APPENDIX II
Bycatch Estimation Methods

Marine mammals have been incidentally taken in the following commercial fisheries since 1989: 1) New England multispecies sink gillnet fishery; 2) the Pelagic Drift Gillnet; 3) the Pelagic Pair Trawl; 4) the North Atlantic Bottom Trawl fishery; and 5) the Longline fishery. Table 1 identifies the species that have been incidentally killed by commercial fishery and the time period used to estimate total mortality. Bycatch data have been collected by the Northeast Fisheries Science Center's (NEFSC) Sea Sampling Program. Observers are placed on commercial vessels to collect information on the fishing activity, operations, fish discards and marine mammal interactions. These data are used to estimate take rates of marine mammals.

Calculation of total bycatch for each fishery, require estimates of total fishing effort, and the average take rate of marine mammals per unit of effort. Two data sources have been used to estimate total effort for these four fisheries: 1) the NEFSC weighout (WO) database and 2) the mandatory self-reported fisheries information system for large pelagic fisheries maintained at the Southeast Fisheries Science Center (SEFSC).

Components of the estimation process are: 1) choosing a stratification scheme; 2) calculating a point estimate and; 3) estimating its variance and confidence interval. First, the data are examined for temporal and spatial patterns in both the movement of the marine mammal species and the commercial fishery. Observed patterns may be used to stratify the data. Take estimates are then calculated for each stratum and combined over strata to estimate the total annual take. Standard bootstrap techniques are used to calculate the variance and 95% confidence intervals.

Methods to estimate the total fishery specific marine mammal take are briefly described below. The estimation process within a fishery and year are identical. For example, if three marine mammal species are taken within one year and one fishery, the method of estimating the total take for each species is the same.

New England Multispecies Sink Gillnet Fishery

The US bottom-tending sink gillnet fishery extends from Maine to North Carolina. Sink gillnet gear as fished in the NW Atlantic, consists of nets with 8-10 inch monofilament mesh suspended between a buoyed head rope and a weighted ground line. A sink gillnet vessel fishes four to seven strings per trip on average. One string typically consists of five to twelve nets strung together, in which the standard net length averages three hundred feet and height averages eleven feet. Gear is set in the water to soak for 24 to 72 hours. The gear is then hauled and reset. Target species include pollock, cod, flatfish, monkfish, and dogfish. Marine mammals may become entangled in the gear and suffocate while the gear is in the water.

Marine mammal take rates and total effort were estimated from NEFSC's Sea Sampling and WO data. Total effort for this analysis is measured by total landings of all fish species in terms of 'live' pounds of fish caught (NEFSC 1992; Bisack and Dinardo, 1992), before processing. A haul was chosen as the unit of effort and is defined as the retrieval of a string of nets. This eliminates uncertainty caused by the varying number of hauls within a trip. There is no direct measure of hauls in the WO data. Total hauls are estimated by dividing the average catch per haul in the sea sampling data, into corresponding total landings from the weightout. Therefore, the total marine mammal bycatch is equal to the product of the estimated take per haul from the Sea Sampling data and the estimated total hauls, as shown below.

$$Total\ Take = \frac{Total\ Observed\ Take}{Total\ Observed\ Hauls} * Total\ Estimated\ Hauls$$

$$Total\ Estimated\ Hauls = \frac{Total\ WO\ Landings}{Average\ Catch\ per\ Haul}$$

$$Average\ Catch\ per\ Haul = \frac{Total\ Observed\ Catch}{Total\ Observed\ Hauls}$$

The temporal stratification to make harbor porpoise bycatch estimate in 1995, for example, was three seasons: winter (January to May), summer (June to August) , and fall (September to December). The spatial stratification consisted of six groups of ports covering: 1) northern Maine; 2) southern Maine; 3) New Hampshire; 4) north of Boston; 5) south of Boston; and 6) south of Cape Cod.

Take estimates are made for each stratum and then combined over strata to estimate the total annual take. Standard bootstrap techniques were used to calculate the variance and 95% confidence intervals and the resampling unit was defined as a trip. The use of a trip ensures that any within trip dependence in the original data is carried over into the resamples and into the bycatch estimates.

Harbor porpoise have the largest take within this fishery and have been studied the most. Several methods have been developed to obtain comparable and consistent harbor porpoise bycatch estimates within a changing and evolving sampling scheme (Bisack, 1993; Smith *et. al*, 1993; Bravington and Bisack, 1996; Bisack, in press).

Pelagic Drift Gillnet Fishery

The Atlantic pelagic drift gillnet fishery is distributed geographically from the shelf edge region of the Grand Banks off Newfoundland to the Gulf of Mexico. The driftnet is an entanglement net. On average, vessels fish 20 to 22 inch mesh, 60 to 70 meshes deep, and 1.5 miles long. The gear is typically deployed at sunset and suspended below the surface 18 to 30 feet with poly ball floats spaced approximately 125 feet apart. The gear is retrieved in the morning and usually one set is made nightly.

Marine mammal take rates and total effort were estimated from NEFSC's Sea Sampling data and SEFSC's mandatory self-reported fisheries information system for large pelagics, respectively. The unit of effort chosen for these analyses is a set. Most fishing effort is concentrated along the southern edge of Georges Bank in the summer months (mainly June to September), and off Cape Hatteras in the winter (most recently January through March). Based on the examination of the species composition of the catch and the locations of the fishery throughout the year suggested that the driftnet fishery be stratified into two strata, a southern or winter stratum, and a northern or summer stratum.

Estimates of the total bycatch, for each year from 1989 to 1993 were obtained using aggregated (pooled 1990 to 1993) catch rates times the annual effort. Details of these analyses can be found in Northridge (1996). Estimates of total annual bycatch for 1994 and 1995 were estimated from the sum of the observed take and the product of the average take per haul and the number of unobserved hauls as recorded in the logbooks, as shown below.

$$Total\ Take = Total\ Observed\ Take\ +\ \frac{Total\ Observed\ Take}{Total\ Observed\ Sets} * Total\ Unobserved\ Sets$$

In 1994 and 1995, 87% and 99% of the sets were observed. Since the observer coverage was high, a finite population correction (fpc) factor was applied (Cochran, 1977). If the fpc were not applied, the variance would be upwardly biased. Standard bootstrap techniques were used to calculate the variance and 95% confidence intervals, and the resampling unit was defined as a set. For more details of these analyses see Bisack (in prep).

Pelagic Pair Trawl Fishery

Pair trawling for tuna or other large pelagics involves the deployment, towing, and retrieval of a large mesh net between two trawlers. The trawl nets used for this fishery are unusual due to their large mesh size (3.2 to 20 meters) and large overall dimensions (300 to 1200 meter circumference). In addition, unlike most trawls, these designs cannot be towed in contact with the seabed. Pair trawlers can sweep a much wider area of the seabed than otter trawlers twice their size. The long warps on either side of the net herds the fish schools into the net without towing through the school of fish. This is probably one of the most significant factors to its success in catching fish. It is a night time fishery with tows typically 3 to 5 hours in duration.

Marine mammal take rates and total effort were estimated from NEFSC's Sea Sampling data and SEFSC's mandatory Pelagic Logbook data, respectively. The unit of effort chosen for these analyses is a set. The fishery is concentrated along the outer shelf in the mid-Atlantic region, especially around Hudson Canyon. The fishing season

extends from June through November. Examination of the locations and species composition of the bycatch, showed little seasonal change for the six months of operation and did not warrant any seasonal or areal stratification of this fishery. The calculation of the point estimate, variance and confidence intervals are identical to those explained in the Pelagic Drift Gillnet Fishery for 1994 and 1995.

North Atlantic Bottom Trawl

Otter trawls are the most widely used type of bottom trawl in commercial fisheries, and owe most of their success to the herding action of the trawl doors and sweeplines. A substantial body of research on the behavior of fish in the path of otter trawls (Maine and Sangster 1981, Wardle 1986) has shown that the trawl doors, sweeplines, and mud or sand clouds produce strong auditory and visual stimuli that can actually herd fish or shellfish in the path of the oncoming net. To be effective, the length of the sweeplines, attack angle of the sweeplines, and vessel speed must be carefully "tuned" to the maximum swimming speed of the target species.

The North Atlantic bottom trawl operates in waters of the Gulf of Maine, Georges Bank, and Mid-Atlantic area. The gear is towed on average of 2 hours. The target species in tows where marine mammals have been caught consisted of a mixture of groundfish, monkfish, silver and white hake, and Atlantic long-fin squid.

Marine mammal take rates and total effort were estimated from NEFSC's Sea Sampling data and WO data, respectively. The unit of effort chosen for these analyses is days fished. Days fished is the amount of time the gear is in the water fishing. The fishery was stratified into 4 quarters of the year and 3 large geographic areas. The areas are: 1) the Gulf of Maine; 2) Georges Bank and: 3) the Mid-Atlantic area. Given the extremely low observer coverage (less than 1%), it was not possible to determine whether any of the marine mammal species that were observed taken were correlated with any particular species the gear was targeting at that time and area of capture. Therefore, large geographical strata were chosen. The total take is the product of the take per days fished and total days fished, as shown below.

$$Total\ Take\ =\ \frac{Total\ Observed\ Take}{Total\ Observed\ Days\ Fished}\ *\ Total\ Days\ Fished$$

Standard bootstrap techniques were used to calculate the variance and 95% confidence intervals and the resampling unit was defined an individual tow.

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Table 1. Marine mammals incidentally taken by commercial fishery, years total take estimates have been made and are reported within this stock assessment report. Only strategic stocks have been included in this table in 1994 and 1995 since assessments were completed.

Common Species Name	New England Multispeicies Sink Gillnet	Pelagic Drift Gillnet	Pelagic Pair Trawl	North Atlantic Bottom Trawl	Mid-Atlantic Coastal Sink Gillnet	Longline
Beaked Whale		91-95				
Bottlenose Dolphin		89-95	91-95	91	94	
Common Dolphin		91-95	92, 93, 95	95	95	
Dwarf Sperm Whale		95				
Harbor Porpoise	90-95	93			95	
Harbor Seals	90-93					
Humpback Whale		91-93, 95				
Minke Whale	91	95				
Pilot Whale		91-95	92-95			93
Right Whale		91-93				
Risso Dolphin		89-93	91-93			92-93
Sperm Whale		91-93				
Spinner Dolphin		89-93				
Spotted Dolphin		89-94				93
Striped Dolphin		89-95		91		
Whitesided Dolphin	91-95	91-93		92, 94		