unpubl. data). Observers record information for each set, including location, presence, and functionality of pingers, and bycatch of protected species. During the 1996–97 pinger experiment, observers carried acoustic pingers with them, and, therefore, all pingered sets were observed during this period. For each marine mammal incidentally killed, observers record the species and gender of the animal. Additional biological data and samples (e.g. total body length, gonads, teeth, skin sample) are collected whenever possible. When practical, the entire carcass of the marine mammal is retained for life history studies. Species identifications made in the field are validated, if necessary, and corrected using molecular genetic methods when the species identification is in doubt (Chivers et al., 1997; Henshaw et al., 1997). A summary of the number of species identifications corrected using genetic methods is presented in the Results section. A description of the data collected and life history information available from incidental kills in this fishery has been summarized in Chivers et al. (1997) and Henshaw et al. (1997). Occasionally, entangled animals were released with injuries that made future survival doubtful. These cases of “serious injuries” were defined by reviewing observer notes and comparing the extent of the injuries with the serious injury guidelines used by NMFS (Angliss and DeMaster, 1998). A serious injury is defined as “any injury that will likely to lead to mortality”.[2] Serious injuries may include, but are not limited to, the following: animals released with trailing gear that would impair the animal’s mobility or ability to feed, ingested hooks, visible blood flow, loss or damage to an appendage, listless appearance or inability to defend itself, inability to swim or dive upon release from fishing gear, signs of equilibrium imbalance, perforation of any part of the body by fishing gear, and animals that swim abnormally after release. Serious injuries were treated as observed mortalities and are included as such when estimating overall mortality.

Effort Estimation

Effort was measured in “effort days” which is defined as one day of fishing effort for one vessel. In the drift gillnet fishery, one effort day is equivalent to the setting and retrieving of one net, which is typically fished for 12–14 h. Fishing effort is estimated by the California Department of Fish and Game (CDFG), based on a combination of observer records, logbook data, and landing receipts. Total fishing effort may be underestimated for two reasons. First, unobserved effort may not be recorded, especially for trips where no marketable target fish are caught and logbook entries are not made. Second, where no logbook or observer records correspond to a landing receipt, estimated effort is based on an assumption that one landing receipt corresponds to one day of fishing effort, when in fact, there may be several days of fishing associated with a given landing receipt. Correcting for this bias is not practical, as the number of days fished per vessel trip varies from 1 to 18 days in this fishery (the average trip length was 5.8 days during 1996 to 2002). It is also unlikely that catch data from landing receipts can be effectively modeled to provide a measure of fishing effort, as the catch per unit effort (CPUE) of target species is highly variable by trip. For these reasons, the total fishing effort and estimated mortality levels reported in this paper are underestimated by an unknown amount.

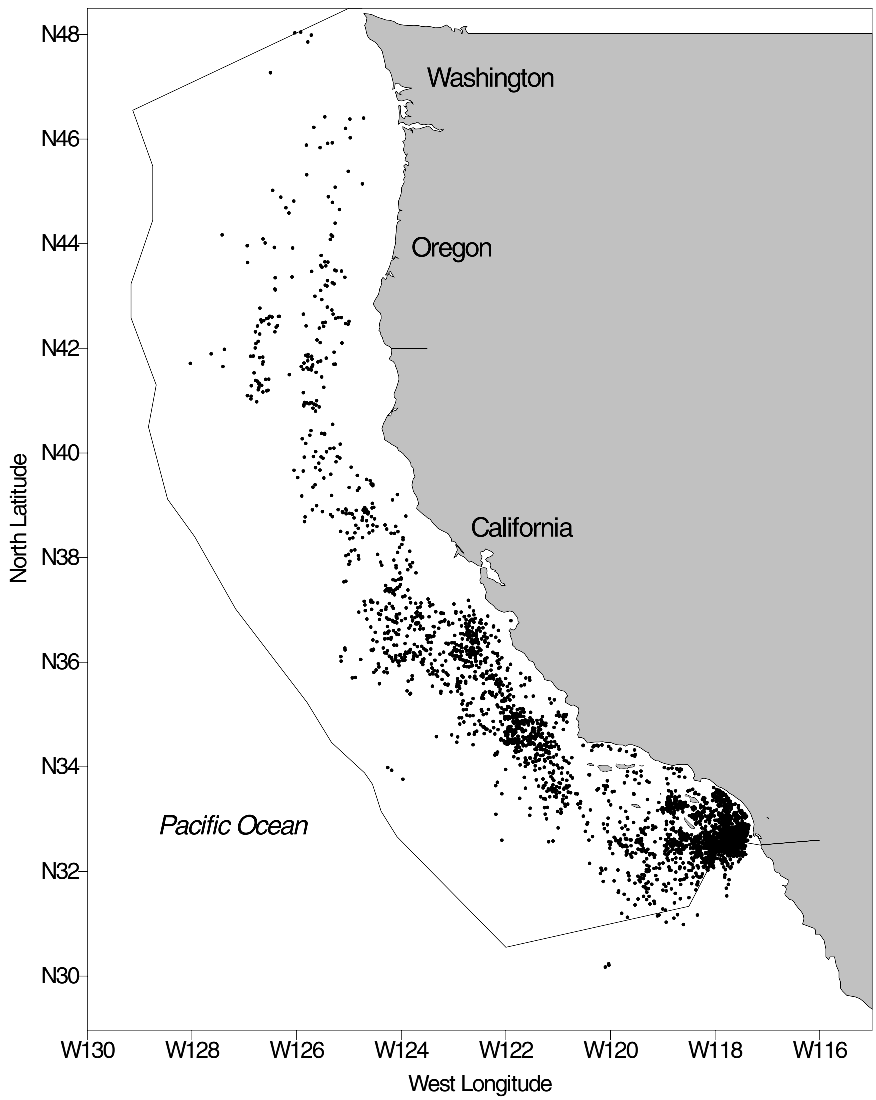

Figure 2.—Locations of 3,369 observed sets in the California drift gillnet fishery for thresher shark and swordfish, 1996–2002.

Mortality Estimation

Ratio estimators were used to estimate mortality with vessel trips as the sampling unit and the number of days per trip as an auxiliary variable (Julian and Beeson, 1998). No geographic or season-

[2]Code of Federal Regulations 50 CFR part 229.2.

al strata were used to calculate kill rates or estimate mortality. Sample sizes for all species except short-beaked common dolphins and California sea lions were insufficient for such stratification, and previous estimates of annual mortality and associated coefficients of variation (CV) are only negligibly changed with such stratification.[3,4] In 1996 and 1997, sets with and without pingers were analyzed as separate strata and total mortality was estimated as the sum of observed mortalities from pingered sets plus a ratio estimate of mortality from unpingered sets (see "1996–97 Pinger Experiment and Mortality Estimation" section). For the years 1998–2002, all fishing effort was assumed to represent pingered sets, so all sets were analyzed as one stratum. For each species, the annual kill rate ($\hat{r}_{s,y}$) of species s in year y was calculated as:

$$\hat{r}_{s,y} = \frac{\sum_i k_{i,s,y}}{\sum_i d_{i,y}} \qquad (1)$$

$k_{i,s,y}$ = the sum of observed mortalities of species s in year y for the i^{th} trip and

$d_{i,y}$ = the number of observed days of fishing effort for the i^{th} trip in year y (equal to number of sets observed).

Annual estimates of mortality ($\hat{m}_y$) and associated variance ($\sigma^2_{m,y}$), were estimated for each species using the following formulae:

$$\hat{m}_y = D_y \hat{r}_{s,y} \qquad (2)$$

$$\sigma^2_{m,y} = D_y^2 \sigma^2_{r,y} \qquad (3)$$

where D_y = the estimated minimum number of days fished in year y,

$\hat{r}_{s,y}$ = the kill rate estimated in year y, and

$\sigma^2_{r,y}$ = the bootstrap estimate of kill rate variance in year y.

[3] Carretta, J. V. Preliminary estimates of cetacean mortality in California gillnet fisheries for 2001. Unpubl. paper SC/54/SM12 presented to the International Whaling Commission Scientific Committee, April 2002, 22 p.

[4] Carretta, J. V. Preliminary estimates of cetacean mortality in California gillnet fisheries for 2000. Unpubl. paper SC/53/SM9 presented to the International Whaling Commission Scientific Committee, July 2001, 21 p.

Table 1.—Number of drift gillnet sets observed from 1996 to 2002 with and without pingers and estimated number of sets fished.

	Observed sets			
Year	Pingered	Unpingered	Observed total	Estimated sets fished
1996	146	275	421	3,392
1997	388	304	692	3,039
1998	573	14	587	3,353
1999	524	2	526	2,634
2000	444	0	444	1,936
2001	338	1	339	1,665
2002	360	0	360	1,630
Total	2,773	596	3,369	17,649

Table 2.—Summary of annual fishing effort, observer coverage, and observed and estimated mortality in the California drift gillnet fishery, 1996–2002.

Item	1996	1997	1998
Estimated days fishing effort	3,392	3,039	3,353
Number of vessels	123	115	123
Observed days fishing effort	421	692	587
Observed trips effort	71	118	104
Percent Observer coverage (days)	12.4%	22.8%	17.5%

	1996 Mortality			1997 Mortality			1998 Mortality		
Species	Obs.	Est.	CV	Obs.	Est.	CV	Obs.	Est.	CV
Dall's porpoise	2	25	0.74	4	19	0.74			
Pacific whitesided dolphin	3	25	0.98	3	12	0.75			
Risso's dolphin				3	10	0.95			
Common dolphin (shortbeaked)[1]	28	345	0.20	22	114	0.24	9	51	0.38
Common dolphin (longbeaked)[1]				4	27	0.58			
Northern right whale dolphin	5	25	0.71	5	29	0.46			
Shortfinned pilot whale				1	7	0.96			
Sperm whale[1]	1	1					1	6	0.97
Fin whale									
Minke whale	1	12	1.06						
Gray whale							1	6	0.97
California sea lion	4	37	0.55	37	212	0.34	23	131	0.25
Northern elephant seal	5	37	0.53	8	44	0.37	4	23	0.48
Unidentified pinniped							2	11	0.68
Leatherback turtle	2	25	0.63	2	8	0.85			
Loggerhead turtle[1]				1	7	0.93	2	11	0.72
Northern fulmar[1]									
Unidentified bird				1	1	0.00			
All cetaceans	40	433	0.18	42	218	0.18	11	57	0.36
All pinnipeds	9	74	0.38	45	256	0.29	29	165	0.21
All turtles	2	25	0.63	3	15	0.63	2	11	0.72
All seabirds				1	1	0.00			

[1] Includes one animal that was judged to be seriously injured under NMFS guidelines.

For the years 1998–2002, kill rate variances were estimated using a bootstrap procedure, where one trip (1–18 days) represented the sampling unit. Trips were resampled with replacement until each bootstrap sample contained the same number of trips as the actual observed level of effort. A kill rate was then calculated from each bootstrap sample. This procedure was repeated 1,000 times, from which the bootstrap sample variance (kill rate variance) was calculated. For the years 1996–97, kill rate variances were also estimated with a bootstrap, but the sampling unit was represented by individual sets because within an individual trip, some sets utilized pingers while others did not.

1996–97 Pinger Experiment and Mortality Estimation

An experiment to test the effectiveness of pingers on reducing marine mammal entanglement began in 1996 and continued through 27 October 1997, after which time, pingers became mandatory. The experiment was based on a design where sets were randomly assigned as “pingered” or “control” sets after the vessel captain had chosen a set location (Barlow and Cameron, 2003). During the experiment, 534 of 1,113 observed sets (48%) utilized pingers. During the 1997 mandatory period, 214 of 285 observed sets (75%) utilized pingers, and compliance rapidly increased to 90% pinger use in observed sets by December 1997. From 1998–2002, greater than 99% of all observed sets utilized pingers (Table 1).

For 1996 and 1997, mortality estimates were calculated with pingered and unpingered sets/effort representing different strata. In 1996, all pingered sets were observed, so mortality was estimated as the sum of observed mortalities recorded in pingered sets, plus a ratio estimate of mortality from unpingered sets. For 1997, mortality was estimated separately for an experimental period (1 January–27 October) and a mandatory period (28 October–31 December). During the 1997 experimental period, all pingered sets were observed, so mortality was estimated as the sum of observed mortalities recorded in pingered sets, plus a ratio estimate of mortality from unpingered sets. During the 1997 mandatory period, not all pingered sets were observed, so mortality was estimated as the sum of ratio estimates for pingered and unpingered sets.

Estimated effort during the 1997 experimental period was calculated by multiplying estimated 4th quarter fishing effort (2,145 days) by the fraction of observed 4th quarter sets occurring in the experimental period (188/473), plus the sum of fishing effort in calendar quarters 1–3 (894 days). This yielded a total estimate of 1,747 days fished during the experimental period. All pingered sets during the experimental period (n=174) were observed, which leaves 1,747 – 174 = 1,573 days of unpingered effort in the experimental period. Estimated fishing effort for the mandatory period was calculated as the estimated 4th quarter fishing effort (2,145 days), times the fraction of observed 4th quarter sets occurring in the mandatory period (285/473). This yielded a total estimate of 1,292 days fished during the mandatory period. Not all pingered sets were observed during the mandatory period, so the total number of pingered sets for the mandatory period was estimated as the number of estimated fishing days for the mandatory period (1,292), times the fraction of observed sets with pingers

1999			2000			2001			2002			1996–2002		
2,634			1,936			1,665			1,630			17,649		
96			81			65			56					
526			444			339			360			3,369		
92			85			65			64			599		
20.0%			22.9%			20.4%			22.1%			19.1%		
Mortality			Mortality			Mortality			Mortality			Mortality		
Obs.	Est.	CV	Obs.	Est.	CV	Obs.	Est.	CV	Obs.	Est.	CV	Obs.	Est.	CV
												6	44	0.53
			2	9	0.68	2	10	0.71	1	5	0.86	11	61	0.46
			2	9	0.71							5	19	0.60
36	180	0.27	24	105	0.26	7	34	0.41	7	32	0.46	133	861	0.11
1	5	1.05	1	4	1.08				4	18	0.79	10	54	0.41
3	15	0.72	11	48	0.48	5	25	0.57	2	9	0.70	31	151	0.25
												1	7	0.96
												2	7	0.83
1	5	1.05										1	5	1.05
												1	12	1.06
1	5	1.05										2	11	0.71
6	30	0.39	13	57	0.38	2	10	0.67	18	81	0.25	103	553	0.16
2	10	0.65	6	26	0.39	1	5	0.94	1	5	0.92	27	150	0.21
												2	11	0.68
												4	33	0.52
												3	18	0.57
			3	13	0.73							3	13	0.73
									1	5	0.86	2	6	0.72
42	205	0.25	40	175	0.21	14	69	0.31	14	64	0.34	203	1221	0.09
8	40	0.33	19	83	0.29	3	15	0.55	19	86	0.24	132	719	0.13
												7	51	0.39
			3	13	0.73				1	5	0.86	5	19	0.55

during this period (214/285). This yielded a total of 969 pingered effort days for the mandatory period. The number of unpingered effort days in the mandatory period was calculated as the difference between total estimated effort and the estimated number of pingered sets for the period: 1,292 – 969 = 323.

Results

Annual and total estimates of mortality by species, estimated fishing effort, and percent observer coverage for 1996 to 2002 are given in Table 2. Total estimated mortality (CV and observed mortality in parentheses) for 1996 to 2002 is 1,221 (0.09, 203) cetaceans, 719 (0.13, 132) pinnipeds, 51 (0.39, 7) sea turtles, and 19 (0.55, 5) seabirds (Table 2). Observer coverage for 1996 to 2002 was 19% (3,369 days observed out of a total 17,649 estimated days fished, Fig. 2). Annual observer coverage ranged from 12.4% in 1996 to over 22% in 1997, 2000, and 2002. There were 203 individual cetaceans observed killed from 1996 to 2002, comprising 11 species (Fig. 3, 4). Short-beaked common dolphins were the most frequently observed cetacean killed (n=133), followed by northern right whale dolphins (n=31). The 203 cetacean mortalities included three animals (one sperm whale, one short-beaked common dolphin, and one long-beaked common dolphin) that were seriously injured and were likely to result in mortality. Observer notes on the injured sperm whale included observations that the whale rammed the vessel several times hard enough to create deep bleeding wounds on its head. This whale was also released with trailing gear and drifted away from the vessel unable to swim or feed due to the gear entanglement. Observer notes of the injured short-beaked common dolphin indicated that the "dolphin remained motionless and was right-side up at the surface." Observations of the seriously injured long-beaked common dolphin indicated that the animal was "making noises and small movements." This dolphin was released from the net and immediately became entangled again. After a second release, the animal was not seen to surface. Two other long-beaked common dolphins died in this same set. There were 132 pinnipeds observed killed between 1996 and 2002, including 103 California sea lions, 27 northern elephant seals, and 2 unidentified pinnipeds (Fig. 5). The 132 pinniped mortalities included one California sea lion that was seriously injured. Observations of the seriously injured sea lion stated that the animal "displayed some indication of life." The estimate of total loggerhead turtle mortality includes one seriously injured turtle that was released. Observer notes indicated that the "turtle barely moved, even after biopsy was taken." Following release, the turtle moved a little then "sank quickly." The estimate of total northern fulmar mortality includes one bird that was released injured.

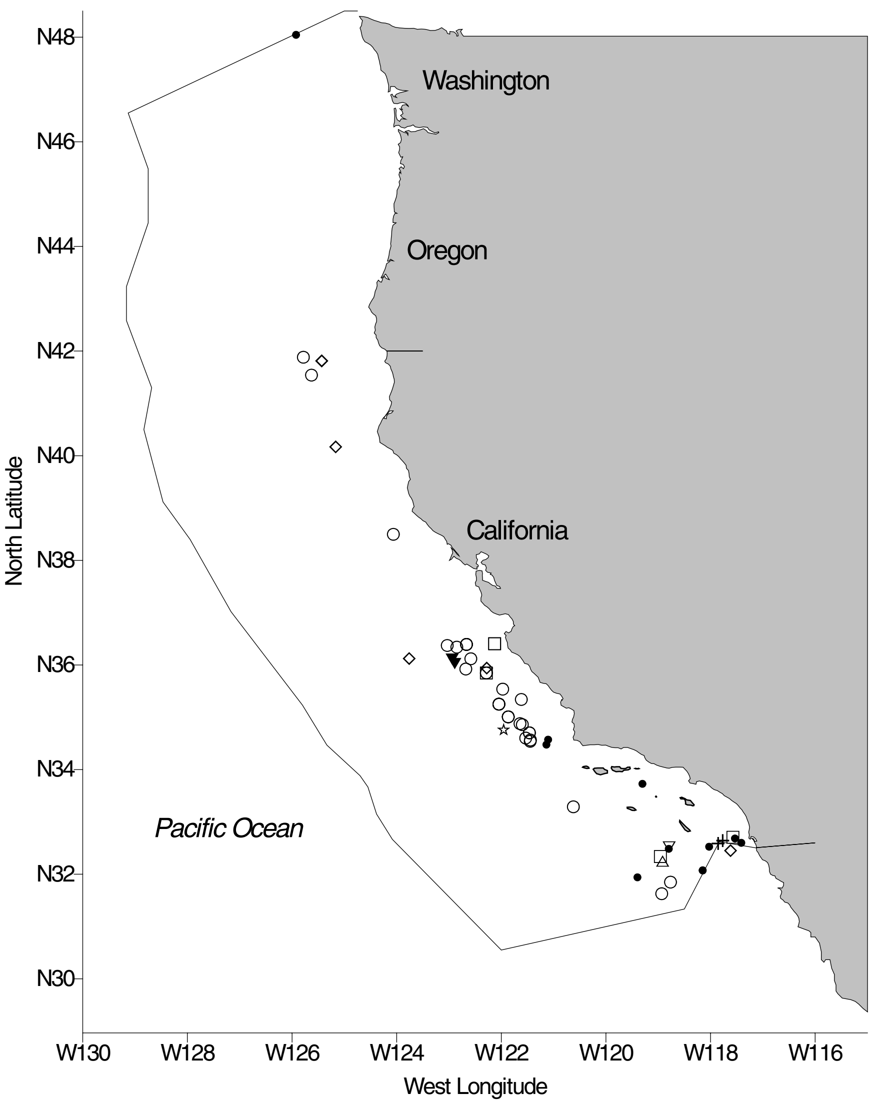

Figure 3.—Observed cetacean kills (other than common dolphins) in the California drift gillnet fishery for swordfish and thresher shark, 1996–2002. Key: ○ = northern right whale dolphin; ● = Pacific white-sided dolphin; ◊ = Dall's porpoise; □ = Risso's dolphin; + = gray whale; △ = minke whale; ▽ = fin whale; ☆= pilot whale; ▼ = sperm whale.

Of the 197 cetacean specimens collected in the fishery from 1996 to 2002, there were 33 where the field identification was changed after a review of genetic and morphological evidence. A summary of these changes is given in Table 3. Long-beaked common dolphins were the most frequently misidentified species. Of the 13 field identifications of long-beaked common dolphins, nine were genetically identified as short-beaked common dolphins and the remaining four were accurately identified in the field. There were 109 field identifications of short-beaked common dolphins, of which, 104 were correct and five were misidentifications of long-beaked common dolphins. There were 15 specimens where the field identification was either short-beaked common dolphin or long-beaked common dolphin. All were genetically identified as short-beaked common dolphins. Other field identification changes included two unidentified whales that were identified in the laboratory as a minke and fin whale, respectively, one unidentified cetacean identified as a Risso's dolphin, and one unidentified dolphin identified as short-beaked common dolphin.

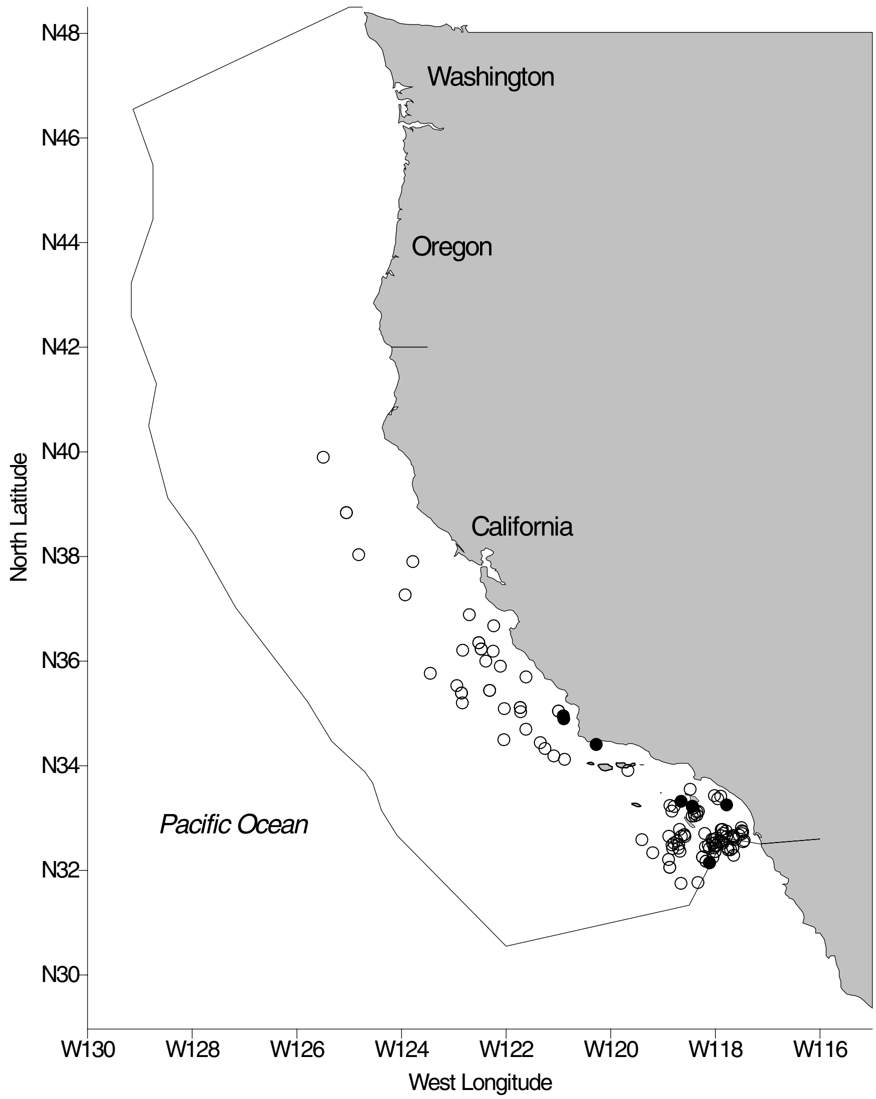

Figure 4.—Observed kills of common dolphin in the California drift gillnet fishery for swordfish and thresher shark, 1996–2002. Key: ○ = short-beaked common dolphin; ● = long-beaked common dolphin.

Discussion

Observed mortality from 1996 to 2002 in the drift gillnet fishery generally reflects species abundance in California waters. Short-beaked common dolphins are the most abundant marine mammal in California waters (>400,000 animals[5]) (Barlow, 1995; Forney et al., 1995), and they were the most frequently (n=133) observed species killed in this fishery. California sea lions are the second most abundant (>200,000) marine mammal in California waters (Carretta et al., 2003) and they were the next most frequently (n=103) observed species killed. Although the Dall's porpoise is abundant in California waters (>90,000 animals[5]), it is infrequently entangled (n=6) because it mainly occurs in northern waters where drift gillnet fishing effort is relatively low. The number of northern right whale dolphins (n= 31) and northern elephant seals (n= 27) observed killed are nearly equal, although the estimated population size of northern elephant seals (100,000 animals, NMFS, unpubl. data, cited in Carretta et al., 2003) is much greater than that of northern right whale dolphins (20,000 animals[5]). Northern elephant seals spend a significant portion of the year feeding north and west of the area where the fishery operates, and they are ashore during their molting period, so it is expected that elephant seal entanglements would be considerably lower based on relative population size.

Mortality estimates in this paper represent minimum estimates, because of negative biases in effort estimation (see "Effort Estimation" section) and because they do not include unobserved mortalities (those occurring in the absence of a fishery observer). Although fishermen are required to report interactions with marine mammals, there is strong evidence that these interactions are grossly underreported. For example, between 1998 and 2002 in the drift gillnet fishery, observers reported 201 marine mammal interactions, with only 20% observer coverage. Over the same time period, all drift gillnet fishermen reported a total

[5] Barlow, J. 2003. Preliminary estimates of the abundance of cetaceans along the U.S. west coast: 1991–2001, 33 p. Southwest Fisheries Science Center Administrative Report LJ-03-03, available from NMFS Southwest Fisheries Science Center, 8604 La Jolla Shores Drive, La Jolla, CA 92037, 33 p.

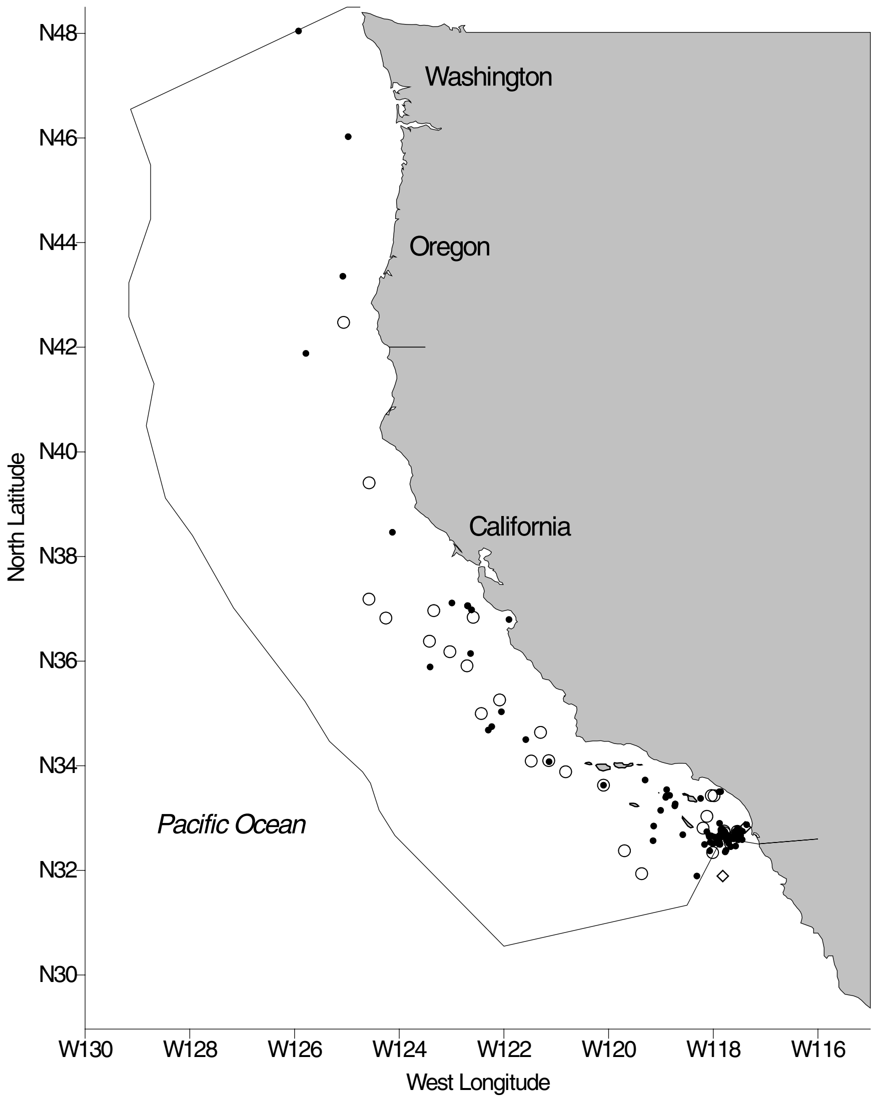

Figure 5.—Observed kills of pinnipeds in the California drift gillnet fishery for swordfish and thresher shark, 1996–2002. Key: ● = California sea lion; ○ = northern elephant seal; and ◇ = unidentified pinniped.

of 115 interactions where no observers were present (Carretta et al., 2005).

During the 1996–97 pinger experiment, kill rates of short-beaked common dolphins were significantly lower in nets utilizing pingers (Barlow and Cameron, 2003), and the lowest kill rate observed in this fishery occurred in 1998, the first full-year of pinger use (Fig. 6). However, kill rates increased to pre-pinger levels in 1999 and 2000, but have returned to relatively low levels in 2001 and 2002. Reasons for the increase in common dolphin kill rates in 1999 and 2000 are unknown, but a pattern of high kill rates in winter was noted for both years.[6] There were no apparent changes in fishing methodology or location that may have contributed to an increase in common dolphin kill rates in those two years. Common dolphin densities are highest in southern California waters, and the fraction of sets fished there has increased because of time/area closures to the north. In 2001 and 2002, the fraction of observed sets south of Point Conception (>85%) was the highest since observations of the fishery began in 1990. However, common dolphin kill rates in 2001–02 were among the lowest recorded for this species since 1990 (Fig. 6). Lack of pinger maintenance may have contributed to high entanglement rates in 1999–2000; observers began checking pinger function once per trip starting in 2001. Variability in annual kill rates for this species is likely influenced by changes in the local distribution and abundance of animals and small-scale changes in the distribution of fishing effort.

Kill rates of California sea lions were significantly lower during the 1996–97 experiment in pingered nets (Barlow and Cameron, 2003). Extremely high kill rates of sea lions in unpingered nets were observed in 1997, during a strong El Niño. In fact, kill rates of sea lions in pingered nets in 1997 were higher than kill rates observed for any previous year (Fig. 7). One possible explanation is that decreased prey availability during El Niño may pressure sea lions into finding alternative food sources, such as stealing fish from commercial nets. This is plausible if, during El Niño conditions, sea lions forage farther from rookeries (Melin, 2002), where they are more likely to interact with the drift gillnet fishery. Sea lion kill rates for the period 1997–2002 were about double of those observed from 1990–96, even though pingers have been required on all sets since late 1997 (Fig. 7).

There was a noteworthy difference between observed beaked whale mortalities in this fishery from 1990 to 1995 and 1996 to 2002. Julian and Beeson (1998) reported a total of 20 Cuvier's beaked whales, *Ziphius cavirostris*; one Baird's beaked whale, *Berardius bairdii*; one Stegneger's beaked whale, *Mesoplodon stegnegerii*; five Hubb's beaked whales, *Mesoplodon hubbsi*; two unidentified mesoplodont beaked whales, *Mesoplodon* sp.; and three unidentified beaked whales observed killed in this fishery between the years 1990 and 1995. Since

[6] Cameron, G. A., and K. A. Forney. 2000. Preliminary estimates of cetacean mortality in California/Oregon gillnet fisheries for 1999. Unpubl. paper SC/52/O24 presented to the International Whaling Commission Scientific Committee, June 2000, 12 p.

Table 3.—Summary of laboratory vs. field identification of cetaceans incidentally killed in the thresher shark and swordfish drift gillnet fishery, 1996–2002. Summary includes only those 197 specimens for which a tissue sample resides in the SWFSC Genetics Archive. There were an additional four short-beaked common dolphins, one long-beaked common dolphin, and one sperm whale observed killed or seriously injured in the fishery over this period for which no biological samples were collected. The field identification "D spp" denotes an uncertain identification of either short or long-beaked common dolphin.

Laboratory Identification		Field Identification														
Scientific Name	Code	B acu	D cap	D del	D spp	E rob	G gri	G mac	L bor	L obl	P dal	P mac	Unid. cetacean	Unid. dolphin	Unid. whale	Total
Balaenoptera acutorostrata	B acu	1													1	2
Balaenoptera physalus	B phy														1	1
Delphinus capensis	D cap		4	5												9
Delphinus delphis	D del		9	104	15									1		129
Eschrichtius robustus	E rob					2										2
Globicephala macrorhynchus	G mac							1								1
Grampus griseus	G gri						4						1			5
Lagenorhynchus obliquidens	L obl									11						11
Lissodelphis borealis	L bor								30							30
Phocoenoides dalli	P dal										6					6
Physeter macrocephalus	P mac											1				1
Total		1	13	109	15	2	4	1	30	11	6	1	1	1	2	197

that time, no beaked whales have been observed entangled in this fishery. It is unknown whether pinger use has contributed to the decline of beaked whale entanglements since 1996. Barlow[5] noted a decrease in beaked whale abundance from vessel surveys in U.S. west coast waters over the period 1991 to 2001, but it is unclear whether rougher sea states encountered during more recent line-transect vessel surveys has contributed to the apparent decline in beaked whale abundance or whether other factors, such as the susceptibility of beaked whales to anthropogenic noise (Frantzis, 1998; Simmonds and Lopez-Jurado, 1991; U.S. Dep. Commer. and Secretary of the Navy, 2001) might be a factor in their apparent regional decline.

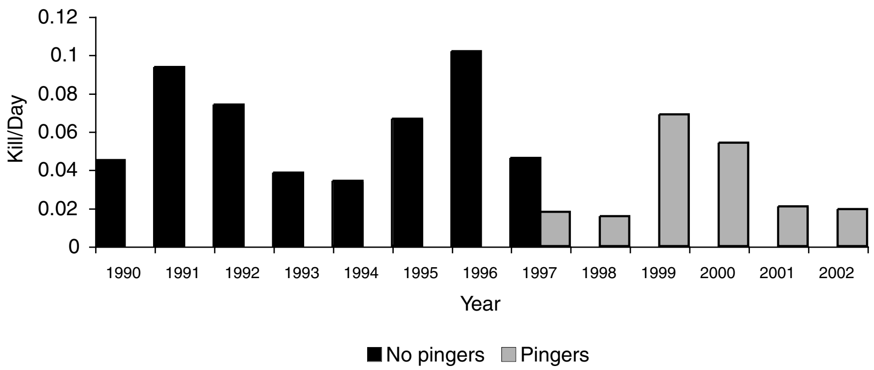

Figure 6.—Kill rates of short-beaked common dolphin per day fished in the California drift gillnet fishery for swordfish and thresher shark, 1990–2002. Kill rates include observations from pingered and unpingered sets. Pingers were not used from 1990 to 1995 and were used experimentally in 1996 and 1997. In 1996, no short-beaked common dolphin were observed killed in 146 pingered sets. For the period 1998 to 2002, over 99% of all observed sets utilized pingers.

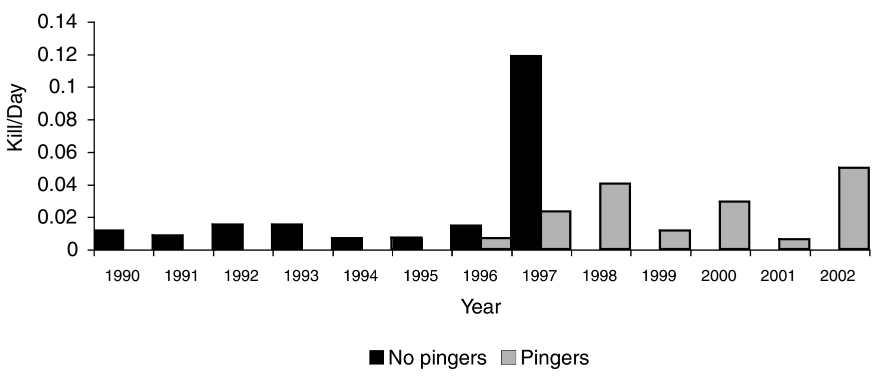

Figure 7.—Kill rates of California sea lions observed in the drift gillnet fishery for 1990 to 2002. Kill rates include observations from pingered and unpingered sets. Pingers were not used from 1990 to 1995 and were used experimentally in 1996 and 1997. For the period 1998 to 2002, over 99% of all observed sets utilized pingers.

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al strata were used to calculate kill rates or estimate mortality. Sample sizes for all species except short-beaked common dolphins and California sea lions were insufficient for such stratification, and previous estimates of annual mortality and associated coefficients of variation (CV) are only negligibly changed with such stratification.[3,4] In 1996 and 1997, sets with and without pingers were analyzed as separate strata and total mortality was estimated as the sum of observed mortalities from pingered sets plus a ratio estimate of mortality from unpingered sets (see "1996–97 Pinger Experiment and Mortality Estimation" section). For the years 1998–2002, all fishing effort was assumed to represent

[3] Carretta, J. V. Preliminary estimates of cetacean mortality in California gillnet fisheries for 2001. Unpubl. paper SC/54/SM12 presented to the International Whaling Commission Scientific Committee, April 2002, 22 p.

[4] Carretta, J. V. Preliminary estimates of cetacean mortality in California gillnet fisheries for 2000. Unpubl. paper SC/53/SM9 presented to the International Whaling Commission Scientific Committee, July 2001, 21 p.

Table 1.—Number of drift gillnet sets observed from 1996 to 2002 with and without pingers and estimated number of sets fished.

	Observed sets			
Year	Pingered	Unpingered	Observed total	Estimated sets fished
1996	146	275	421	3,392
1997	388	304	692	3,039
1998	573	14	587	3,353
1999	524	2	526	2,634
2000	444	0	444	1,936
2001	338	1	339	1,665
2002	360	0	360	1,630
Total	2,773	596	3,369	17,649

pingered sets, so all sets were analyzed as one stratum. For each species, the annual kill rate ($\hat{r}_{s,y}$) of species *s* in year *y* was calculated as:

$$\hat{r}_{s,y} = \frac{\sum_i k_{i,s,y}}{\sum_i d_{i,y}} \quad (1)$$

$k_{i,s,y}$ = the sum of observed mortalities of species *s* in year *y* for the i^{th} trip and

$d_{i,y}$ = the number of observed days of fishing effort for the i^{th} trip in year *y* (equal to number of sets observed).

Annual estimates of mortality ($\hat{m}_y$) and associated variance ($\sigma^2_{m,y}$), were estimated for each species using the following formulae:

$$\hat{m}_y = D_y \hat{r}_{s,y} \quad (2)$$

$$\sigma^2_{m,y} = D_y^2 \sigma^2_{r,y} \quad (3)$$

where D_y = the estimated minimum number of days fished in year *y*,

$\hat{r}_{s,y}$ = the kill rate estimated in year *y*, and

$\sigma^2_{r,y}$ = the bootstrap estimate of kill rate variance in year *y*.

For the years 1998–2002, kill rate variances were estimated using a bootstrap procedure, where one trip (1–18 days) represented the sampling unit. Trips were resampled with replacement until each bootstrap sample contained the same number of trips as the actual observed level of effort. A kill rate was then calculated from each bootstrap sample. This procedure was repeated 1,000 times, from which the bootstrap sample variance (kill rate variance) was calculated. For the years 1996–97, kill rate variances were also estimated with a bootstrap, but the sampling unit was represented by individual sets because within an individual trip, some sets utilized pingers while others did not.

1996–97 Pinger Experiment and Mortality Estimation

An experiment to test the effectiveness of pingers on reducing marine mammal entanglement began in 1996 and continued through 27 October 1997, after which time, pingers became mandatory. The experiment was based on a design where sets were randomly assigned as "pingered" or "control" sets after the vessel captain had chosen a set location (Barlow and Cameron, 2003). During the experiment, 534 of 1,113 observed sets (48%) utilized pingers. During the 1997 mandatory period, 214 of 285 observed sets (75%) utilized pingers, and compliance rapidly increased to 90% pinger use in observed sets by December 1997. From 1998–2002, greater than 99% of all observed sets utilized pingers (Table 1).

For 1996 and 1997, mortality estimates were calculated with pingered and unpingered sets/effort representing different strata. In 1996, all pingered sets were observed, so mortality was estimated as the sum of observed mortalities recorded in pingered sets, plus a ratio estimate of mortality from unpingered sets. For 1997, mortality was estimated separately for an experimental period (1 January–27 October) and a mandatory period (28 October–31 December). During the 1997 experimental period, all pingered sets were observed, so mortality was estimated as the sum of observed mortalities recorded in pingered sets, plus a ratio estimate of mortality from unpingered sets. During the 1997 mandatory period, not all pingered sets were observed, so mortality was estimated as the sum of ratio estimates for pingered and unpingered sets.

Estimated effort during the 1997 experimental period was calculated by multiplying estimated 4th quarter fishing effort (2,145 days) by the fraction of observed 4th quarter sets occurring in the experimental period (188/473), plus the sum of fishing effort in calendar quarters 1–3 (894 days). This yielded a total estimate of 1,747 days fished during the experimental period. All pingered sets during the experimental period (n=174) were observed, which leaves 1,747 – 174 = 1,573 days of unpingered effort in the experimental period. Estimated fishing effort for the mandatory period was calculated as the estimated 4th quarter fishing effort (2,145 days), times the fraction of observed 4th quarter sets occurring in the mandatory period (285/473). This yielded a total estimate of 1,292 days fished during the mandatory period. Not all pingered sets were observed during the mandatory period, so the total number of pingered sets for the mandatory period was estimated as the number of estimated fishing days for the mandatory period (1,292), times the fraction of observed sets with pingers

Table 2.—Summary of annual fishing effort, observer coverage, and observed and estimated mortality in the California drift gillnet fishery, 1996–2002.

Item		1996			1997			1998			1999			2000			2001			2002			1996–2002	
Estimated days fishing effort		3,392			3,039			3,353			2,634			1,936			1,665			1,630			17,649	
Number of vessels		123			115			123			96			81			65			56				
Observed days fishing effort		421			692			587			526			444			339			360			3,369	
Observed trips effort		71			118			104			92			85			65			64			599	
Percent Observer coverage (days)		12.4%			22.8%			17.5%			20.0%			22.9%			20.4%			22.1%			19.1%	
		Mortality			Mortality			Mortality			Mortality			Mortality			Mortality			Mortality			Mortality	
Species	Obs.	Est.	CV	Obs.	Est.	CV	Obs.	Est.	CV	Obs.	Est.	CV	Obs.	Est.	CV	Obs.	Est.	CV	Obs.	Est.	CV	Obs.	Est.	CV
Dall's porpoise	2	25	0.74	4	19	0.74																6	44	0.53
Pacific whitesided dolphin	3	25	0.98	3	12	0.75							2	9	0.68	2	10	0.71	1	5	0.86	11	61	0.46
Risso's dolphin				3	10	0.95							2	9	0.71							5	19	0.60
Common dolphin (shortbeaked)[1]	28	345	0.20	22	114	0.24	9	51	0.38	36	180	0.27	24	105	0.26	7	34	0.41	7	32	0.46	133	861	0.11
Common dolphin (longbeaked)[1]				4	27	0.58				1	5	1.05	1	4	1.08				4	18	0.79	10	54	0.41
Northern right whale dolphin	5	25	0.71	5	29	0.46				3	15	0.72	11	48	0.48	5	25	0.57	2	9	0.70	31	151	0.25
Shortfinned pilot whale				1	7	0.96																1	7	0.96
Sperm whale[1]	1	1					1	6	0.97													2	7	0.83
Fin whale										1	5	1.05										1	5	1.05
Minke whale	1	12	1.06																			1	12	1.06
Gray whale							1	6	0.97	1	5	1.05										2	11	0.71
California sea lion	4	37	0.55	37	212	0.34	23	131	0.25	6	30	0.39	13	57	0.38	2	10	0.67	18	81	0.25	103	553	0.16
Northern elephant seal	5	37	0.53	8	44	0.37	4	23	0.48	2	10	0.65	6	26	0.39	1	5	0.94	1	5	0.92	27	150	0.21
Unidentified pinniped							2	11	0.68													2	11	0.68
Leatherback turtle	2	25	0.63	2	8	0.85																4	33	0.52
Loggerhead turtle[1]				1	7	0.93	2	11	0.72													3	18	0.57
Northern fulmar[1]													3	13	0.73							3	13	0.73
Unidentified bird				1	1	0.00													1	5	0.86	2	6	0.72
All cetaceans	40	433	0.18	42	218	0.18	11	57	0.36	42	205	0.25	40	175	0.21	14	69	0.31	14	64	0.34	203	1221	0.09
All pinnipeds	9	74	0.38	45	256	0.29	29	165	0.21	8	40	0.33	19	83	0.29	3	15	0.55	19	86	0.24	132	719	0.13
All turtles	2	25	0.63	3	15	0.63	2	11	0.72													7	51	0.39
All seabirds				1	1	0.00							3	13	0.73				1	5	0.86	5	19	0.55

[1] Includes one animal that was judged to be seriously injured under NMFS guidelines.