

By-Catches Of Marine Mammals In U.S. Fisheries and a First Attempt to Estimate the Magnitude of Global Marine Mammal By-Catch

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ABSTRACT

We provide estimates of the magnitude of cetacean and pinniped by-catches in fisheries of the United States from 1990 to 1999 using data from the stock assessment reports required by the Marine Mammal Protection Act. The mean annual by-catch of marine mammals in U.S. fisheries during this period was $6,215 \pm 1,415$. By-catches of cetaceans and pinnipeds occurred in similar numbers. Most by-catches of cetaceans (84%) and pinnipeds (98%) occurred in gill net fisheries. Marine mammal by-catches declined significantly over the decade, primarily due to a reduction in by-catches of cetaceans. Total marine mammal by-catch was significantly lower after the implementation of take reduction measures in the latter half of the decade. We use these observations to explore the possibility of deriving a first estimate of the magnitude of marine mammal by-catches in the world's oceans, by expanding U.S. by-catches with FAO data on fisheries landings and fleet composition. We conclude that the global by-catch of marine mammals is likely to number in the hundreds of thousands. Such by-catches likely have significant demographic effects on many populations of marine mammals. We urgently need better data to fully understand the impact of these interactions.

INTRODUCTION

By-catches are one of the most widely known forms of interactions between marine mammals and fisheries. These interactions occur in many fisheries, but are particularly common in fixed fishing gear, such as gill nets (Perrin et al. 1994). By-catches can have important consequences for the demography of cetacean populations (Reeves et al. 2003) and endanger the existence of some species (e.g. D'Agrosa et al. 2000).

By-catches are particularly relevant to the work of the Scientific Committee (SC) of the International Whaling Commission. At its 53rd meeting, the Commission passed a Resolution (2001-4) acknowledging the critical nature of this problem for many species and urging all member countries to contribute fully to the work of the SC in the estimation of by-catches. Knowledge of the magnitude of by-catches is particularly important to the SC, because catch

limits calculated under the Revised Management Procedure are calculated after deducting all other human-induced mortalities, such as by-catches (IWC 1998).

Despite the impact of by-catches on many cetacean populations, we still understand little about the global magnitude of these interactions. In many areas of the world, the resources needed to conduct assessments of the magnitude and impact of cetacean by-catches do not exist. This is particularly true in many areas of the developing world where demand for protein is intense and conflicts between fisheries and marine mammals may be severe.

In this brief paper we provide estimates of the magnitude of cetacean and pinniped by-catches in fisheries of the United States during the past decade. In 1994, the United States implemented a management scheme designed to assess and mitigate by-catches of marine mammals in commercial fisheries (Wade 1998; Read and Wade 2000; Young 2001). The existence of this scheme allows us to determine the total magnitude of marine mammal by-catches in the United States for the first time. We also explore the possibility of extrapolating from these observations to derive a first estimate of the magnitude of marine mammal by-catches in the world's oceans.

METHODS

By-Catches in U.S. Fisheries

We obtained estimates of the magnitude of by-catches for 125 stocks of marine mammals in U.S. waters from published stock assessment reports (NOAA 2002). These assessments are updated every three years, or more frequently, depending on the status of the stock. Information on by-catches is provided in the section of each report entitled *Annual Human Caused Mortality and Serious Injury*. This information is typically stratified by year and fishery. We compiled information on by-catches for each stock from 1990-1999 and combined by-catches into three categories of fisheries: *Gill Nets*, *Trawls* and *Other* (including longlines, purse seines, traps, etc.).

In some cases, particularly when it is difficult to identify individuals at sea during surveys, two or more species from a genus are lumped together in the stock assessment reports (e.g. some stocks of *Mesoplodon*, *Globicephala*, *Stenella* and *Kogia*). In these cases, we included by-catch data only from the genus.

Most estimates of the magnitude of by-catches in the reports are derived from observer programmes. Occasionally, however, these estimates are augmented with supplemental information from other sources, such as reports of stranded, entangled animals or data from fishery logbooks. In addition, the reports include information on both mortality and serious injuries that will likely lead to mortality. We include both categories in our analysis. Throughout our compilation, we followed the format of stock assessment report and use the total estimated mortality and serious injury reported for each stock.

We assessed whether the magnitude of by-catches changed over the decade by conducting simple linear regressions of by-catches against year for cetaceans, pinnipeds and all marine mammals. We also compared mean by-catches in two periods (1990-1994 and 1995-1999) using simple analysis of variance. We chose these periods because most attempts to reduce marine mammal by-catches in U.S. fisheries began after 1994, when the U.S. Marine Mammal Protection Act was amended to deal with this issue (Bache 2001; Young 2001). Finally, we compared the time series of marine mammal by-catches with landings of target species from selected gear types obtained from the NOAA Commercial Fisheries Landings database (NOAA 2003).

Towards an Estimate of Global By-Catches

We used two simple methods to extrapolate to global marine mammal by-catches from the U.S. data set. First, we used the ratio of U.S. fisheries landings to global landings to expand the annual estimates of U.S. by-catch to global totals. We obtained data on U.S. and global landings of marine fishes from the FAOSTAT fisheries database (FAOSTAT 2002). We then employed a similar approach, but used the number of fishing vessels as the expansion metric, rather than fisheries landings. We stratified the U.S. marine mammal by-catch by fishery type (Gill Net, Trawl and Other) and used ratios of the number of U.S. to global vessels in each fishery category to expand the U.S. by-catch estimates to a global total. We obtained data on the number of fishing vessels from the FAO FIGIS database of global fishing fleets (FIGIS 2003). These data were available only to 1995 and, for reasons described below, we only used data from 1990-1994.

RESULTS

By-Catches in U.S. Fisheries

The mean annual by-catch of marine mammals in U.S. fisheries between 1990 and 1999 was 6,215 (SD 1,415) (Tables 1 and 2). By-catches of cetaceans ($3,029 \pm 1,000$) and pinnipeds ($3,187 \pm 1,078$) occurred in similar numbers. The vast majority of both cetacean (84%) and pinniped (98%) by-catches occurred in gill net fisheries.

Marine mammal by-catches declined over the decade ($p = 0.002$, $r^2 = 0.714$; Figure 1). A significant negative trend was apparent in by-catches of cetaceans ($p = 0.011$, $r^2 = 0.576$) but not for pinnipeds ($p = 0.244$, $r^2 = 0.165$). Total marine mammal by-catch was significantly lower ($F = 11.21$, $p = 0.010$) in 1995-1999 ($5,189 \pm 1,053$) than in 1990-1994 ($7,241 \pm 876$). By-catches of both cetaceans and pinnipeds were lower in 1995-1999 than in 1990-1994, but not significantly ($F = 2.99$, $p = 0.122$ and $F = 2.954$, $p = 0.124$, respectively). These declines were not likely the result of a reduction in fishing effort as landings from gill net fisheries in the U.S. rose throughout this period (Figure 2).

Some temporal trends can be explained by examining the by-catches of single species. For example, the Gulf of Maine stock of harbour porpoises *Phocoena phocoena* was subject to the largest by-catch of any marine mammal in the early 1990s. This by-catch declined dramatically, from 2900 in 1990 (57% of cetacean by-catch) to 323 in 1999 (19% of cetacean by-catch) (Figure 3). Several mitigation measures, including time-area closures and the use of acoustic alarms, were employed in the late 1990s to reduce this by-catch. At the same time, however, landings of target species in the New England sink gill net fishery declined dramatically (Figure 3), due to measures designed to conserve these overfished fish stocks.

Towards an Estimate of Global By-Catches

U.S. marine fisheries landings comprised approximately 5% of the global total from 1990 to 1999 (Table 3). Using this ratio as an expansion factor, we estimate a mean global marine mammal by-catch of 119,141 (SD 24,315) between 1990 and 1999. This estimate is biased for several reasons (see below), including the fact that by-catch reduction measures were employed during the late 1990s in the U.S., but in few other parts of the world. Thus, we used data from 1990-1994 to generate estimates of the annual global by-catches of marine mammals ($132,724 \pm 18,964$), cetaceans ($64,120 \pm 15,130$) and pinnipeds ($68,605 \pm 26,236$).

The U.S. fleet comprised 1.1%, 5.9% and 4.2% of the global registry of gill net, trawl and other vessels, respectively, in the FIGIS database between 1990 and 1994 (Tables 4, 5 and 6). Using these ratios to extrapolate to global by-catches during this period yielded an annual estimate of $653,365 \pm 108,851$ marine mammals, comprised of $307,753 \pm 98,303$ cetaceans and $345,611 \pm 140,441$ pinnipeds. The preponderance of gillnet vessels in the global fleet, coupled with the known high bycatch rates of marine mammals in gillnet fisheries in the US and elsewhere, suggest that the vast majority (98%) of the world's cetacean and pinniped by-catches occur in gill net fisheries.

DISCUSSION

Our estimates of the magnitude of marine mammal by-catches in United States fisheries are negatively biased. Potential by-catches in many fisheries, particularly those in remote regions such as Alaska, have yet to be properly assessed. Existing information for such fisheries rely on anecdotal reports or logbook accounts, which are unlikely to reflect the true magnitude of marine mammal by-catches. Nevertheless, it has been possible, for the first time, to generate an estimate of the magnitude of marine mammal by-catches in U.S. fisheries.

Two points are worth noting regarding U.S. by-catches. First, it is clear that most by-catches occur in gill net fisheries, despite the existence of fleets of large, industrial fishing vessels using other types of gear. We believe that this is likely to be typical of most of the world's fisheries, particularly those in developing nations. Thus, efforts to document the magnitude of by-catches and to assess their impact on marine mammal populations should, in general, focus on gill net fisheries. This does not imply that significant by-catches do not occur in other gear types, such as some pelagic trawl fisheries, but we conclude that by-catches are much more likely to occur in gill nets.

Secondly, by-catches of marine mammals in U.S. fisheries decreased by 40% between 1990 and 1999. This decline was attributable almost entirely to a reduction in the by-catch of cetaceans, which decreased by almost two-thirds (Table 1). At least some of this reduction in cetacean by-catch was due to conservation measures implemented through the take reduction process (Bache 2001; Young 2001). This success demonstrates that it is possible to reduce by-catches while maintaining viable fisheries (see also Hall 1996). We caution, however, that at least some of the reduction may have come from reduced fishing effort brought about by the collapse of important fish stocks, particularly in New England (Figure 3). It will be important to monitor by-catches of harbour porpoises and other species in the gill net fisheries of this region as these fish stocks recover, to determine whether or not the conservation measures in place will be effective at higher levels of fishing effort.

Clearly the global estimates we present here are very crude. For example, by-catches of pinnipeds in many tropical countries are likely to be minimal or non-existent. In addition, U.S. fisheries and their associated by-catch rates are unlikely to be representative of fisheries throughout the world. Indeed the U.S. fleet is more capital intensive than many other fleets, particularly in the developing world, and thus may have higher CPUEs of landed catch than many other countries. This may bias downwards global estimates of by-catches extrapolated from fisheries landings. On the other hand, the average fishing power (and by implication the by-catch rate per boat) of a US vessel may be higher than the global average, which may positively bias estimates based on vessel numbers.

There may also be significant differences in the by-catch rates of marine mammals in similar gears in different locations. However, some small cetacean by-catch rates in gill net fisheries are quite similar where they have been measured in Europe and North America (Table 7).

More importantly, however, the registry of fishing vessels in the FIGIS database is both incomplete and of unknown accuracy. These data are contributed voluntarily to the FAO by member countries, but many countries fail to report or do not report the composition of their fleet by vessel type (Maurizio Perotti, FAO, personal communication, 24 February 2003). Thus our extrapolation to global by-catches using the number of vessels may be biased downwards. Given the incomplete nature of the FIGIS database, we believe that it is likely the total by-catch of marine mammals may be even greater than the figures we present here.

Despite these limitations, we believe that our simple extrapolations provide some credible first estimates of the potential magnitude of global marine mammal by-catches. We conclude that the global by-catch of marine mammals is likely to number in the hundreds of thousands each year. This is consistent with what we know of the existence of large, documented by-catches in some areas (Table 8).

Our estimates could be improved considerably if better data were made available by fishing nations on the composition of the fleet and on relative measures of effort in different fleet sectors. Such information might also assist management organizations, such as the FAO, to direct conservation efforts to areas where marine by-catches are likely to be large, but where no research infrastructure exists to assess their size or impact. For example, we can predict that a country with a large fleet of coastal gill net vessels is likely to experience significant marine mammal by-catches, even in the absence of other direct information.

Finally, we note that with a global marine mammal by-catch of several hundred thousand animals per year, it is likely that important conservation problems exist but have not yet been identified. Furthermore, it is likely that some by-catches have not yet been identified as important factors influencing the dynamics of many marine mammal populations. It is important to improve on the simple methods and incomplete data described here so that we can better understand the impacts of by-catches on marine mammals.

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Table 1. Estimates of cetacean by-catches in U.S. fisheries. See text for data sources and analytical methods.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Gillnet	4902	3154	2373	2489	2928	2261	2624	2095	1481	1051
Trawl	195	297	232	133	199	195	999	436	116	332
Other	3	9	256	60	388	475	114	11	70	408
Total	5100	3460	2861	2682	3515	2931	3737	2543	1668	1791

Table 2. Estimates of pinniped by-catches in U.S. fisheries. See text for data sources and analytical methods.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Gillnet	1921	3312	5626	3573	3540	3136	2472	2873	2323	2344
Trawl	19	36	34	10	29	3	15	17	14	11
Other	151	149	148	10	29	30	6	20	15	0
Total	2091	3497	5808	3593	3598	3169	2493	2910	2352	2355

Table 3. Estimates of by-catch of marine mammals in the world's fisheries using marine fisheries landings to expand U.S. estimates to global totals. See text for data sources and analytical methods.

	U.S. Landings (000 mt)	Global Landings (000 mt)	Global Cetacean By-Catch	Global Pinniped By-Catch	Global Marine Mammal By-Catch
1990	4,034	69,116	87,380	35,827	123,208
1991	3,535	67,813	66,367	67,088	133,455
1992	3,622	68,134	53,818	109,267	163,085
1993	3,854	68,847	47,920	64,193	112,113
1994	3,946	73,093	65,113	66,649	131,761
1995	3,578	72,194	59,131	63,939	123,070
1996	3,515	73,903	78,571	52,413	130,983
1997	3,694	72,988	50,237	57,496	107,732
1998	3,440	66,286	32,133	45,318	77,451
1999	3,330	71,107	38,256	50,292	88,548

Table 4. Estimates of by-catch of marine mammals in the world's gill net fisheries using number of gill net vessels to expand U.S. estimates to global totals. See text for data sources and analytical methods.

	Number of U.S. Vessels	Total Number of Vessels	Global Cetacean By-Catch	Global Pinniped By-Catch	Global Marine Mammal By-Catch
1990	2,140	203,598	466,392	182,763	649,154
1991	2,140	217,585	320,633	336,748	657,381
1992	2,160	218,272	239,766	568,518	808,283
1993	2,500	219,461	218,513	313,654	532,167
1994	2,500	220,500	258,250	312,228	570,478

Table 5. Estimates of by-catch of marine mammals in the world's trawl fisheries using number of trawling vessels to expand U.S. estimates to global totals. See text for data sources and analytical methods.

	Number of U.S. Vessels	Total Number of Vessels	Global Cetacean By-Catch	Global Pinniped By-Catch	Global Marine Mammal By-Catch
1990	7,446	129,403	3,389	330	3,719
1991	7,440	130,128	5,198	630	5,828
1992	8,150	132,957	3,790	555	4,344
1993	8,290	137,720	2,213	166	2,379
1994	8,030	137,479	3,407	496	3,904

Table 6. Estimates of by-catch of marine mammals in the world's other fisheries using number of vessels to expand U.S. estimates to global totals. See text for definitions of fishery type, data sources and analytical methods.

	Number of U.S. Vessels	Total Number of Vessels	Global Cetacean By-Catch	Global Pinniped By-Catch	Global Marine Mammal By-Catch
1990	3,220	77,640	72	3,645	3,717
1991	3,180	79,045	222	3,708	3,930
1992	3,230	80,606	6,382	3,698	10,079
1993	3,495	80,366	1,377	235	1,612
1994	3,430	80,991	9,164	685	9,849

Table 7. Standardized by-catch rates (porpoises per 10,000 net km hours) of harbour porpoises *Phocoena phocoena* in European and North American demersal gill net fisheries.

Region	By-Catch Rate	Source
UK Celtic Sea	8.08	Tregenza et al.1997
Irish Celtic Sea	7.02	Tregenza et al.1997
Danish North Sea	8.22	Vinther 1999
UK North Sea	8.34	Northridge & Hammond 1999
US Gulf of Maine	10.8	Bisack 1997

Table 8. Large, documented by-catches of marine mammals between 1990-99.

Species	Country	Fishery	Year	Estimate	Source
Dall's Porpoise	Japan	Drift Net	1991	3,207	IWC 2002
Harbour Porpoise	Denmark	Gill Net	1992-4	6,785	Vinther 1999
Harp Seal	Canada	Gill Net	1994	36,000	Walsh et al. 2001
Pelagic Dolphins	IATTC	Purse Seine	1991	47,448	MMC 2002

Figure 1. By-catch of cetaceans and pinnipeds in U.S. fisheries from 1990 to 1999. See text for data sources and notes on analytical methods.

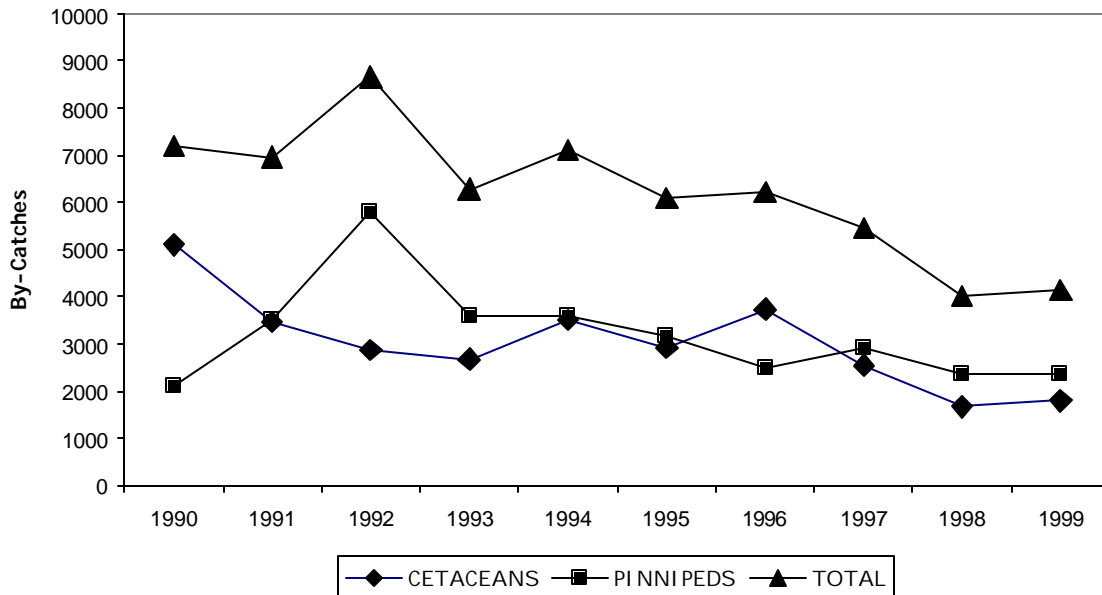


Figure 2. By-catch of marine mammals in U.S. fisheries from 1990 to 1999 shown with gill net fisheries landings from the same period. See text for data sources and notes on analytical methods for by-catch data. Gill net fisheries landings were obtained from NOAA (2003).

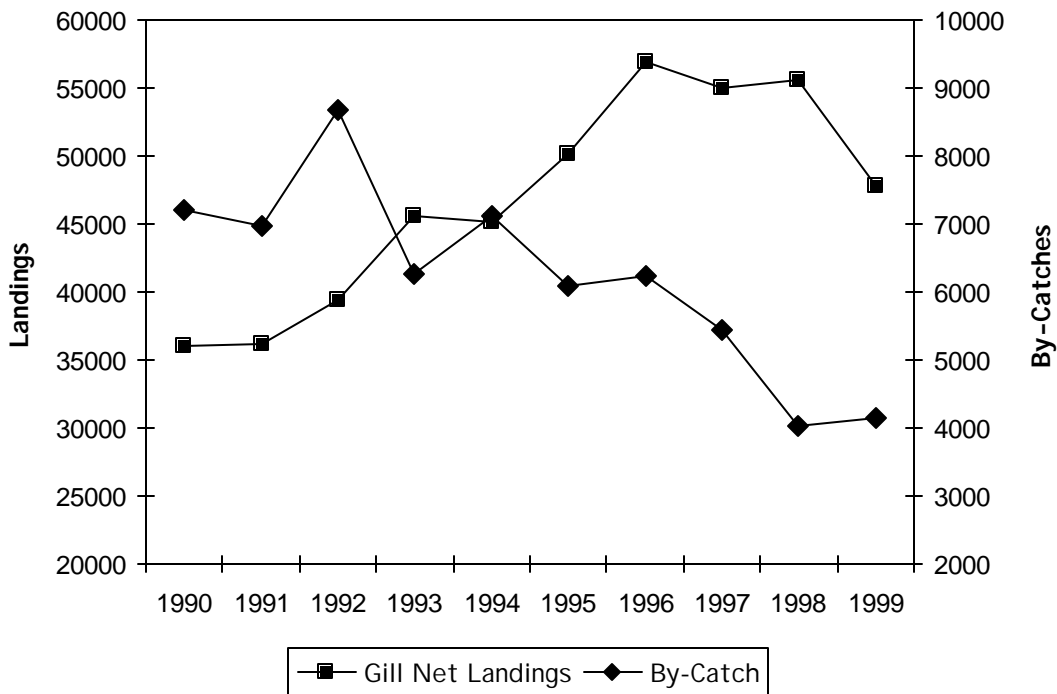


Figure 3. By-catches of harbour porpoises *Phocoena phocoena* in New England from 1990 to 1999. Catches of Atlantic cod *Gadus morhua* in the New England sink gillnet fishery are also shown for comparison. See text for data sources and analytical methods for harbour porpoise by-catch. Data on cod landings were obtained from NEFSC (2001).

