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ESTIMATION OF CETACEAN MORTALITY IN THE US ATLANTIC SWORDFISH AND TUNA DRIFTNET AND PAIR-TRAWL FISHERIES.

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1. INTRODUCTION

The Atlantic pelagic driftnet and trawl fisheries for swordfish, tuna and other large pelagic species, were both identified by NMFS as Category 1 fisheries under the provisions of the 1994 amendments to the Marine Mammal Protection Act of 1972. As such, vessels in both fisheries have been subject to sea sampling or monitoring by independent observers. The driftnet fishery is distributed geographically from the shelf edge region of the Grand Banks off Newfoundland to the Gulf of Mexico. Most fishing effort is concentrated along the southern edge of George's Bank in the summer months (mainly June to September), and off Cape Hatteras in the winter (most recently January through March). Effort peaked in this fishery in 1990. Thereafter, with the introduction of quotas, effort was greatly reduced. The driftnet fishery was subject to increased sea sampling between 1989 and 1993.

The pair trawl fishery was started in 1991, and effort was increased through 1992 and 1993, with participation by a total of 19 vessels. The fishing season extends from June through November, and the fishery is concentrated along the outer shelf in the mid-Atlantic region, especially around Hudson Canyon. Sea sampling of this fishery began in October 1992.

Estimating the numbers of cetaceans which have been killed as an accidental result of fishing operations in the pelagic driftnet and pair-trawl fisheries requires estimates of the cetacean catch rates and estimates of the total fishing effort in each fishery. To this end, three datasets have been analysed. Sea sampling data, on-board observer data collected by the Sea Sampling Investigation (SSI) at the Northeast Fisheries Science Center (NEFSC) at Woods Hole from a sample of the fleet, have been used to generate fleet-wide estimates of cetacean catch rates in each of the two fisheries. Logbook data (daily reporting forms) collected by the Southeast Fisheries Center (SEFC) and commercial weighout data collected by port agents have been used to generate estimates of total fishing effort for each fishery. Sea sampling data have also been used to calibrate units of fishing effort which differ between the two effort data sources. In all three cases data gave been examined for the years 1989-1993 only.

This report is divided into five further sections. The first deals with preliminary analysis of the three data sets, through which an oversight of the fisheries and their by-catch was obtained. Secondly, the derivation of total effort figures is described. Thirdly, estimates of catch rates derived from the sea-sampling data are described. Fourthly, estimates of total catch are derived from the catch rate estimates and their associated variances. Finally these results are discussed in relation to possible inaccuracies.

2. PRELIMINARY ANALYSIS.

Preliminary analysis of the sea sampling (SS) data yielded summary statistics on the species impacted by the two fisheries, the geographical and temporal extent of the sampling program, and seasonal differences in catches of cetacean species.

TABLE 1
MARINE MAMMAL SPECIES OBSERVED IN THE TWO FISHERIES.
Numbers of individuals recorded by the sea sampling program
in the driftnet (D.N.) and pair-trawl (P.T.) fisheries

Species Name	Code	D.N.	P.T.
Phocoena phocoena Harbour porpoise	HAPO	1	0
Lagenorhynchus acutus Atlantic white-sided dolphin	WSDO	2	0
Delphinus delphis Common dolphin	CODO	312	9
Stenella plagiodon Spotted dolphin	SPOD	10	0
Stenella coeruleoalba Striped dolphin	STDO	19	0
Stenella longirostris Spinner dolphin	SPID	1	0
Stenella spp.	USDO	9	0
Tursiops truncatus Bottlenose dolphin	BODO	39	21
Grampus griseus Risso's dolphin	RIDO	38	1
Globicephala macrorhynchus Short-finned pilot whale	SFPW	7	0
Globicephala melas Long-finned pilot whale	LFPW	2	0
Globicephala spp. Pilot whale	-	38	0
Ziphius cavirostris Cuvier's beaked whale	BEWH	1	0
Mesoplodon mirus True's beaked whale	BEWH	2	0
Mesoplodon bidens Sowerby's beaked whale	BEWH	1	0
Mesoplodon spp.	BEWH	18	0
Megaptera novaeangliae Humpback whale	HUBA	1	0
Eubalaena glacialis Right whale	RIWH	1	0
Physeter macrocephalus Sperm whale	SPWH	1	0
Unidentified dolphin species	UNDO	2	1

The SS data set included information on 14 vessels using pair-trawls, and 17 driftnet vessels, with 27 pair-trawl trips and 65 driftnet trips observed. In terms of hauls, there were 150 pair-trawl hauls (or tows) and 362 drift net hauls observed during the four years 1989-1993. The observed pair-trawl hauls

resulted in the capture of 3 identified cetacean species, namely bottlenose dolphins, common dolphins and Risso's dolphins (Latin names are given in Table 1, together with 4-letter coded identifiers used below), together with one individual dolphin which was not specifically identified. In pair-trawl 150 hauls, 32 individuals were recorded, with a gross cetacean catch rate of just over 0.21 animals per haul.

The observed drift net hauls resulted in the capture of 16 identified cetacean species, and further individuals which were identified only to generic level in the case of the genera *Stenella, Mesoplodon* and *Globicephala*. Two individuals were also recorded as unidentified dolphins. A total of 548 individual cetaceans were recorded in the 362 observed hauls, a gross cetacean catch rate of just over 1.5 animals per haul. There were no pinnipeds recorded in any observed hauls in either fishery. The species composition as recorded in the SS data set is shown in Table 1.

A small proportion of animals, 16 of 548 in the driftnet fishery (but none of the 32 in the pair-trawl fishery), were reported as alive when caught, although only 5 of these 16 animals were also recorded uninjured.

Certain species showed a degree of seasonality in their appearance in the catch statistics. This seems to be a reflection of the changing distribution pattern of the driftnet fishery in particular. Mean latitudes and longitudes of observed (SS) driftnet hauls showed a distinct shift in observed haul locations with season. During winter months (November through May), the mean location of observed hauls was south of 38°N, or along the shelf edge region from the Delmar peninsula to Cape Hatteras. During the summer months, observed driftnet fishing activity had shifted north and east to the shelf edge region to the south of George's Bank.

No such seasonal shift could be detected in observed hauls in the pair-trawl fishery which were concentrated to a greater extent in the mid-Atlantic region from Rhode Island to Delaware.

The logbook data also contain latitude and longitude points for each day's fishing activity, and the seasonal pattern found in the logbook data closely reflected that shown by the observer data.

Among the species recorded caught in sea sampled driftnet trips, Atlantic white-sided dolphins were recorded only in September and October, at which time the driftnet fishery reaches its most northerly limits. This species is most abundant in US waters in and around the Gulf of Maine. The observed catches probably reflect the limited likelihood of white-sided dolphins encountering driftnets further south.

Similar patterns are observed for pilot and beaked whales, and for Risso's dolphins. Short-finned pilot whales were only recorded in the driftnet fishery during winter months when the fishery was located in southern waters, while long-finned pilot whales were only recorded in northern waters and summer months. Unidentified pilot whales fell into two groups, in the summer and winter respectively. Beaked whales and Risso's dolphins were only recorded in northern waters and summer months. Bottlenose

dolphins and common dolphins were taken throughout the year, as were *Stenella* species, although in all of these groups there were bi-modal peaks in catch rate (numbers of animals per haul) in the summer and winter respectively, in all three cases the highest catch rates being in the winter.

These observations suggest that the driftnet fishery is impacting two different 'cetacean zones' characterised by differences in species presence and abundance. The northern zone, extending from the shelf-edge waters south of Rhode Island east towards George's Bank, is characterised by the presence of long-finned pilot whales, beaked whales and Risso's dolphins in the catch, while the southern zone is characterised by short-finned pilot whales, spotted and spinner dolphins.

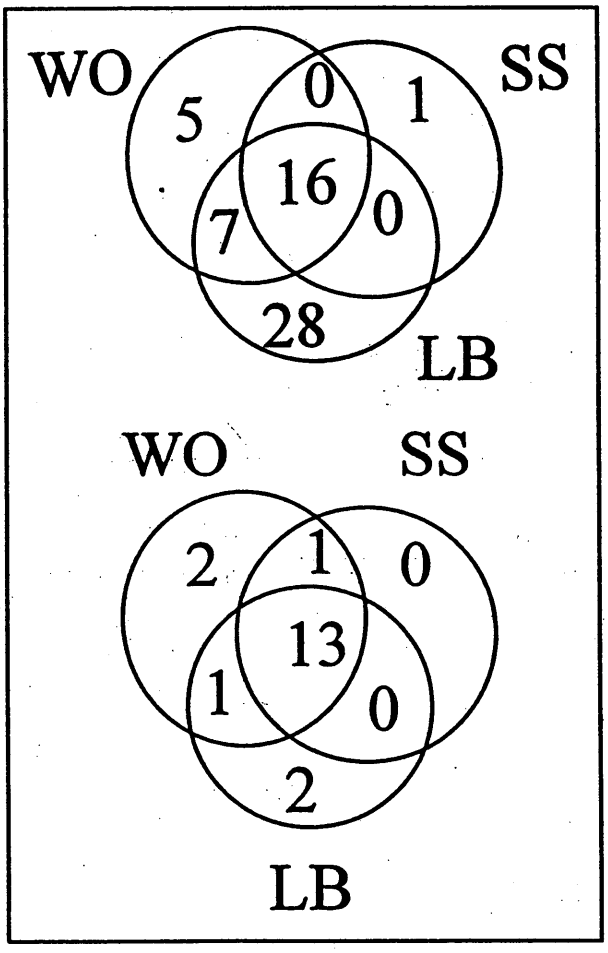
FIGURE 1
COMPARISON OF PAIR-TRAWL AND DRIFTNET FLEETS IN THREE DATABASES.

Driftnet fleet:

Only 23 out of 59 vessels appear in both the main databases. One vessel appears in the sea sampling database but nowhere else.

Pair-trawl fleet:

Of 19 vessels known to be involved in this fishery, 14 are recorded in both the main databases.



This preliminary examination of the species composition of the catch and locations of the driftnet fishery through the year, suggested that it would be sensible to separate this fishery into two strata, a southern or winter stratum, and a northern or summer stratum. Examination of the locations and species composition of the pair-trawl fishery, which showed little seasonal change for the 6 months of operation (June to November) did not warrant any seasonal or geographical stratification of this fishery.

An examination of the weighout and logbook data sets yielded information about the numbers of vessels involved in the fishery and the completeness of the data sets. A total of 59 vessels was identified from US Coastguard document numbers to have operated driftnets during the period 1989 to 1993 (inclusive), while 19 vessels were found to have reported the use of pair-trawls. There was, however, a considerable lack of consistency between these two data sets, with several vessels appearing in one data set but not the other. Additionally, one vessel which was sea sampled did not occur in either data set. The degree to which the data sets matched for vessel-activity is shown in Figure 1.

In the case of the driftnet fishery, of the 59 vessels known to have engaged in this activity, only 28 were found in the weighout database; of these 5 were not recorded in the logbook database. The pair-trawl fishery involved 19 vessels, two of which were found in the weighout database but did not appear in the logbook database, and a further two of which appeared in the logbook database but not in the weighout. Clearly, there is a considerable degree of misreporting in these two databases, which makes the accurate estimation of total fishing effort extremely difficult.

3. ESTIMATION OF TOTAL EFFORT IN THE TWO FISHERIES.

The two main fishery databases used here, the weighout (WO) and the logbook (LB) databases, differ in the way in which effort data are recorded. In the WO database, a record should be made for each vessel at every landing. At this point the number of days absent, number of days fished, the area fished and the type of gear used should be recorded, as well as the commercial landings data on fish by species. In theory, this database should provide a useful index of fishing effort (days fished), but an examination of the data suggested that the 'days fished' statistic was recorded unreliably in too many cases for it to be used in analysis. Given the unreliability of this statistic, it is necessary to treat the WO data as a source of information on trips alone. The number of trips by each vessel was tallied on the assumption that each landing (unique date) by each vessel defines a single trip.

The logbook database appears to be slightly more reliable as an indication of fishing effort. The logbook forms are headed 'daily form', and it is clear that for many vessels, reports were filed on a daily basis, as there are series of records from the same vessel using consecutive dates. In general, the number of daily forms completed appears to be a fairly good indication of the number of hauls made during a trip, as it is evident from sea sampled trips that there is an average of about 1 haul per day of fishing in both driftnet and pair-trawl fisheries. There were a number of cases, however, where sea sampling observers recorded more than one pair-trawl haul by a boat in a single day, yet only a single corresponding daily record was recorded in the LB database. Furthermore, sometimes daily records appeared to be missing. It is clear that in both fisheries LB records underestimate the number

of hauls made when compared with observer data, presumably due to loss of the paper forms or because the skipper occasionally forgets to fill in a daily report. Nevertheless, the logbook daily forms provide a more detailed database than the WO from which to generate an estimate of total effort. It is also evident from Figure 1 that the logbook database includes more vessels than the WO database. For these reasons, the logbook database was used as the basis for effort estimation in both fisheries.

Because the LB database excludes several vessels known from the WO and SS databases to have been operating driftnets and pair-trawls, the latter two databases were combed for evidence of driftnet and pair-trawl fishing activity which was missing from the LB database. There was no reliable algorithm for comparing these databases automatically, so that lists of all driftnet fishing activity and all pair-trawl fishing activity had to be generated from all three databases and these were compared by eye.

Estimating total driftnet effort.

A list of all sea-sampled driftnet hauls was prepared, giving the vessel identification code, the trip code, the date of the observed haul, the number of hauls made during that trip, and the number of days absent. This list was then compared with the logbook database to find any trips (i.e. entire series of hauls) or any hauls missing from the logbook database.

This comparison was complicated slightly by the fact that although the haul date in the sea sampling database is recorded as the date the net was observed being hauled, the logbook daily reports often, though not always, give the date on which the net was set, usually the previous day. For this reason an automated comparison was not practicable. Instead trips were identified as consecutive series of haul or set dates in the logbook, and these were counted off against the known number of hauls made during observed trips.

Of 65 driftnet trips recorded in the SS database, only 1 was missing from the LB database. Of the 355 hauls observed during the remaining 64 trips, some 4.5% (16 hauls) appeared to be missing from the logbook database, presumably as the skipper may have forgotten to fill forms in for these days or because the forms had been lost. If this 4.5% missing daily records from the sea sampled part of the fleet is assumed to be consistent with lost daily record forms for the rest of the fleet, then this provides a basis for estimating the number of hauls missing from those trips which are reported in the LB database.

An examination of the WO database enabled those trips recorded there which were missing from the LB database to be identified. Trips missing from the LB database included those made by 5 driftnet vessels missing entirely from the LB database as well as trips made by vessels which were represented in the LB database but were not reported fishing at the same time as in the WO database.

To compare the LB with the WO database, as with the SS database, a list of vessel numbers, dates of landing and days fished were compared by eye with the daily reports of driftnet activity in the LB database. The selection of driftnet vessels was made from the WO by including all those vessels

recorded using large pelagic driftnets (gear code 115) or other drift gill nets (gear code 110) where the main target was tuna or swordfish. Landing dates in the WO were compared with daily report or haul dates in the LB. Usually, the landing date was one or two days after the last daily record in the LB. When a driftnet landing occurred in the WO but there were no daily records in the LB database for seven days prior tot he landing date, it was assumed that the entire trip was missing from the LB database. For most landings recorded in the WO there was a corresponding series of hauls recorded in the LB just prior to the landing date. The arbitrary seven day criterion was used because driftnet trips appear to be around a week in duration, but it was rare that this criterion had to be used to establish whether a trip was missing from the LB database. Most missing trips were clearly absent from the LB database. Of 333 driftnet trips recorded in the WO, 44 appeared to be missing from the LB records.

To calculate the total fishing effort in terms of hauls, the number of hauls recorded in the LB was first increased by 4.7% to account for lost or missing daily records from recorded trips. Secondly, the LB was augmented by the 44 missing trips recorded in the WO and the 1 missing trip from the SS database. To convert missing trips to a number of missing hauls, the SS database was used to calculate the average number of hauls per trip for each vessel, and overall for the fleet. The number of hauls in each missing WO trip was then estimated either by the average number of hauls made by the same vessel if observed by the sea-samplers, or else by the fleet average (5 hauls). The number of hauls made in the SS trip was actually known. By this means, a further 269 hauls from the missing 45 trips were added to the LB total.

Estimates of total driftnet effort are given in Table 2, by year and by zone. The two zones, North and South, are those described above, and refer to the area fished in the summer months, north of 39°50'N and east of 71°40'W, and the area fished in the winter, south and west of this zone. The number of observed hauls, and proportion of hauls observed are also given in Table 2.

Estimating total pair-trawl effort.

Lists of all SS trips and WO trips using pair-trawls were compared by eye with a list of fishing activities by the same set of vessels in the LB database. Of 27 pair-trawl trips recorded in the SS database, five were missing from the logbook database. During the remaining 22 trips a total of 129 hauls was observed. Of these observed hauls, 19 could not be matched with daily records in the LB data. Some of the missing records in the LB were due to only one daily record being made on a day when two hauls were observed. If it is assumed, again, that the observed part of the fleet records hauls with the same efficiency as the rest of the fleet, then the actual number of hauls for trips which are represented in the LB should be 129/110, or 1.1727, times greater than the number recorded there.

TABLE 2
DRIFTNET FISHING AND SAMPLING EFFORT
TABULATED BY YEAR AND BY FISHING ZONE

YEAR / ZONE:	TOTAL	NORTH	SOUTH
ESTIMATED TOTAL NUMBER OF DRIFTNET HAULS			
1989	714	643	71
1990	1144	976	168
1991	233	160	73
1992	243	157	86
1993	232	155	77
TOTAL	2566	2091	475
NUMBER OF HAULS SEA SAMPLED			
1989	54	53	1
1990	69	60	9
1991	46	36	10
1992	96	51	45
1993	97	68	29
TOT	362	268	94
PROPORTION OF HAULS SAMPLED			
1989	0.08	0.08	0.01
1990	0.06	0.06	0.05
1991	0.20	0.23	0.14
1992	0.40	0.32	0.52
1993	0.42	0.44	0.38
TOT	0.14	0.13	0.20

A minimum estimate of the number of trips which are missing from the LB can be obtained by comparing the LB data to the WO and SS data. Five SS trips missing from the LB were noted above. A comparison with the WO data revealed three pair-trawl vessels which were missing entirely from the LB database. Comparisons between WO records of pair-trawl trips and daily report records in the LB for the remaining vessels were made difficult prior to 1993 because there was no code available on the LB daily report form to denote pair-trawling as a fishing activity. Instead, for the years 1991 and 1992 (there was no pair-trawling prior to 1991) pair-trawl activity was recorded under an 'other gear' heading in the LB, and was thus included with several other gear types. A major exercise in disentangling the number of hauls made and trips missing from the LB database was therefore to determine which days fishing recorded as 'other gear' in the LB were in fact pair-trawls. Again, because of various inconsistencies among the data, this had to be done by eye.

A list of the pair-trawl trips recorded in the WO was constructed and each trip by each vessel was compared with the daily reports made by the same vessel during the period prior to the WO landing date. In this way, when several tuna/swordfish landings were made and recorded as pair-trawl trips in the WO, and where the same vessel was recorded as fishing between the landing dates with 'other gear' in the LB, LB records were edited to include a code indicating a pair-trawl effort day. In a number of cases, the WO database indicated that a vessel was pair-trawling during one month, which was recorded in the LB as an 'other gear' record, after which the vessel was not recorded in the WO at all, whereas fishing records continued in the LB database for the same vessel. Under these circumstances, when it was not clear what gear was being used, but when the vessel had previously been pair-trawling, records were edited in the LB to indicate probable pair-trawling.

The log-book database originally contained only 367 pair-trawl records (all in 1993). After searching the WO database, an additional 371 daily records in which 'other gear' was recorded in the LB were clearly identified as pair-trawl records for the years 1991 and 1992. In addition to these, 171 daily records in which 'other gear' was recorded were identified as probably pair-trawl days, on the basis of recently preceding WO trips which had been pair-trawl trips, but where no contemporaneous information was available in the WO. The total of 909 daily records was then converted to an estimated 1066 hauls using the ratio of 129 hauls to 110 daily records described above. This accounts for all the LB records which are recorded as pair-trawl days or 'other gear' days which were assumed to be pair-trawl days prior to 1993.

The final adjustment to the LB pair-trawl data consists of adding in trips which are missing from the LB but are recorded in the WO or SS. Examining the WO database, 14 pair-trawl trips were found for which there were no corresponding LB daily record entries. These included the three vessels not recorded in the LB at all. There were also the five (out of 27) SS pair-trawl trips which were not recorded in the LB database.

To add these extra 19 pair-trawl trips to the LB effort total it is necessary to estimate the number of hauls in each missing trip. In the case of the five missing SS trips, this task is trivial as the number of hauls was recorded by the observers and was added to the LB totals. This amounted to an extra 21 hauls.

TABLE 3
ESTIMATED TOTAL PAIR-TRAWL EFFORT BY YEAR AND BY MONTH
WITH OBSERVER EFFORT AND PROPORTION OF HAULS OBSERVED

1991							
MONTH	6	7	8	9	10	11	TOTAL
NO OF LB RECORDS	0	0	31	39	8	2	80
CONVERTED TO HAULS	0	0	36	46	9	2	94
EXTRA HAULS (WO & SS)	0	0	0	0	0	0	0
ESTIMATED TOTAL	0	0	36	46	9	2	94
OBSERVED HAULS	0	0	0	0	0	0	0
PROPORTION OBSERVED	0	0	0	0	0	0	0
1992							
MONTH	6	7	8	9	10	11	TOTAL
NO OF LB RECORDS	4	53	89	103	121	48	418
CONVERTED TO HAULS	5	62	104	121	142	56	490
EXTRA HAULS (WO & SS)	0	0	8	0	23	15	46
ESTIMATED TOTAL	5	62	112	121	165	71	536
OBSERVED HAULS	0	0	0	0	25	23	48
PROPORTION OBSERVED	0.00	0.00	0.00	0.00	0.15	0.32	0.09
1993							
MONTH	6	7	8	9	10	11	TOTAL
NO OF LB RECORDS	17	51	130	168	45	0	411
CONVERTED TO HAULS	20	60	152	197	53	0	482
EXTRA HAULS (WO & SS)	0	36	36	24	8	0	104
ESTIMATED TOTAL	20	96	188	221	61	0	586
OBSERVED HAULS	9	17	29	26	21	0	102
PROPORTION OBSERVED	0.45	0.18	0.15	0.12	0.35	0.00	0.17

The 14 missing WO trips were made by six vessels, four of which has been sea-sampled at another time. Where a vessel had been sea-sampled the average number of hauls made per observed trip by that vessel was used as an estimate of the number of hauls made in each missing trips. For the remaining two vessels and five trips, the SS database was used to calculate an overall mean of eight hauls per trip among all vessels. The overall mean number of hauls-per-trip in the SS was therefore used to generate an estimate of the number of hauls still missing from the LB. In all an estimated 152 missing hauls were added to the LB database. Of these, 131 were estimated made during 14 trips found in the WO but missing from the LB, and the remaining 21 were the hauls observed in the five SS trips which were missing from the LB.

The estimation of pair-trawl effort is summarised in Table 3. For each month of the three years of the fishery (1991-1993), the number of LB records is given (this number includes all probable pair-trawl records); below this is the number of hauls which this corresponds to. Next, the estimated 131 missing hauls are added, and then the estimated total number of hauls is given for each month in the next row. Annual totals are given in the final column. As an indication of Sea Sampling coverage of the fleet the number of observed hauls by month is also given, and finally the proportion of hauls observed.

4. CATCH RATE ESTIMATION.

The total numbers of each species caught in the 150 observed pair-trawl hauls and the 362 observed drift net hauls were used to make estimates of catch rates, and to compute the standard errors of the catch per haul.

Initially, catches per haul were estimated for each of the two zones in the driftnet fishery, for each of the 5 sampled years. However, as sampling was at a low level in the earlier years, estimates of total catch for these years were anomalous. Similarly, when catch rates were computed for each of the 3 years in the pair-trawl fishery, there were wide discrepancies between years. It was assumed that these discrepancies were due to the small sample sizes rather than any actual change in catch rate, so catch rates were calculated for the two driftnet zones and for the pair-trawl fishery by aggregating all the years. It is assumed, therefore, that there has been no change in the vulnerability or catch rate of the species recorded between years.

The estimated overall catch rates and standard errors are shown for each of the two fisheries in Table 4. Higher driftnet catch rates of common and bottlenose dolphins are observed in the southern zone than the northern zone. The beaked whales (*Mesoplodon* species and Cuvier's beaked whale) have been grouped together, and all catches of these species occurred in the northern zone of the driftnet fishery.

TABLE 4
ESTIMATES OF CETACEAN CATCH RATES AND STANDARD ERRORS FOR THE PAIR-TRAWL AND DRIFTNET FISHERIES (Driftnet fishery by zone).

	DRIFTNET FISHERY				PAIR-TRAWL	
	Catch Rate		Standard Error of Catch Rate		Catch Rate	Stand. Error
Species	NORTH	SOUTH	NORTH	SOUTH		
CODO	0.74	1.21	0.169	0.283	0.06	0.032
LFPW	0.09	0.00	0.029	0.000	0.00	0.000
SFPW	0.00	0.24	0.000	0.108	0.00	0.000
BODO	0.09	0.16	0.021	0.046	0.14	0.073
RIDO	0.14	0.00	0.035	0.000	0.007	0.007
BEWH	0.08	0.00	0.022	0.000	0.00	0.000
STDO	0.05	0.05	0.020	0.028	0.00	0.000
USDO	0.03	0.02	0.026	0.021	0.00	0.000
SPOD	0.00	0.11	0.000	0.047	0.00	0.000
WSDO	0.01	0.00	0.005	0.000	0.00	0.000
UNDO	0.01	0.00	0.005	0.000	0.007	0.007
HUBA	0.00	0.01	0.000	0.011	0.00	0.000
SPID	0.00	0.01	0.000	0.011	0.00	0.000
SPWH	0.004	0.00	0.004	0.000	0.00	0.000
RIWH	0.004	0.00	0.004	0.000	0.00	0.000
HAPO	0.00	0.01	0.000	0.011	0.00	0.000
ALL	1.24	1.83	0.185	0.320	0.21	0.081

5. ESTIMATION OF TOTAL CATCH

Estimates of the total catch of all species in the two fisheries were achieved using the aggregated catch rates, by zone in the case of the driftnet fishery. These were combined with the estimated number of unobserved hauls made by each fishery in every year and appropriate zone. Thus the total kill K for each year (y), zone (z) and species (s) is:

$$K_{s,y,z}=D_{s,y,z}+U_{y,z}.t_{s,z}$$

where D is the number of observed catches of species s in year and zone y,z, U is the number of unobserved hauls and t is the catch rate, or average kill per haul for each species, and zone. The log-normal confidence intervals for these annual (and zonal) kill estimates are given by:

$$D_{s,y,z}+U.\exp(\mu+{}_1.96\sqrt{\sigma^2})$$

and where:

where

$$\mu=\frac{1}{2}.\ln.(\frac{t^2_{s,z}}{(1-CV^2)})$$

$$\sigma^2=\ln$$

Here, H is the number of observed hauls in year y and zone z, and S is the standard deviation of the catch per hour.

$$CV=U.$$

The results of these calculations for all species taken in the two fisheries are given in Tables 5 to 8. Table 5 gives the results for the pair-trawl fishery, while results for the driftnet fishery are presented in Tables 6 to 8. Table 6 deals with species which are taken throughout the range of the driftnet fishery, and presents results for the northern zone and southern zone separately, as well as combined or total catches of these species. Table 7 deals with those species only observed taken in the northern zone, while Table 8 deals with the species which were only observed taken in the southern zone.

TABLE 5
OBSERVED CATCHES OF MARINE MAMMALS IN THE PAIR-TRAWL FISHERY
TABULATED BY SPECIES AND BY YEAR

SPECIES /YEAR	BODO	CODO	RIDO	UNDO	ALL CETS
1991	0	0	0	0	0
1992	4	3	1	1	9
1993	17	6	0	0	23

ESTIMATED TOTAL NUMBERS OF MARINE MAMMALS TAKEN

1991	13	5.63	0.63	0.63	20
1992	73	32	4.27	4.27	114
1993	85	35	3.23	3.23	126

CVs OF TOTAL CATCH ESTIMATES

1991	0.517	0.527	0.997	0.997	0.379
1992	0.489	0.478	0.763	0.763	0.349
1993	0.414	0.436	0.997	0.997	0.310

LOWER 95% CONFIDENCE INTERVALS FOR ESTIMATED
MARINE MAMMAL TAKES

1991	4.49	1.89	0.09	0.09	9.13
1992	29	14	1.69	1.69	60
1993	46	18	0.45	0.45	77

UPPER 95% CONFIDENCE INTERVALS FOR ESTIMATED
MARINE MAMMAL TAKES

1991	30	13	2.26	2.26	38
1992	157	68	11	11	201
1993	153	66	12	12	202

TABLE 6a

NET FISHERY WITH CONFIDENCE LIMITS AND CVs:

Species taken in both northern and southern fishery zones

COMMON DOLPHINS [CODO]					
YEAR	1989	1990	1991	1992	1993
NORTHERN ZONE					
UPPER 95% CL	670	1037	175	142	144
POINT ESTIMATE	455	700	147	115	128
LOWER 95% CL	298	454	124	94	115
CV	0.219	0.221	0.143	0.155	0.115
SOUTHERN ZONE					
UPPER 95% CL	130	295	117	123	126
POINT ESTIMATE	85	193	76	112	110
LOWER 95% CL	53	120	47	102	97
CV	0.234	0.234	0.234	0.104	0.123
BOTH ZONES					
UPPER 95% CL	765	1257	275	256	261
POINT ESTIMATE	540	893	223	227	238
LOWER 95% CL	385	648	188	205	221
CV	0.188	0.181	0.123	0.094	0.084

BOTTLENOSE DOLPHINS [BODO]					
YEAR	1989	1990	1991	1992	1993
NORTHERN ZONE					
UPPER 95% CL	85	129	20	16	13.02
POINT ESTIMATE	61	88	16	12	9.79
LOWER 95% CL	43	58	13	10	7.32
CV	0.205	0.220	0.162	0.179	0.187
SOUTHERN ZONE					
UPPER 95% CL	19	43	16.83	17	15
POINT ESTIMATE	11	27	10.05	16	12
LOWER 95% CL	6	17	5.54	14	9
CV	0.289	0.268	0.289	0.122	0.190
BOTH ZONES					
UPPER 95% CL	98	161	34	32	26
POINT ESTIMATE	72	115	26	28	21
LOWER 95% CL	54	86	21	25	18
CV	0.179	0.179	0.149	0.104	0.134

TABLE 6b

ESTIMATED TOTAL NUMBERS OF MARINE MAMMALS TAKEN IN THE DRIFT NET FISHERY WITH CONFIDENCE LIMITS AND CVs:

Species taken in both northern and southern fishery zones

STRIPED DOLPHINS [STDO]					
YEAR	1989	1990	1991	1992	1993
NORTHERN ZONE					
UPPER 95% CL	60	93	12.57	10.74	15
POINT ESTIMATE	35	49	6.48	5.54	14
LOWER 95% CL	19	23	2.90	2.48	12
CV	0.343	0.379	0.387	0.387	0.130
SOUTHERN ZONE					
UPPER 95% CL	8.64	19.62	7.64	5.06	7.71
POINT ESTIMATE	3.72	8.46	4.35	2.18	6.55
LOWER 95% CL	1.26	2.87	2.46	0.74	5.69
CV	0.522	0.522	0.402	0.522	0.203
BOTH ZONES					
UPPER 95% CL	65	105	18	14.17	22
POINT ESTIMATE	39	57	11	7.72	20
LOWER 95% CL	24	33	7	4.85	19
CV	0.314	0.332	0.282	0.314	0.110

STENELLA SPECIES [USDO]					
YEAR	1989	1990	1991	1992	1993
NORTHERN ZONE					
UPPER 95% CL	56	79	11.71	10.01	8.22
POINT ESTIMATE	15	31	3.24	2.77	2.27
LOWER 95% CL	2	12	0.45	0.38	0.31
CV	1.000	0.774	1.000	1.000	1.000
SOUTHERN ZONE					
UPPER 95% CL	5.38	12.23	4.85	3.49	3.69
POINT ESTIMATE	1.49	3.38	1.34	2.87	1.02
LOWER 95% CL	0.21	0.47	0.19	2.47	0.14
CV	1.000	1.000	1.000	0.304	1.000
BOTH ZONES					
UPPER 95% CL	59	86	14.69	13.02	10.51
POINT ESTIMATE	17	34	4.58	5.64	3.29
LOWER 95% CL	5	18	2.50	3.34	1.85
CV	0.916	0.704	0.765	0.515	0.756

TABLE 7

ESTIMATED MARINE MAMMAL TAKES IN THE DRIFT NET FISHERY: Northern zone.

LONG-FINNED PILOT WHALES [LFPW]					
YEAR	1989	1990	1991	1992	1993
UPPER 95% CL	95	145	21	20	14.91
POINT ESTIMATE	60	86	14	16	10.79
LOWER 95% CL	36	47	10	14	7.83
CV	0.285	0.308	0.254	0.186	0.233
RISSO'S DOLPHIN [RIDO]					
YEAR	1989	1990	1991	1992	1993
UPPER 95% CL	131	208	29	35	20
POINT ESTIMATE	87	144	21	31	14
LOWER 95% CL	55	97	15	28	10
CV	0.234	0.219	0.207	0.117	0.209
BEAKED WHALES [BEWH]					
YEAR	1989	1990	1991	1992	1993
UPPER 95% CL	84	122	18	14.43	15
POINT ESTIMATE	60	76	13	9.70	12
LOWER 95% CL	43	45	10	6.33	10
CV	0.213	0.263	0.206	0.239	0.157
WHITE-SIDED DOLPHINS [WSDO]					
YEAR	1989	1990	1991	1992	1993
UPPER 95% CL	12.51	19.42	2.63	2.25	2.90
POINT ESTIMATE	4.40	6.84	0.93	0.79	2.65
LOWER 95% CL	1.03	1.61	0.22	0.19	2.46
CV	0.706	0.706	0.706	0.706	0.173
UNIDENTIFIED DOLPHINS [UNDO]					
YEAR	1989	1990	1991	1992	1993
UPPER 95% CL	11.88	18.68	2.63	2.25	1.84
POINT ESTIMATE	5.40	7.84	0.93	0.79	0.65
LOWER 95% CL	2.34	2.92	0.22	0.19	0.15
CV	0.575	0.616	0.706	0.706	0.706
SPERM WHALES [SPWH]					
YEAR	1989	1990	1991	1992	1993
UPPER 95% CL	7.96	11.35	1.67	1.43	1.17
POINT ESTIMATE	2.20	4.42	0.46	0.40	0.32
LOWER 95% CL	0.30	1.71	0.06	0.05	0.04
CV	1.000	0.774	1.000	1.000	1.000
RIGHT WHALES [RIWH]					
YEAR	1989	1990	1991	1992	1993
UPPER 95% CL	7.96	12.36	1.67	1.43	1.51
POINT ESTIMATE	2.20	3.42	0.46	0.40	1.32
LOWER 95% CL	0.30	0.47	0.06	0.05	1.20
CV	1.000	1.000	1.000	1.000	0.245

TABLE 8

ESTIMATED MARINE MAMMAL TAKES IN THE DRIFT NET FISHERY: Southern zone.

SHORT-FINNED PILOT WHALES [SFPW]					
YEAR	1989	1990	1991	1992	1993
UPPER 95% CL	36	81	32	23	27
POINT ESTIMATE	17	46	16	17	20
LOWER 95% CL	7	25	8	13	15
CV	0.440	0.373	0.413	0.259	0.262
SPOTTED DOLPHINS [SPOD]					
YEAR	1989	1990	1991	1992	1993
UPPER 95% CL	15.49	35	13.94	16	10.62
POINT ESTIMATE	7.45	17	6.70	14	5.11
LOWER 95% CL	3.00	7	2.70	13	2.06
CV	0.437	0.437	0.437	0.133	0.437
HUMPBACK WHALES [HUBA]					
YEAR	1989	1990	1991	1992	1993
UPPER 95% CL	2.69	6.12	2.42	1.58	1.92
POINT ESTIMATE	0.74	1.69	0.67	0.44	1.51
LOWER 95% CL	0.10	0.23	0.09	0.06	1.25
CV	1.000	1.000	1.000	1.000	0.338
SPINNER DOLPHINS [SPID]					
YEAR	1989	1990	1991	1992	1993
UPPER 95% CL	2.69	6.12	2.42	1.75	1.85
POINT ESTIMATE	0.74	1.69	0.67	1.44	0.51
LOWER 95% CL	0.10	0.23	0.09	1.23	0.07
CV	1.000	1.000	1.000	0.304	1.000
HARBOR PORPOISE [HAPO]					
YEAR	1989	1990	1991	1992	1993
UPPER 95% CL	2.69	6.12	2.42	1.58	1.92
POINT ESTIMATE	0.74	1.69	0.67	0.44	1.51
LOWER 95% CL	0.10	0.23	0.09	0.06	1.25
CV	1.000	1.000	1.000	1.000	0.338

6. DISCUSSION.

The estimates presented here were derived using a pooled estimate of average catch rates across all years. It is entirely possible that catch rates may vary from year to year, if, for example, the distribution of any of these cetacean varies significantly from year to year with respect to the two fisheries. An examination of the annual catch rates, however, revealed that abnormally low or high catch rates were associated with those zones and years where sampling effort was limited, as for example in the southern driftnet zone during the first two years of the program, when only 10 driftnet hauls were observed, with no observed common dolphin takes. Conversely a single haul in 1991 was responsible for taking 38 common dolphins, yielding an anomalously large kill rate for that year. For this reason, pooled catch rates were calculated across all years for each species.

Not all the animals taken in these fisheries were dead, so the impact of these takes on the population may not be quite as large as these figures suggest. Nevertheless the number of animals which were reported released alive was very small. Of those 16 animals released alive from the two fisheries (i.e. 3% alive from a total of 580 cetaceans observed taken in the two fisheries), only five (1%) were deemed to have been released uninjured, while eight were recorded as injured, and three were in an unknown condition. It is reasonable to assume that a proportion, if not all of the injured animals may have subsequently died from injuries, or at least been impaired by their injuries. Furthermore, the lack of any obvious signs of injury among the 'uninjured' five animals does not guarantee the absence of internal injuries or trauma. For these reasons, all takes have been included in estimating the catch rates of all species. Of the 16 animals released alive, five were common dolphins, and only one of those was deemed uninjured. Even assuming all the common dolphins which were released alive had survived, the effect on the total catch estimate would be very slight. Of the remaining animals released alive, there were six pilot whales, four of which were from the northern zone and two from the southern zone, one *Mesoplodon*, one Risso's dolphin, one bottlenose dolphin, and the single right and sperm whales. Both the sperm whale and the right whale appear to have been seriously injured.

Actual catch rates may be under-estimated if observers did not see all the animals taken (due to dropout), and if, as is likely, there were further undocumented fishing trips. The estimates of fishing effort are likely minimum estimates.

Among the recorded species there are a number of animals which were not identified to the species level, or which were subsequently grouped. The beaked whale group, for example, includes one Cuvier's beaked whale, one Sowerby's beaked whale and two True's beaked whales, together with 18 unidentified *Mesoplodon* species. Given the difficulty in identifying these species, it is more sensible to treat this as a group which includes these three species, at least, in undetermined proportions. The nine unidentified *Stenella* dolphins comprised seven taken in the northern driftnet zone and two in the south. Among the identified *Stenella* species, only striped dolphins were taken in the northern zone, while striped, spinner and (mainly) spotted dolphins were taken in the south, suggesting that the seven unidentified animals taken in the northern zone were most likely also striped dolphins.

When considering any population level impact on these cetacean species, it should be remembered

that these catches need to be viewed in addition to catches in other fisheries covering the distribution of the populations affected. Population level impacts are considered for all of these species by Blaylock *et al.* 1995.

REFERENCE

Blaylock, R.A., J.W. Hain, L.J. Hansen, D.L. Palka and G.T. Waring. 1995. U.S. Atlantic and Gulf of Mexico marine mammal stock assessments. NOAA Tech. Mem. NMFS-SEFSC-363, 211 pp.

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