Table 4

Observed (obs) and estimated (est) cetacean, pinniped, turtle, and seabird mortality, stratified by year, in the California halibut and angel shark set gillnet fishery during the NMFS Observer Program, July 1990–December 1995. Estimates of total mortality are reported to the nearest individual. Estimated coefficients of variation (CV) are included in parentheses; (—) indicates CV was undefined. Effort and estimates for 1990 pertain to the third and fourth quarters only.

Year	1990			1991			1992			1993			1994			1995[1]		
Estimated days effort	3,041			7,171			5,577			5,680			1,943			2,257		
Observed days effort	158			706			698			875			150			0		
Percent observer coverage	5.2%			9.8%			12.5%			15.4%			7.7%			0%		
Observed trips effort	406			2,233			2,123			2,642			547			0		
	obs	est	CV	obs	est	CV	obs	est	CV	obs	est	CV	obs	est	CV	obs	est	CV
Harbor porpoise	4	37	(0.56)	5	38	(0.47)	6	48	(0.46)	2	13	(0.64)	1	14	(0.96)	—	14	(0.64)
Common dolphin (unknown stock)	0	0	(—)	0	0	(—)	2	15	(0.65)	0	0	(—)	0	0	(—)	—	—	(—)
Unidentified cetacean	0	0	(—)	0	0	(—)	1	8	(0.92)	0	0	(—)	0	0	(—)	—	—	(—)
California sea lion	67	867	(0.22)	142	1,842	(0.16)	338	3,418	(0.28)	237	1,942	(0.13)	109	905	(0.15)	—	724	(0.08)
Unidentified sea lion	1	23	(0.96)	6	109	(0.53)	7	54	(0.34)	0	0	(—)	0	0	(—)	—	—	(—)
Harbor seal	30	411	(0.23)	42	601	(0.23)	90	1,204	(0.47)	71	475	(0.13)	23	227	(0.33)	—	228	(0.13)
Northern elephant seal	13	119	(0.40)	3	30	(0.55)	7	51	(0.35)	11	70	(0.27)	2	16	(0.66)	—	47	(0.29)
Unidentified pinniped	2	42	(0.79)	3	30	(0.55)	7	50	(0.39)	7	32	(0.90)	1	8	(0.94)	—	17	(0.83)
Sea otter	3	27	(0.53)	0	0	(—)	0	0	(—)	0	0	(—)	0	0	(—)	—	—	(—)
Green/black turtle	0	0	(—)	0	0	(—)	1	8	(0.92)	1	6	(0.90)	0	0	(—)	—	2	(0.61)
Loggerhead turtle	0	0	(—)	0	0	(—)	1	8	(0.92)	0	0	(—)	0	0	(—)	—	—	(—)
Leatherback turtle	0	0	(—)	0	0	(—)	0	0	(—)	0	0	(—)	1	8	(0.94)	—	—	(—)
Unidentified turtle	0	0	(—)	0	0	(—)	0	0	(—)	1	6	(0.90)	0	0	(—)	—	2	(0.61)
Pacific loon	0	0	(—)	1	13	(0.94)	0	0	(—)	0	0	(—)	0	0	(—)	—	—	(—)
Common loon	0	0	(—)	2	22	(0.68)	1	7	(0.92)	0	0	(—)	0	0	(—)	—	—	(—)
Unidentified loon	1	23	(0.96)	4	48	(0.48)	0	0	(—)	0	0	(—)	0	0	(—)	—	—	(—)
Western grebe	0	0	(—)	1	8	(0.92)	3	23	(0.70)	1	6	(0.90)	0	0	(—)	—	2	(0.61)
Unidentified grebe	0	0	(—)	0	0	(—)	4	31	(0.92)	1	6	(0.90)	0	0	(—)	—	3	(0.83)
Double-crested cormorant	2	18	(0.93)	0	0	(—)	1	7	(0.92)	0	0	(—)	1	8	(0.94)	—	—	(—)
Brandt's cormorant	2	41	(0.78)	36	409	(0.44)	14	279	(0.67)	3	13	(0.64)	2	16	(0.66)	—	3	(0.43)
Pelagic cormorant	1	33	(0.98)	1	8	(0.92)	0	0	(—)	0	0	(—)	0	0	(—)	—	—	(—)
Unidentified cormorant	9	132	(0.45)	15	450	(0.92)	9	68	(0.30)	5	32	(0.40)	0	0	(—)	—	10	(0.35)
Common murre	142	1,300	(0.21)	289	2,201	(0.27)	292	2,333	(0.28)	137	879	(0.32)	20	284	(0.29)	—	967	(0.32)
Unidentified alcid	1	9	(0.93)	0	0	(—)	0	0	(—)	0	0	(—)	0	0	(—)	—	—	(—)
Unid. seabird	0	0	(—)	2	22	(0.68)	3	23	(0.53)	1	6	(0.90)	0	0	(—)	—	3	(0.83)

[1] Estimates for 1995 were based on stratified rates from 1993 results.

when a trip was chosen to be observed, the NMFS technician observed all net pulls during the trip. A single net per day was set at dusk and retrieved before dawn. Net pulls and effort-days were equivalent units for this fishery. For estimation of incidental kill, the collection of observed trips during a year was treated as a random sample (an approximation) and a ratio estimator was used. Trips were treated as sampling units and the number of days per trip was treated as an auxiliary variable. Stratification by quarter of year or set location was not used for yearly estimates because previous exploratory analysis had not found this type of stratification to be significantly related to incidental kill. Yearly estimates, 1991–95, were calculated for each species observed entangled ("Results" section). Estimates for 1990 correspond only to the last two quarters of that year. Formulae from Cochran (1977) were used for estimating kill rate, $\hat{r}$, total incidental kill, $\hat{m}$, and variances:

$$\hat{r} = \frac{\Sigma_i k_i}{\Sigma_i d_i}, \quad (1)$$

$$\hat{\sigma}_r^2 = \left(1 - \frac{d}{D}\right)\left(\frac{1}{n}\right)\left(\frac{1}{d_{avg}^2}\right)\left(\hat{r}^2\sigma_d^2 + \hat{\sigma}_k^2 - 2\hat{r}\hat{\sigma}_{d,k}\right), \quad (2)$$

Table 5

Observed and estimated cetacean, pinniped, turtle, and seabird entanglement, stratified by year, in the California halibut and angel shark set gillnet fishery during the NMFS Observer Program, July 1990–December 1995. Estimates of entanglement are reported to the nearest individual. Estimated coefficients of variation (CV) are included in parentheses; (—) indicates CV was undefined. Effort and estimates for 1990 pertain to the third and fourth quarters only.

Year	1990			1991			1992			1993			1994			1995[1]		
Unidentified sea lion	67	867	(0.22)	143	1,850	(0.16)	341	3,438	(0.28)	239	1,977	(0.13)	109	905	(0.15)	—	729	(0.08)
Harbor seal	30	411	(0.23)	43	615	(0.23)	90	1,204	(0.47)	71	475	(0.13)	23	227	(0.33)	—	228	(0.13)
Unidentified turtle	0	0	(—)	0	0	(—)	0	0	(—)	2	13	(0.64)	0	0	(—)	—	5	(0.59)
Common loon	0	0	(—)	4	48	(0.60)	1	7	(0.92)	0	0	(—)	0	0	(—)	—	—	(—)
Western grebe	0	0	(—)	2	22	(0.68)	3	23	(0.70)	1	6	(0.90)	0	0	(—)	—	2	(0.61)
Brandt's cormorant	2	41	(0.78)	41	494	(0.37)	20	321	(0.58)	5	25	(0.45)	2	16	(0.66)	—	9	(0.40)
Unidentified seabird	0	0	(—)	2	22	(0.68)	5	37	(0.41)	1	6	(0.90)	0	0	(—)	—	3	(0.83)

[1] Estimates for 1995 were based on stratified rates from 1993 results.

$$\hat{m} = D\hat{r}\,, \tag{3}$$

$$\hat{\sigma}_m^2 = D^2\hat{\sigma}_r^2\,. \tag{4}$$

Variables k_i and d_i represent the observed kill and number of days for the i^{th} trip; d_{avg} is the sampled mean number of days per trip; $\hat{\sigma}_d^2$, $\hat{\sigma}_k^2$, and $\hat{\sigma}_{d,k}$ are the sample variances and covariance of d_i and k_i; d and n are the observed number of days and trips, and D represents the total number of days of effort. The finite population correction factor, $(1 - n/N)$, where N is the total number of trips, was approximated by using $(1 - d/D)$ because the total number of driftnet trips was not determined during the estimation of effort.

Mortality estimation in the set gillnet fishery In the setnet fishery, a trip was selected and all net pulls during the trip were observed. Because greater than 99% of all observed set gillnet trips were one day in length, a trip was considered equivalent to an effort-day. Net pulls were not randomly sampled and total number of net pulls per trip was not recorded for unobserved trips, therefore a trip was considered the sampling unit. For observed trips, the overall average number of net pulls per trip (or effort-day) was 3.08 (CV=0.43), and the overall average number of marine mammal entanglements per trip was 0.48 (CV=3.10) during the NMFS Observer Program.

Researchers had previously shown (Perkins et al.[5]) that quarter of year and set location were significant predictors of sea lion and harbor seal entanglement. Consequently, estimation of incidental kill in the setnet fishery was stratified by area for all mammal species. The geographic area fished was divided into four strata: southern California, Channel Islands, Ventura, and central California. Central California included all effort south of Bodega Bay and north of Point Conception, 34°30'N (CDFG blocks 437–650). There was no legal coastal setnet fishing north of Bodega Bay. The Channel Islands stratum included all effort within CDFG blocks containing part of any Channel Islands (CDFG blocks 684–690, 707–713, 760–762, 765, 806–807, 813–814, 829, 849–850, and 867). The southern California stratum included all effort south of 33°50' N (blocks 718–918), excluding CDFG block 776 and the Channel Islands stratum. The Ventura stratum contained the remaining area. Incidental kill estimation for sea lions and harbor seals included additional stratification by quarter of the year for the southern California and Ventura areas because for these species, overstratification was not a problem.

Yearly estimates of incidental kill in the setnet fisheries were calculated for all species of marine mammals observed entangled (Tables 4 and 5). Estimates for turtles and seabirds were calculated by the same method. For each species, kill rate, r_s, and total incidental kill, m_s, were estimated for each area by using a mean-per-unit (MPU) estimator with effort-days as the sampling unit (Diamond and Hanan[1]). Formulae for MPU estimators and their estimated variances for each area are (Cochran, 1977)

$$\hat{r}_s = \frac{\Sigma_i k_{i,s}}{d_s}\,, \tag{5}$$

$$\hat{\sigma}_{r,s}^2 = \left(1 - \frac{d_s}{D_s}\right)\left(\frac{1}{d_s}\right)\hat{\sigma}_{k,s}^2\,, \tag{6}$$

$$\hat{m}_s = D_s\hat{r}_s\,, \tag{7}$$