Northeast Fisheries Science Center Reference Document 93-11

Estimates of Total U.S. Harbor Porpoise Bycatch in the Gulf of Maine Sink Gill-net Fishery

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INTRODUCTION

Information on abundance and by-catch of harbor porpoise in the Gulf of Maine (GOM) and Bay of Fundy (BOF) suggests that large numbers of animals are being removed from a relatively small population. One component of the by-catch is due to the U.S. sink gillnet fishery operating in the GOM, for which annual harbor porpoise by-catch in excess of 600 has been suggested (Polacheck 1989).

To determine whether harbor porpoise by-catch is too high for the population to sustain requires estimates of population abundance and by-catch. Shipboard sighting surveys are being used to estimate harbor porpoise abundance (Palka 1993, in review). To estimate total by-catch, data from the Northeast Fisheries Science Center (NEFSC) Weighout Data Program (WO) and the NEFSC Domestic Sea Sampling Program (SS) are available. The WO data can be used to estimate the total effort, and the SS can be used to estimate a kill rate of harbor porpoise in the sink gillnet fishery. The objective of this paper is to present estimates of the annual by-catch of harbor porpoise by U.S. GOM sink gillnet fishery for the years 1991, 1990, and part of 1989, based on these two data sources. These estimates supersede those given in Smith *et al.* (1991).

MATERIALS

NEFSC WEIGHOUT DATA PROGRAM (WO)

The WO has existed in various forms since the mid-1930s, and was intended initially to collect landings data from major ports in the northeast U.S. Over the years, the scope of the program has broadened to include collection of data from smaller ports as well. Port agents collect information on landings and fishing activities by obtaining information from the sales receipts that the fish buyer maintains (Appendix A), or by interviews on the dock with the fisher. The latter method allows more detailed information to be collected. Landings are associated with individual vessels if the vessel has a displacement of 5 tons or greater (termed a tonnage vessel). Smaller vessels and unidentified tonnage vessels are not identified uniquely in the data.

Records for approximately 15,900 and 16,700 sink gillnet trips were reported in 1990 and 1991, respectively. These occurred in the region from Delaware to northern Maine. Table 1 shows the numbers of trips, days absent from port, days fished, and numbers of trips for which interviews were conducted. The location of the statistical areas and the distribution of sink gillnet trips along the northeast coastline are shown in Figure 1. For this analysis, the GOM is defined as Statistical Areas numbered 511 through 515 (note that no harbor porpoise kills have been observed in other areas). Most of the reported sink gillnet fishing trips occurred in the GOM as defined here, specifically 88% and 75% in 1990 and 1991, respectively.

SEA SAMPLING PROGRAM (SS)

The NEFSC Sea Sampling Program places technicians aboard fishing vessels to observe fishing activity, fishery discards and marine mammal interactions in the sink gillnet fishery (Power and Drew 1991, manuscript). Observer sea days are allocated proportionately to the total vessel days absent collected in the WO the previous year, by month and statistical area. The Northeast Fisheries Science Center plans the number of trips to be sampled by area and time. The Manomet Bird Observatory under contract to NEFSC, has been responsible for observer and vessel selection to meet these time and area constraints.

Observer coverage of the sink gillnet fishery began in June 1989, with 1% coverage of the total effort in statistical areas numbered 521 and lower. Starting in June 1991, the coverage was increased to 10%, and sampling was also done in statistical area 538.

METHODS FOR CALCULATING BY-CATCH ESTIMATES

STRATIFICATION SCHEME

The data were stratified by time and area to account for differences in by-catch rates and sampling intensity. The number of fishing trips sampled and the observed by-catch are shown in Appendix B for each statistical area by month and year. The northern area was apparently undersampled in 1989 and early 1990. Coverage was improved markedly beginning in June 1991,

Table 1. United States sink gillnet effort in the North Atlantic by statistical area and year recorded in the NEFSC weighout (wo) data base[1]

	1989				1990				1991			
Area	Trips	DA	DF	Int	Trips	DA	DF	Int	Trips	DA	DF	Int
464	12	38	14	4	18	104	53	17				
465					7	37	14	4	3	13	7	
511	279	279	423		466	468	446	1	444	444	444	4
512	1129	1185	1157	11	977	1002	985	9	1253	1344	1295	16
513	5493	5823	5436	139	6205	6632	6241	103	5361	5956	5418	248
514	3849	3935	3458	283	4046	3971	3441	263	2762	2786	2451	234
515	190	742	360	48	281	1285	805	147	496	2004	1245	135
521	2558	2766	1704	38	2020	2051	1619	147	1820	1834	1458	320
522	40	193	83	14	28	142	76	25	23	125	57	7
537	654	654	599		835	880	740	29	1938	1988	1702	52
538	22	4	3		1	1	1		72	72	66	3
539	353	353	324		336	349	296		974	963	910	5
561	2	20	6	2					1	6	3	1
562					1	8	7					
611					4	4	4		16	16	11	
612					142	142	50	5	170	182	69	17
613					2	12	2		13	31	12	
614	238	238	70	7	438	438	132		587	592	410	11
615					106	112	142		120	120	87	
621	106	39	37	3				1	615	583	649	1
Total	14925	16269	13673	549	15914	17638	15054	751	16668	19059	16292	1054

[1] DA = days absent, DF = days fished, Int = number of interviewed trips

when the coverage target was increased from 1% to 10%. The observed by-catch rates (Table 2) are the highest in the Southern GOM (areas 513, 514, 515) during the fall (September-December) and winter (January-May) and lowest (zero rates except June 1991, area 515) in the summer. The observed by-catch rates for Northern GOM (areas 511, 512) are lowest (zero for four trips observed) in the winter (January-May), and highest in the summer (June, July) and fall (September, October) in 1991.

By-catch was first observed in the SS program in the summer of 1991. No by-catch was observed in August in the present study, although Gilbert and Wynne (1983) reported some, so June to August seemed to be a useful and natural time stratification. In the fall and winter, by-catch occurred in statistical areas 513, 514, and 515. For reporting purposes, it was useful to divide this period at December. These three areas could have been divided into offshore (515) and inshore (513/514) strata, but offshore trips have at times been assigned to inshore areas because of the lack of face-to-face interviews (Ronnee Schultz, personal communication[1]). Based on these considerations, eight strata were defined. Statistical areas 511 and 512 were combined into Northern GOM (N. GOM), and areas 513-515 were combined into Southern GOM (S. GOM). The months January through May, June through August, and September through December were combined as winter, summer, and fall, respectively.

Figure 2 displays three maps for each of the eight time strata starting in June 1989 (summer) and ending in December 1991 (fall). The three maps display harbor porpoise by-catch locations and sink gillnet string locations observed in the SS, and the location of sink gillnet trips recorded in the WO. Table 3 shows the actual number of harbor porpoise takes, sea sampling trips, number of weighout trips, and total weighout catch.

Figure 1. Distribution of 1991 sink gillnet trips recorded in the weighout database with statistical areas.

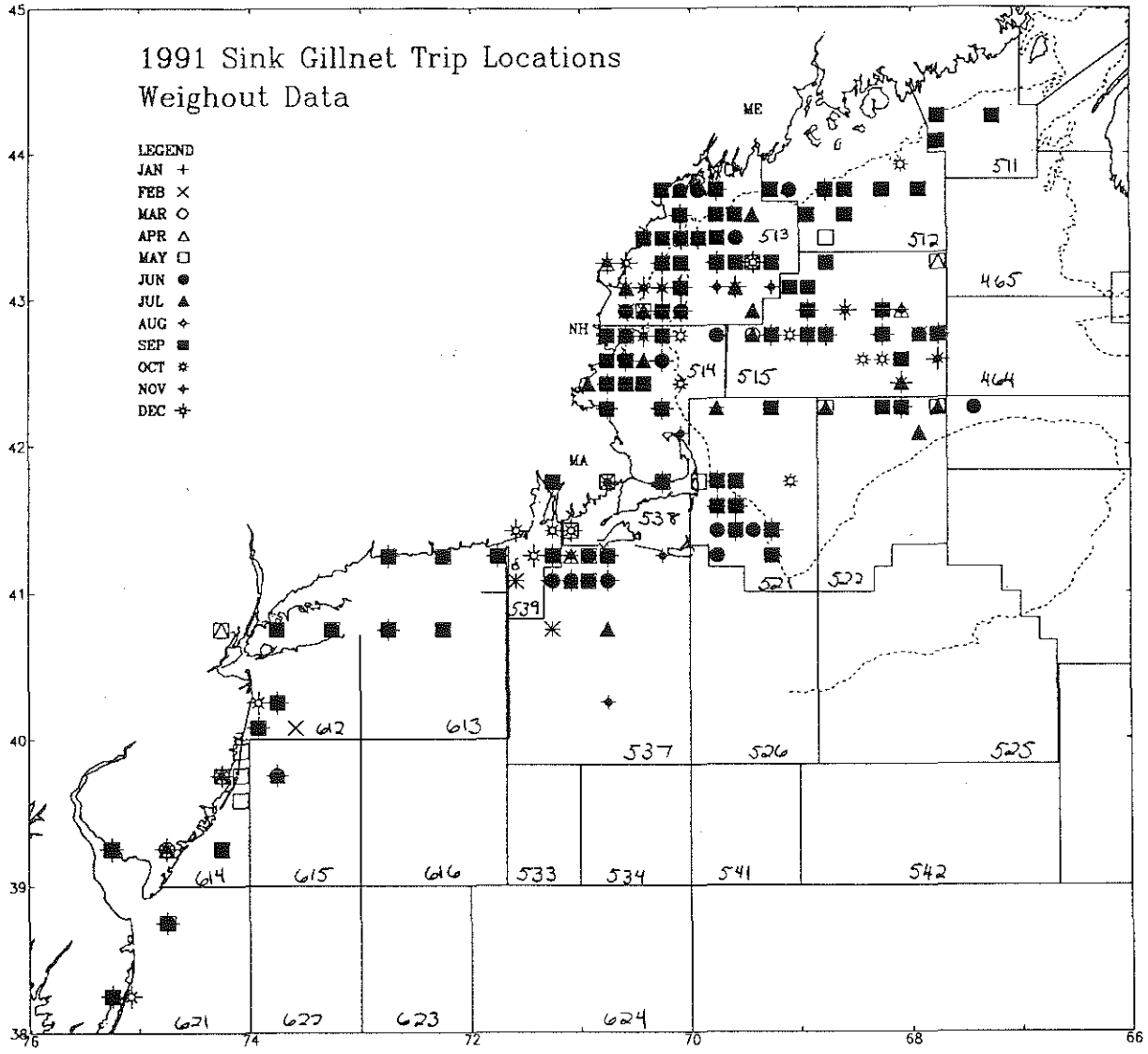
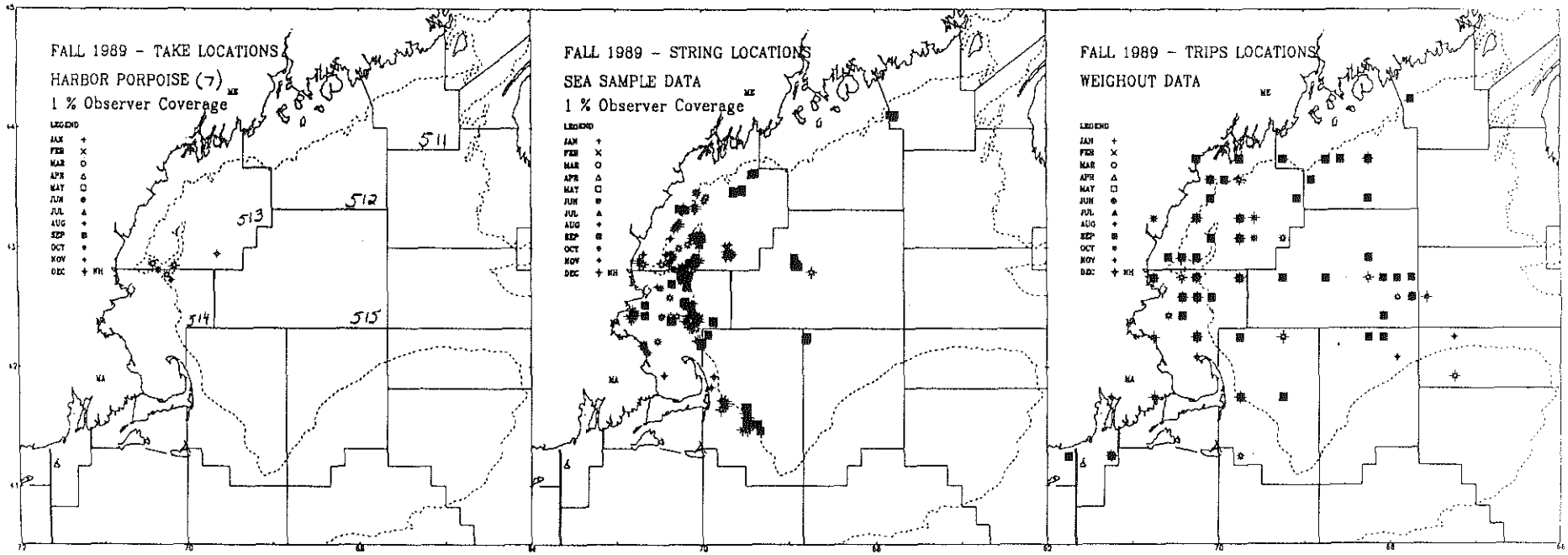


Table 2. Observed by-catch rates (number of kills/number of trips) for all years by statistical area and month, where zeros show that sampling occurred within that area and month but no observed by-catch occurred

Month	N. GOM						S. GOM								
	511			512			513			514			515		
	89	90	91	89	90	91	89	90	91	89	90	91	89	90	91
1								0.67	0.50		0.00	0.33			
2									0.00		0.50	1.00		0.00	
3								0.00	0.33		0.33	0.00		0.00	1.00
4								0.38	0.40		0.11	0.00			
5			0.00		0.00	0.00		0.00	0.50		0.00	0.00			
6			0.33		0.00	0.00		0.00	0.00		0.00	0.00			0.33
7		0.00	0.13			0.06		0.00	0.00		0.00	0.00		0.00	0.00
8	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	
9	0.00		0.00		1.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10			0.00		0.00	0.17	0.14	0.20	0.04	0.18	0.60	0.00			0.00
11						0.00	0.13	0.14	0.46	0.17	0.25	0.04			0.00
12							0.40	0.00	0.08	0.0	0.20	0.07		0.00	

No observed takes

Summer 1989



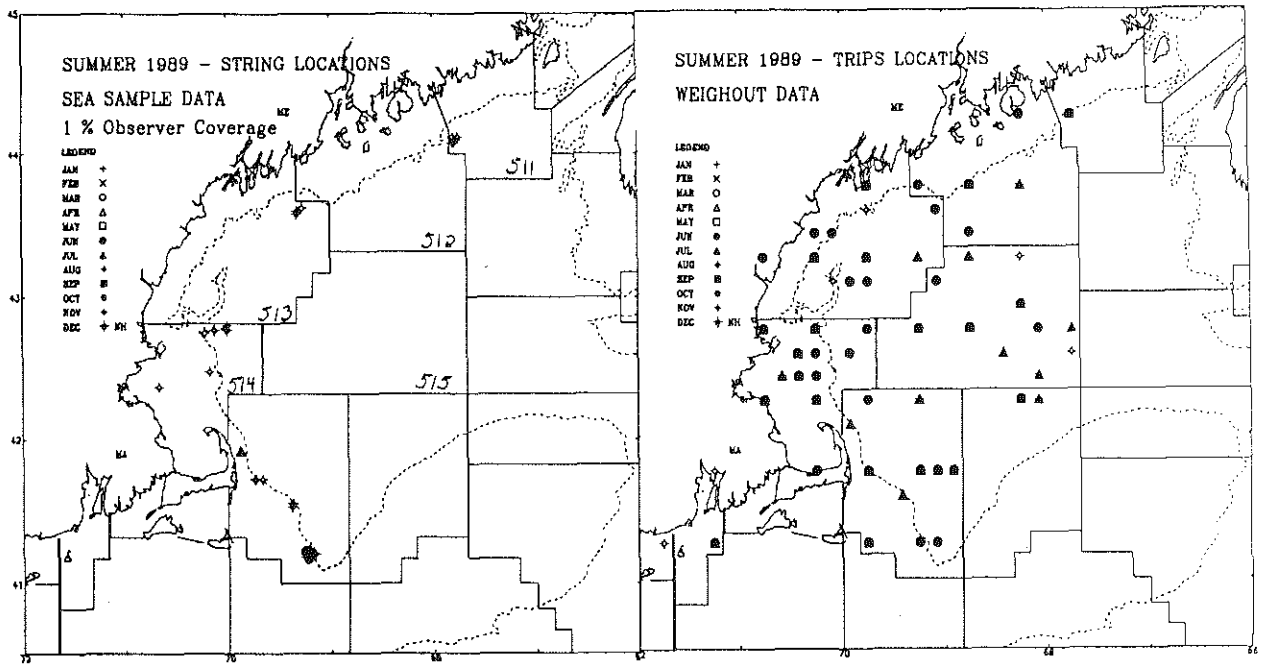
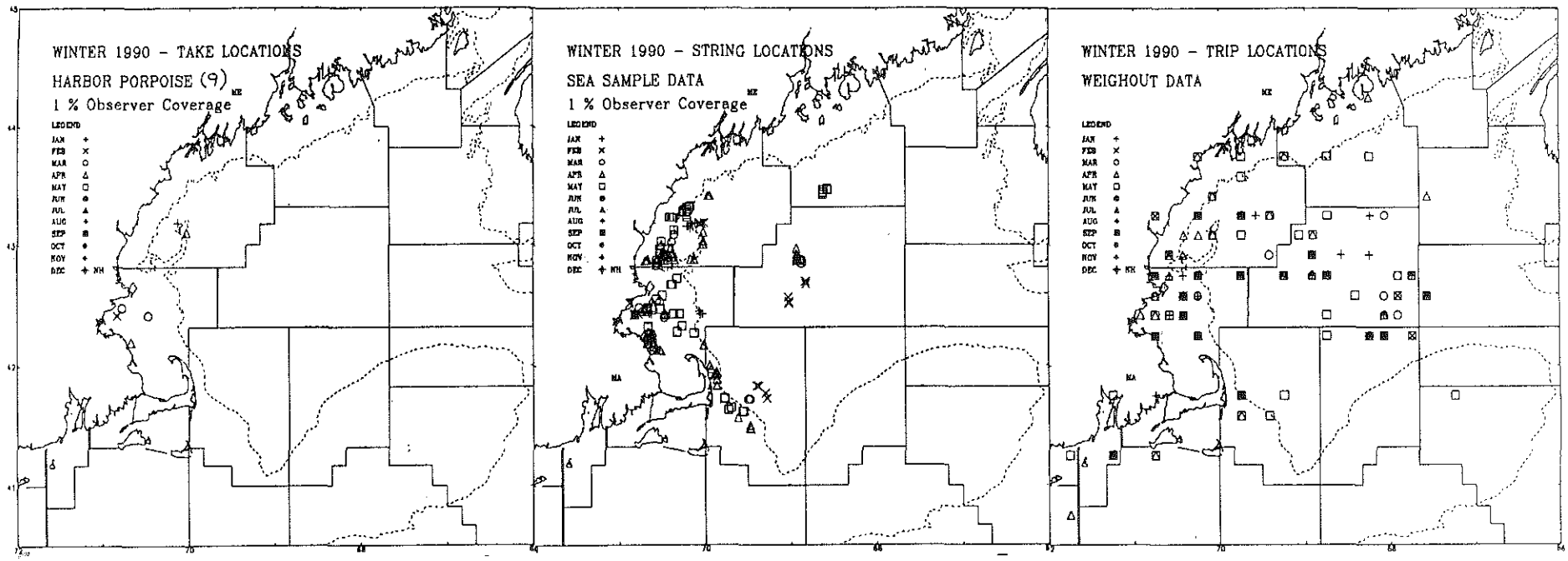
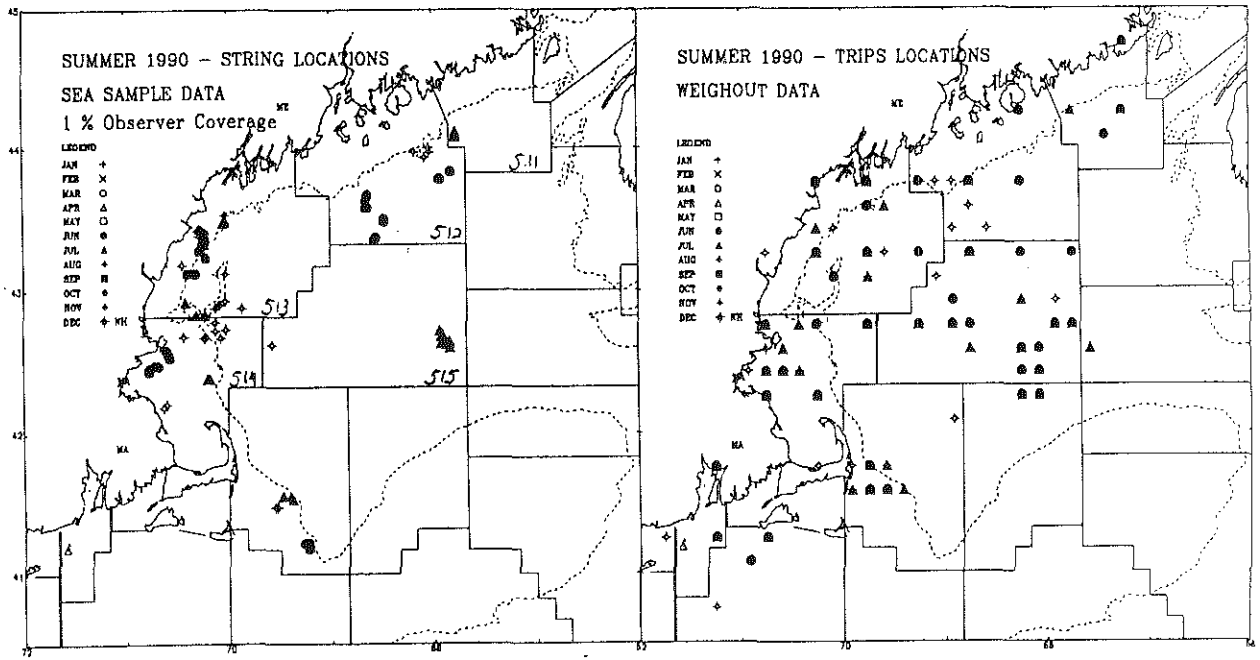


Figure 2. Harbor porpoise observed takes, observed strings, and reported weighout trips by strata.





No observed takes

Summer 1990

Figure 2. Continued.

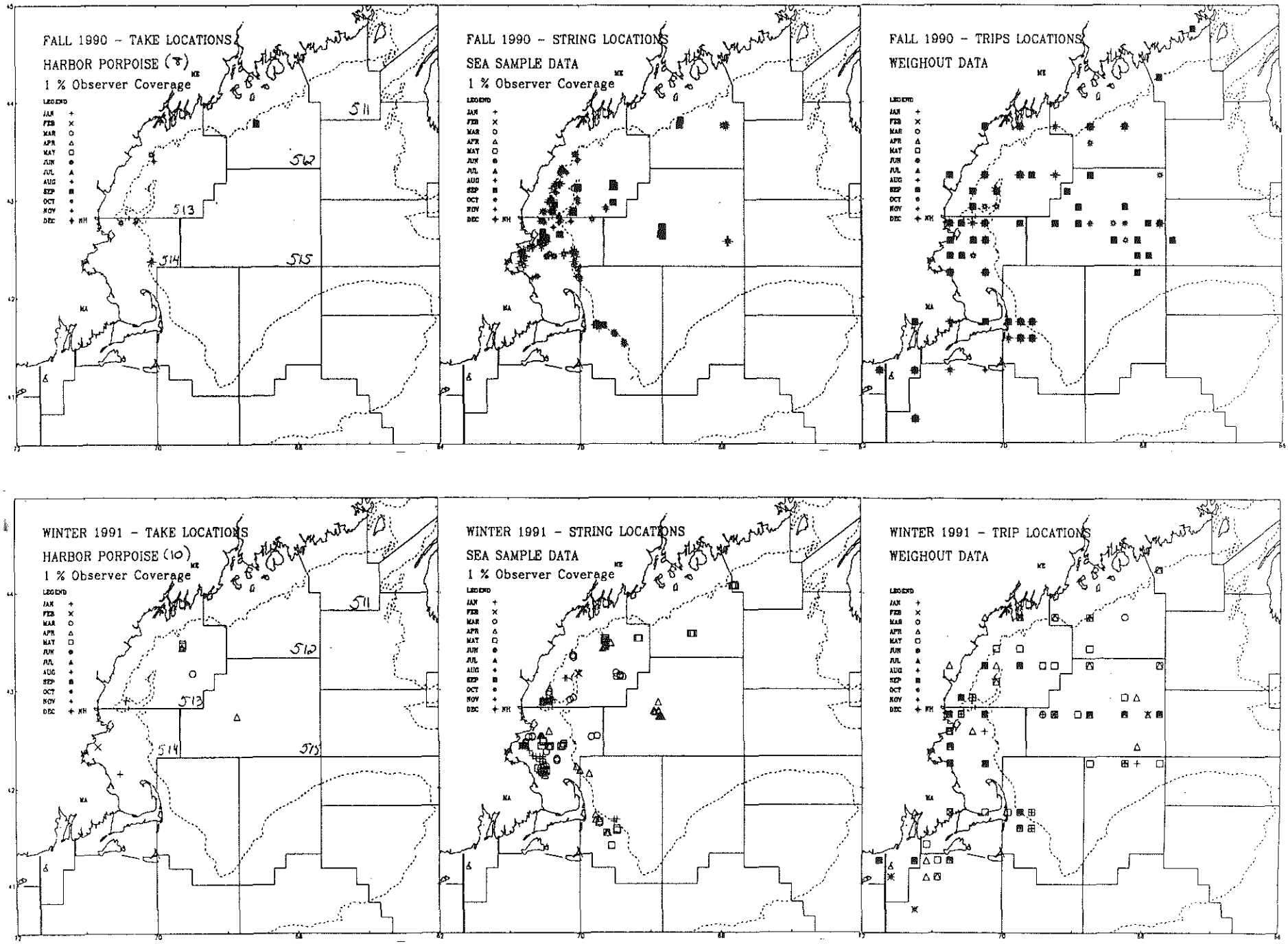


Figure 2. Continued.

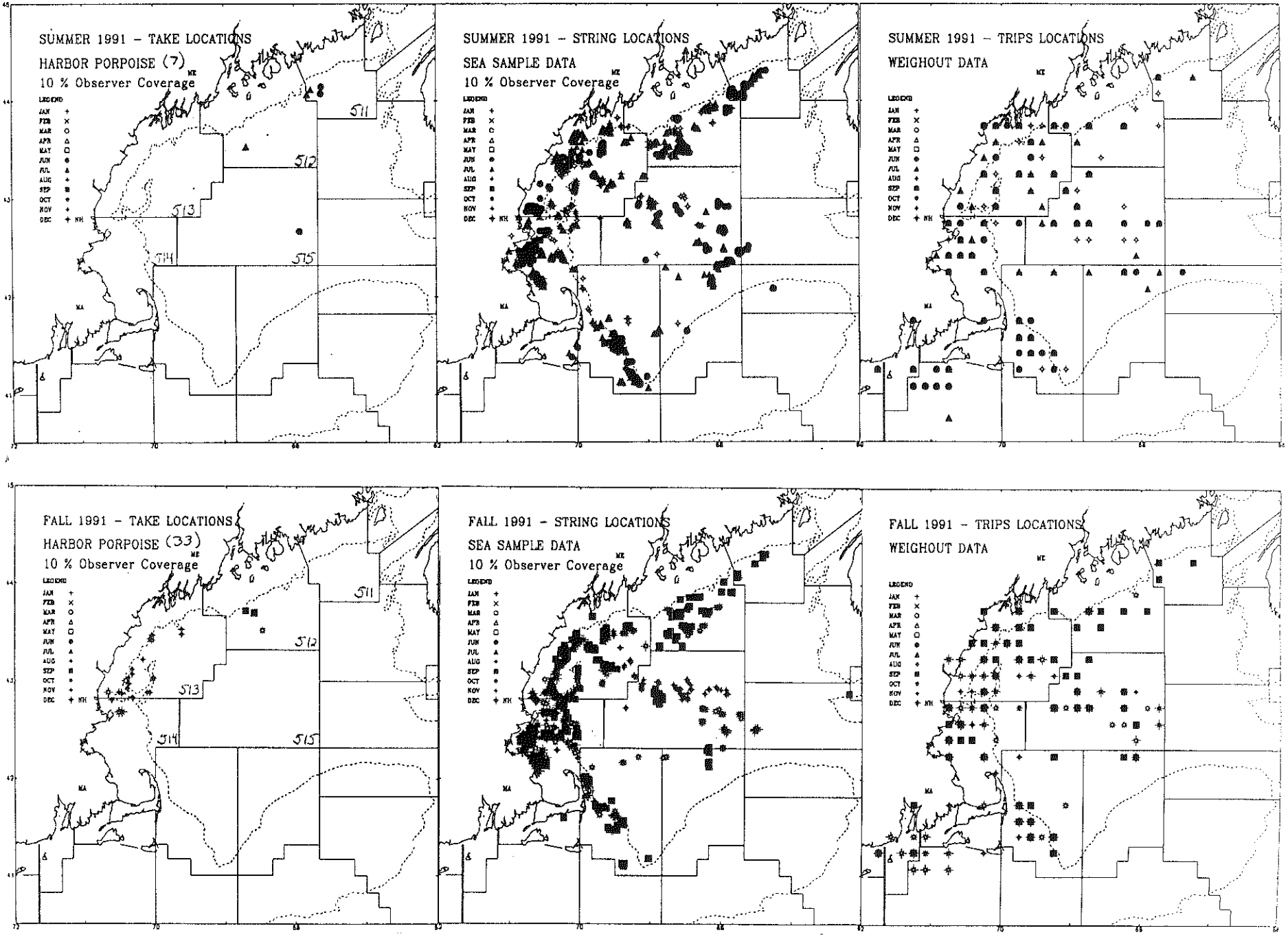


Figure 2. Continued.

Table 3. Annual sea sampling trips (SS), total observed harbor porpoise takes, weighout (WO) trips, weighout (WO) landings (tons) for two area strata: Southern Gulf of Maine (S. GOM) and Northern Gulf of Maine (N. GOM), in summer (S), fall (F), and winter (W)

Year	Time	SS Trips		Harbor Porpoise		WO Trips		WO Landings	
	Period	N.GOM	S.GOM	N.GOM	S.GOM	N.GOM	S.GOM	N.GOM	S.GOM
89	S	2	7	0	0	888	2158	1641	4945
	F	1	72	0	7	378	3821	528	6214
90	W	2	56	0	9	154	3082	186	2916
	S	6	21	0	0	856	3602	1269	7669
	F	2	36	1	7	433	3848	392	5564
91	W	2	36	0	10	235	2693	215	2229
	S	91	325	5	2	1033	2871	1975	5483
	F	33	326	3	30	429	3055	668	3005

POSSIBLE FISHING EFFORT MEASURES FOR ESTIMATION

Four possible measures of fishing effort that could be used for estimating total by-catch of harbor porpoise are included in the SS and WO data bases: days fished, number of trips, days absent, and total landings. These have different levels of reliability and consistency between the SS and WO data bases. Two by-catch estimators used within this paper are based on trips and landings. Data characteristics that led to the selection of trips and landings are discussed next.

"Days fished" in the sink gillnet fishery corresponds to soak time for a string of nets. The methods by which effort data are recorded in the SS program and the WO program are not the same. The SS data includes the number of strings the fisher hauls during the observed trip and the corresponding soak time for each string. The WO does not include the number of strings a fisher hauls on a trip or the soak time of individual or collective strings of gear, even if the fisher is interviewed.

Days absent is recorded as the amount of time the vessel is away from the dock during one fishing trip. Sink gillnet vessels according to the WO are absent from the dock approximately 1.1 days per trip for both 1990 and 1991. A trip is interpreted as an event independent of length of time at sea. Each time a vessel returns to the dock to land its catch, that return is recorded as the end of a trip. The number of trips a vessel makes can be tracked in the WO data to individual vessels for tonnage vessels, but not for undertonnage vessels.

Total landings are reported as weight of fish by species that a fisher sells to a marketer. Landings may be a more reliable measure of fishing effort than trips, since the WO was designed originally to report total landings of fish rather than number or duration of fishing trips. Also, catch may be more reflective of harbor porpoise by-catch since there likely exists a relationship between total catch and soak time. That is, the probability of catching a harbor porpoise in the gear increases with the length of time the gear sets in the water and the length of the gear.

Some complications are known to arise in the collection of the WO data. In the case of uninterviewed trips, the port agent may receive several WO slips from a marketer, or the marketer may combine trips from several fishers on one WO slip. That combined WO slip may be the landed catch for one or several different unidentified vessels. These problems are not believed to occur frequently. The largest component of missing trips is believed to be vessels whose landings are not great enough to generate a WO slip, or which do not follow the normal marketing channels and are therefore missed completely in the WO data system (Ronnee Schultz personal communication)[1]. The proportion of total catch that these vessels account for is again believed to be minimal, but the proportion of trips that these vessel represent is unknown (Ronnee Schultz personal communication). It is not known if these missing trips are predominately associated with tonnage or undertonnage vessels.

During an earlier workshop (NEFSC 1992) it was concluded that the total landings recorded in the WO data base is the most accurate measure of total effort for the sink gillnet fishery. Although resolution of landings (tons of fish) at the number of trips level is coarse, estimates are available for all tonnage classes in the fishery and are more likely to be based on direct observation than are estimates of days fished or days absent. Thus,

[1] 1992, Ronnee Schultz, Chief, Fisheries Statistics Investigation, NEFSC, 166 Water Street, Woods Hole, MA 02543.

the best approach to estimating total by-catch, based on fishing effort, is some form of by-catch per ton of fish landed from the SS data, expanded by total tons of fish landed from the WO. For comparison, an alternative method of estimating total kill could be based on some form of kill rate per number of trips based on SS data, expanded by the number of trips from the WO data.

ESTIMATORS

By-catch Based on Trips

Previous by-catch estimates using SS data (Smith *et al.* 1991) were based on the number of trips during the period June 1989 and May 1991, with a quarterly time stratification. Revised estimates are made here with additional data (June 1991 to December 1991) and with the time and location stratification identified earlier. The SS data are used to estimate the harbor porpoise mean kill per trip ($\hat{KPT}$) and variance by time and location. The total number of trips in the WO represents the total trips in the region. The estimated kill per trip ($\hat{KPT}_{t,l}$) and kill ($\hat{K}_{t,l}$) by time and location and their variances are shown in Equation (1) (see Cochran 1977).

The estimates of kill per trip ($\hat{KPT}$) and total kill($\hat{K}$), across all strata, and their variances are then as shown in Equation (2).

$$\begin{aligned}
\hat{KPT}_{t,l} &= \sum_{i=1}^{n_{t,l}} k_{i,t,l} \,/\, n_{t,l} \\
\hat{\sigma}^2_{\hat{KPT},t,l} &= (1 - f_{t,l})\ (1/n_{t,l})\ \hat{\sigma}^2_{k,t,l} \\
\hat{K}_{t,l} &= N_{t,l}\ \hat{KPT}_{t,l} \\
\hat{\sigma}^2_{\hat{K},t,l} &= N^2_{t,l}\ \hat{\sigma}^2_{\hat{KPT},t,l}
\end{aligned} \tag{1}$$

where
- t = time; 1 = winter, 2 = summer, 3 = fall
- l = location; 1=S. GOM, 2 = N. GOM
- $k_{i,t,l}$ = total kills per trip i, stratum t,l
- $n_{t,l}$ = total observed (SS) trips, stratum t,l
- $N_{t,l}$ = total (WO) trips, stratum t,l
- $f_{t,l}$ = $n_{t,l}/N_{t,l}$

$$\begin{aligned}
\hat{KPT} &= \frac{1}{N}\sum_{t=1}^{3}\sum_{l=1}^{2} N_{t,l} * \hat{KPT}_{t,l} \\
\hat{\sigma}^2_{\hat{KPT}} &= \frac{1}{N^2}\sum_{t=1}^{3}\sum_{l=1}^{2} N^2_{t,l}\ \hat{\sigma}^2_{\hat{KPT},t,l} \\
\hat{K} &= N * \hat{KPT} \\
\hat{\sigma}^2_{\hat{K}} &= N^2\ \hat{\sigma}^2_{\hat{KPT}}
\end{aligned} \tag{2}$$

By-catch Based on Landings

The WO is the source for total pounds of fish landed in the area the vessel fished within a trip. It is assumed that the landings in the WO represents the total landings in the region. The SS is the source of pounds of fish and number of harbor porpoise caught. A separate ratio estimator was used, since both fish catch and harbor porpoise by-catch are variable units. A kill estimate ($\hat{k}_{t,l}$) and variance was calculated for each time and location strata, which are combined for the overall kill ($\hat{K}$) estimate and variance (see Cochran 1977) using Equation (3).

$$\begin{aligned}
\hat{R}_{t,l} &= \sum_{i=1}^{n_{t,l}} k_{i,t,l} \Big/ \sum_{i=1}^{n_{t,l}} c_{i,t,l} \\
\hat{k}_{t,l} &= \hat{R}_{t,l} * C_{t,l} \\
\hat{K} &= \sum_{t=1}^{3}\sum_{l=1}^{2} \hat{k}_{t,l} \\
\hat{\sigma}^2_{\hat{K}} &= \sum\sum \hat{\sigma}^2_{\hat{k},t,l} = \sum_{t=1}^{3}\sum_{l=1}^{2} \frac{N^2_{t,l}(1 - f_{t,l})}{n_{t,l}}\ (S^2_{k,t,l} + \hat{R}^2_{t,l}\ S^2_{c,t,l} - 2\ \hat{R}_{t,l}\ S_{k,c,t,l})
\end{aligned} \tag{3}$$

where
- $c_{i,t,l}$ = tons of fish kept per trip i, stratum t,l (SS data)
- $C_{t,l}$ = tons of fish landed (WO), stratum t,l
- $\hat{R}_{t,l}$ = estimate of kills per ton kept, stratum t,l
- $S_{k,c,t,l}$ = covariance of kills, fish kept stratum t,l

RESULTS

BY-CATCH RATES

In the northern stratum (N. GOM), seasonal patterns cannot be detected (Table 4, Figure 3), although the increased sampling coverage in 1991 suggests that the by-catch rate is higher in the fall than in the summer. The total of four trips observed in this strata in the winter are insufficient to draw any conclusions.

In the southern stratum (S. GOM) by-catch rates are the highest in the fall and winter, and lowest in the summer (Table 4, Figure 3). During the fall, the by-catch rates are similar on trips in 1989 and 1991, and higher in 1990. In contrast, the winter of 1990 has a lower by-catch rate than the winter of 1991 based on trips (.16 *vs* .28). While the by-catch rates during the summer strata appear to be significantly lower than those for fall and winter, other differences, such as that between fall in 1990 and 1991, are not statistically significant.

These estimates of by-catch rates suggest that during the winter by-catch occurs in the southern and not the northern strata. However, this observation is based on very limited sampling coverage. In the summer of 1991 (10% coverage), the by-catch rate was higher in the northern strata than the southern strata by a factor of 10. In the fall of 1991, the by-catch rates were similar in both the northern and southern strata.

FISHING EFFORT AND LANDINGS

In the southern stratum, landings fluctuate more from season to season than do trips (Figure 4). In the southern GOM, trips (+11%) and landings (+12%) increased in 1990, and the trips (-10%) and landings (-26%) decreased in 1991 (1989 baseline). In the northern strata, the number of trips is substantially lower than the southern strata, and the trips and landings do not fluctuate as much from season to season as in S. GOM (Figure 4). The number of trips is higher in the summer than the fall and winter. In 1990, northern GOM, the trips (-22%) decreased and landings (+3%) increased, and in 1991 trips (+21%) and landings (+21%) increased.

Table 4. Estimated kill per trip ($\hat{KPT}$) and standard deviation (SD) by strata

YR	Time Period	Trips N. GOM $\hat{KPT}$	N. GOM SD	S. GOM $\hat{KPT}$	S. GOM SD
89	W	-	-	-	-
	S	.00	.000	.00	.000
	F	.00	.000	.10	.045
90	W	.00	.000	.16	.070
	S	.00	.000	.00	.000
	F	.50	.499	.19	.078
91	W	.00	.000	.28	.109
	S	.06	.027	.01	.006
	F	.09	.049	.09	.018

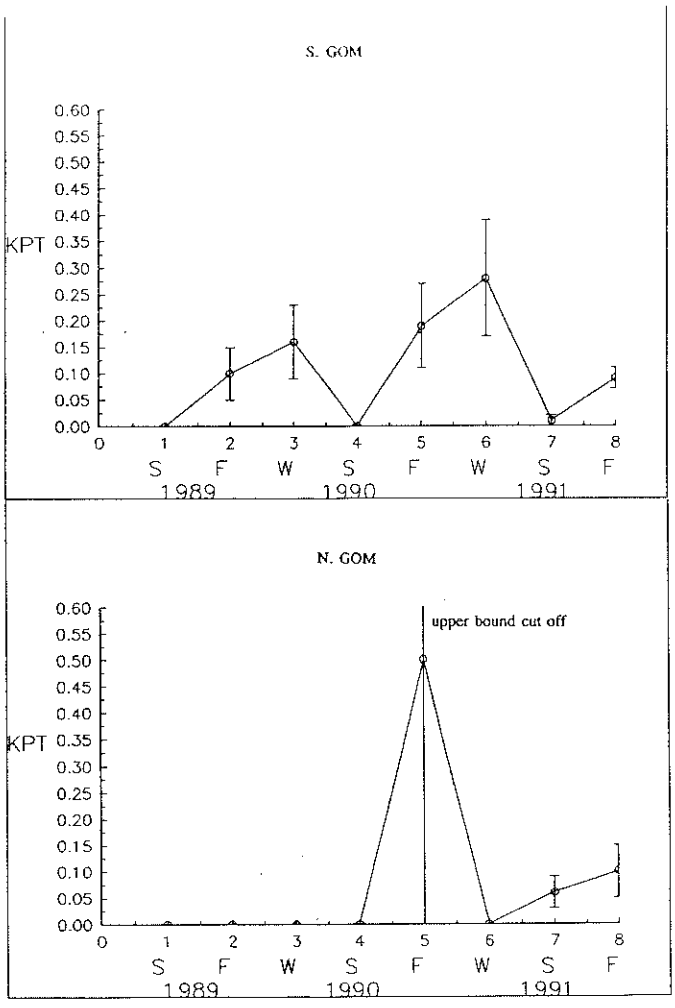


Figure 3. Estimated kill per trip ($\hat{KPT}$), with intervals of plus and minus one standard deviation, for the Southern Gulf of Maine (S. GOM) and northern Gulf of Maine (N. GOM).

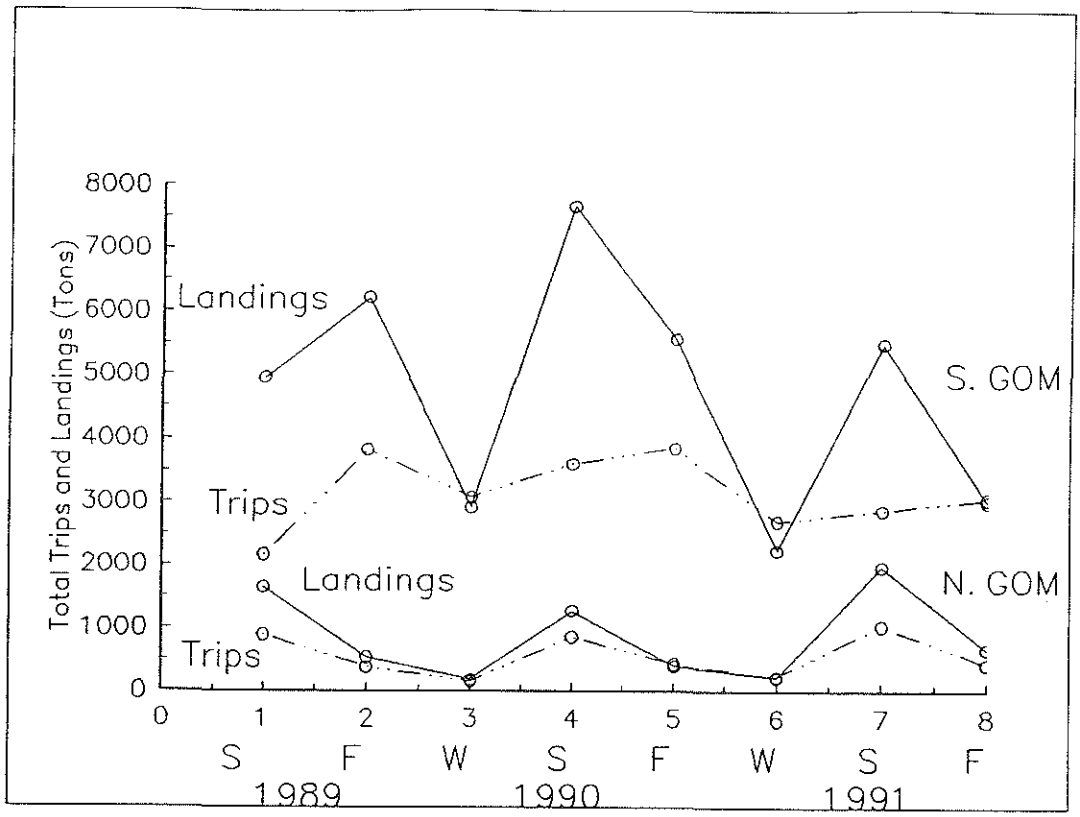


Figure 4. Recorded weighout trips and landings (tons) by strata.

BY-CATCH ESTIMATES

The Southern Gulf of Maine accounts for the largest proportion of the estimated by-catch, most of which is in the fall and winter (Table 5). By-catch estimates based on trips and landings are similar, except in the winter and fall of 1990 and the winter of 1991. The by-catch estimate based on landings is consistently and substantially greater in those strata. By-catch estimates can be compared from 1989 to 1991 only during the fall and summer strata. Using both the trip and landings estimators, the estimated by-catch in the fall of 1990 is two to three times higher than for 1989 and 1991. The sampling is too low during the summer of 1989 (9 SS trips) and 1990 (27 SS trips) *versus* 1991 (416 SS trips) to make between year comparisons. Seasonal estimates differ between years because of the fluctuation in both the $\hat{KPT}$ and the number of WO trips. For example during the fall in S. GOM, the $\hat{KPT}$ in 1991 was half of 1990 and the total WO trips dropped by 21%, leading to a 62% decrease in the kill estimate between fall of 1990 and 1991.

In the N. GOM the estimated by-catch occurred in the summer and fall. Significant differences do not exist between the trips and landings based estimates in 1991.

ESTIMATED TRIPS

An estimate of the total number of trips in the sink gillnet fishery can be made using total landings in the WO and the landings per trip observed in the SS. The estimated trips in each strata ($\hat{T}_{t,l}$) and its approximate variance using a Taylor's series expansion are shown in Equation (4).

(4)

$$\hat{T}_{t,l} = \frac{C_{t,l}}{\bar{c}}$$

$$\bar{c} = c_{t,l} \,/\, n_{t,l}$$

$$\bar{c} = \textit{mean catch per trip(SS)}$$

$$\sigma^2_{\hat{T},t,l} = (C \,/\, \bar{c}^4)\ \sigma^2_{\bar{c}}$$

Table 5. Estimated by-catch ($\hat{K}$) with trips and landings as an estimator by strata

		Trips				Landings			
		N. GOM		S. GOM		N. GOM		S. GOM	
		$\hat{K}$	SD	$\hat{K}$	SD	$\hat{K}$	SD	$\hat{K}$	SD
89	W	-	-	-	-	-	-	-	-
	S	000	00.0	000	00.0	00	00.0	000	00.0
	F	000	00.0	372	170.1	00	00.0	337	174.2
90	W	000	00.0	495	217.0	00	00.0	1264	158.8
	S	000	00.0	000	00.0	00	00.0	000	00.0
	F	217	216.0	748	298.2	87	399.6	1045	347.1
91	W	000	00.0	748	294.0	00	00.0	1201	331.0
	S	57	28.3	18	16.7	65	27.9	19	16.6
	F	39	20.9	281	55.6	48	21.9	339	60.9

Table 6. Estimated trips ($\hat{T}$) and recorded weighout trips (T) by strata

Year	Time Period	S. GOM			N. GOM		
		$\hat{T}$	SD	T	$\hat{T}$	SD	T
89	S	6325	1722	2158	1695	867	888
	F	3462	867	3821	299	169	378
90	W	7866	1695	3082	105	66	154
	S	3286	1121	3602	1460	373	856
	F	5373	1182	3848	174	148	433
91	W	4444	1573	2693	81	18	235
	S	3145	204	2871	1212	80	1033
	F	3679	304	3055	527	47	429

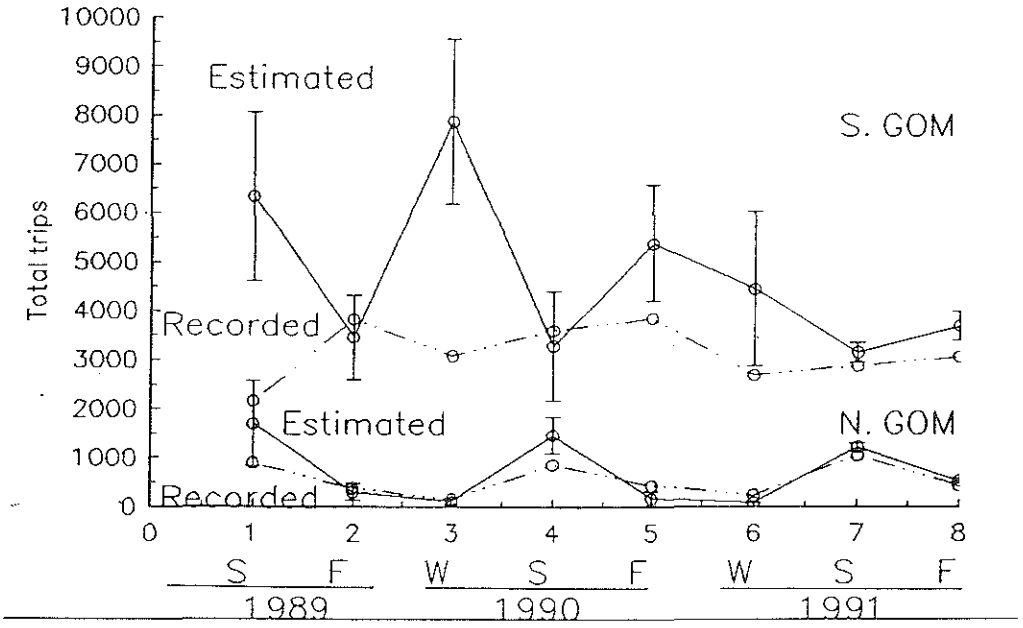


Figure 5. Recorded weighout trips and estimated weighout trips (total weighout landings divided by sea sampling landings per trip), with plus and minus one standard deviation, by strata

Because of the nature of these estimates, if the estimated trips were replaced by the recorded trips in the trip estimator, the by-catch estimate using trips would equal the by-catch using landings. Estimates of the number of trips can be used to determine why the by-catch estimate using the landings estimator is higher than the by-catch estimate using the trips estimator.

In S. GOM, the largest differences between observed and estimated number of trips are seen in the summer of 1989, winter and fall of 1990, and winter of 1991, with the estimated trips being greater than the recorded WO trips (Table 6 and Figure 5). These strata have the largest difference in the by-catch estimates for the trip-based and the landings-based estimators (Table 5).

In the N. GOM, the estimated number of trips is greater than the recorded WO trips in the summer of all three years. There are no other consistent patterns among strata in the N. GOM.

COMPARISONS OF ANNUAL ESTIMATES OF TOTAL BY-CATCH

Estimated total by-catch by year based on landings exceeds the by-catch estimate based on trips for both years for which complete data are available (Table 7). In 1990, the landings based estimate is 39% higher than the trips based estimator, and 32% higher in 1991. Looking at the trip estimator, the 1991 by-catch estimate is 22% lower than in 1990. For the landings estimator, the estimated by-catch in 1991 is 30% lower than 1990. Also shown is the average of the estimates for the two years. These differences between estimated and observed number of trips noted for the S. GOM suggest that the differences in total by-catch using trip-based and landings-based procedures may be due to an underreporting of trips in the WO data.

Table 7. By-catch estimates for 1990 and 1991

	Landings		Trips	
	$(\hat{K})$	SD	$(\hat{K})$	SD
1990	2396	467	1460	427
1991	1672	339	1142	302
Avg	2034	408	1301	370

DISCUSSION

The estimates of by-catch presented here represent a further refinement of earlier estimates (Smith *et al.* 1991). The present estimates are based on the same type of data, but include additional data collected in the second half of 1991, after the sampling coverage was increased to 10%. The new estimates based on numbers of fishing trips are similar to the earlier estimates (1990 and 1991 average of roughly 1300 per year compared to 1989-1990 average of roughly 1250). However, the new estimates based on landings of fish are substantially higher than the trip-based estimates (roughly 2000 versus 1300 for 1990-1991). The estimates differ between 1990 and 1991 using both methods, but because the standard deviations of the estimates are on the same order as these differences, there is no evidence of interannual differences in the level of by-catch.

The southern GOM accounts for the largest proportion of by-catch. By-catch estimates vary within seasons among years because of fluctuations in both by-catch rates and total effort. The 1990 annual estimate of harbor porpoise by-catch is higher than the 1991 estimate for both the landings based and trip-based estimators.

By-catch rates (kill per trip) show spatial and temporal patterns. In the winter months (January-May) by-catch rates occur in the S. GOM and not N. GOM. In the summer (1991), the by-catch rate is higher in the N. GOM than the S. GOM. In the fall (1991), the by-catch rates are similar.

The reason for the differences in the trip-based and landings-based estimates is not clear. Substantial differences occur in both area strata, and not always in the same direction. Thus in the N. GOM in the fall of 1990, the trip-based estimate is greater (217 *vs* 87), while in the southern area the opposite is true for the winter and fall of 1990, and the winter of 1991. Only in the S. GOM, in the winter of 1990 were differences large, relative to the standard deviations of the estimates, however.

These differences in the trip-based and landings-based estimates could be due to several known difficulties with the data bases. Additionally, because of the low sampling intensities through mid-1991, the landings-based estimates may be biased (Cochran 1977). These points are discussed in more detail.

The WO data collection program is currently a voluntary system. Since this system was designed initially for collecting landings data, especially from the otter trawl fishing vessels found in major ports, small sink gillnet vessels scattered along the coastline may be missed by the collection system (Ronnee Schultz, personal

communication). Some trips are missing for some tonnage vessels (Bisack and DiNardo 1992), and no records exist in the WO for some tonnage vessels known to be fishing. The completeness of the WO coverage was explored by using data from 1990 from four other data bases and merging them by vessel with the SS and WO. These data bases consisted of a list of vessels with federal fishing permits (FFP), the Marine Mammal Exemption Program Logbook (MMEP Logbook) data reported by the fishermen, both maintained by the Northeast Regional Office, a list of vessels used for selection of trips for sea sampling maintained by the Manomet Bird Observatory (MBO), and the 1989 master vessel list (the most recent) maintained by the U.S. Coast Guard. From this analysis it appears that 239 tonnage vessels have been reported fishing with gillnet gear on one data base or another. Of the 239 tonnage vessels, 108 vessels raised significant questions about their identity and/or level of activity. The analysis concluded that none of the data bases used have complete records of tonnage vessel fishing activity. The WO was the most complete of the data bases analyzed, but it is missing both some trips and some vessels. Undertonnage vessels represent one-third of the WO trips, but they cannot be tracked and therefore little information is available about the number of participating vessels and their associated effort.

The level of interview coverage introduces additional uncertainty. Of the 183 tonnage gillnet vessels identified in the WO in 1990, 83 had been interviewed (45%), and 7% of the trips were interviewed. Further, there were 1556 trips by tonnage vessels associated with ports north of Portland, Maine, but only three interviews were conducted. One of the major concerns regarding low interview coverage is the ability of the port agent to determine in which statistical areas the vessel fished, as well as which fishing grounds within a statistical area.

The sea sampling coverage started at 1% in June 1989 and increased to 10% by June 1991. The low sampling coverage may contribute to the fluctuation of estimates within seasons over years. Vessel selection is based on a schedule developed by the NEFSC that identifies the number of trips to be sampled by time and area. The contractor finds vessels that meet this schedule criteria. The size of the vessel and ports are not specified and may need to be in the future to insure a representative sample. Additionally, if the WO does not cover all trips and is uncertain as to where vessels fish, and if fishing varies from year to year, allocating sea sampling trips based on the WO may be inappropriate.

Trips as a measure of total effort have been estimated by dividing the total WO landings by the SS landings per trip. The estimated number of trips in most cases are higher than the recorded number of trips. This observation suggests landings are better monitored than trips, however one explanation may be the existence of a bias in the observer's visual landings per trip estimate. The landings based estimate of by-catch is 1264 and the trips based estimate is 495 in the winter 1990 (Table 6), and the estimated number of trips is 7866 versus the recorded 3082 WO trips. Of 56 SS trips in the winter 1990 in the S. GOM, 28 (50%) trips were found in the WO. The SS mean tons per trip was 0.40 (cv = 38%) and the WO mean ton per trip was 0.50 (cv = 34%). If 0.50 (WO) is replaced by 0.40 (SS), then the estimated number of trips is reduced from 7866 to 5831 trips and the landings-based by-catch is reduced from 1264 to 937. This suggests that the SS visual estimate of the landings may account for a portion of the difference between the estimated and recorded trips.

Other sampling biases may be occurring. A bias may be associated with ratio estimators within a stratified random sampling scheme if the cv of the mean catch per trip (within a strata) in the SS data is greater than 0.1 (Cochran 1977). The bias is estimated to be upward of 0.0196 harbor porpoise per ton of landings (WO). This is approximately 4.5% of the ratio estimator $\hat{R}$), which is 0.434 harbor porpoise per ton of landings in the winter of 1990 in S. GOM. This provides a rough indication of the possible bias, although it should not be used to actually adjust the estimate of the ratio. The cell with the most concern would be the winter of 1990 in N. GOM where the cv is .85. However, these strata only contributed 15% and 4% of the 1990 annual by-catch estimate using the trip-based and landings-based estimator methods, respectively.

The selection of the six strata used was based on inspection of the data, both in terms of its spatial and seasonal distribution, and in terms of the general rates of by-catch. To explore the effects of the specific selection made, two other stratification schemes were explored, one with no spatial stratification and one with more spatial stratification. Increasing the amount of spatial stratification resulted in increased point estimates, although the magnitude of the effect was on the order of plus and minus 4% for 1990 and plus 4% and minus 11% for 1991.

Inspection of the original observer field records for 1990 suggests that animals may be falling out of the net before the net rises above the surface. In October of 1991, a special request was made

asking SS observers to record any incidents of harbor porpoise falling out of the net when the gear was being hauled back. Inspection of resulting data for the 28 animals observed killed in November and December of 1991 indicated that some animals are observed to fall from the net during haul back. Information collected to date is insufficient to determine if harbor porpoise are falling out of the net undetected. If animals are falling out before the net reaches the surface, the by-catch rate and estimates would be too low.

Inspection of the original observer data sheets also revealed that one animal was recorded as being released "alive condition unknown", and two were recorded as "condition unknown." These three animal were assumed to have been dead in this analysis. If they were considered alive, the point estimate for that strata would be reduced by 28 animals with the trip estimator and 34 animals with the landings estimator.

The best estimate of the average annual by-catch of harbor porpoise in the U.S. sink gillnet fishery in the Gulf of Maine in recent years is roughly 2000 (95% CI 1200, 2800). This estimate could be upwardly biased if landings are being overestimated. Landings would be only overestimated if there were incorrect gear assignments, that is, if other gear types were recorded as sink gillnet gear. It is more likely, however, that sink gillnet gear have been incorrectly assigned to other gear, which would result in both trips and landings being underestimated. However, there are several sources of uncertainty that are a result of the low SS coverage, and missing trips and low interview coverage in the WO. In addition to the by-catch in the GOM, there is known to be by-catch in Canadian waters (approximately 105 (95% CI, 84,126)) for the Bay of Fundy (Read and Gaskin 1988), and in sink gillnet and other gillnet fishing operations occurring south of Cape Cod. The magnitude of the by-catch in areas south of Cape Cod is not known, although it is likely less than that in the Gulf of Maine region.

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Appendix A

Weighout Slip

This survey is authorized by 16 U.S.C. 742 (a), 1854 (e), Reorg. Plan No. 4 of 1970. While you are not required to respond, your cooperation is needed to make the results of this survey comprehensive, accurate and timely.

NOAA FORM 88-30 10-86

U. S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

FORM APPROVED: O.M.B. NO. 0648-0013 EXPIRES: 10/31/88

PURCHASES FROM FISHING VESSELS(Northeast)

DEALER										DATE		
NAME OF VESSEL					VESSEL CODE			S	PORT		CO.	
SUB	DATE SAILED	DATE LANDED	GEAR	MESH	AREA	DAYS A.	DAYS F.	TOWS				
DUR.	TRIPS	DEPTH	L.I.	PRO.	F.Z.	QTR.SQ.	10 SQ.	T.T.	T.L.	T.D.		

SPECIES AND GRADE		CODE	POUNDS LANDED	PRICE PER POUND	SUBTOTAL Dollars	Cents
COD	Steaker	0816				
	Large	0811				
	Market	0813				
	Scrod	0814				
CUSK		0960				
HADDOCK	Large	1470				
	Scrod	1475				
HAKE	Red	1520				
	White	1530				
OCEAN PERCH(Redfish)		2400				
POLLOCK		2691				
WHITING		5090				
WOLFISH(Catfish)		5120				
GREY SOLE	Large	1221				
	Medium	1224				
	Small	1222				
LEMON SOLE		1201				
BLACKBACK	Large	1202				
	Medium	1206				
	Small	1203				
YELLOWTAIL	Large	1231				
	Small	1232				
DAB	Large	1241				
	Medium	1244				
	Small	1242				
FLUKE	Jumbo	1218				
	Large	1210				
	Medium	1212				
	Small	1214				
SAND DAB		1250				
BUTTERFISH	Large	0510				
	Medium	0515				
	Small	0516				
SCUP	Large	3290				
	Medium	3292				
	Small	3293				
	Pins	3294				
HERRING, SEA		1685				
MACKEREL		2120				
MONKFISH(Angler)		0120				
SKATES		3650				
SHRIMP		7360				
LOBSTER	Large	7274				
	Select	7273				
	Small	7272				
SCALLOPS, SEA		8009				
SQUID		8030				
Other For Food		5260				
Other For Reduction		5290				
		TOTAL				

NOTE:Individual reports are confidential and only summary data are released.

APPENDIX B

Sea Sampling Data[1]

[1] The sea sampling program is designed to be proportional sampling of trips on a statistical area and month basis. Tables B.1 through B.6 show the number of trips sampled, and the number of harbor porpoise observed killed by month and statistical area for 1989 through 1991.

Table B.1 Observed sea sampling trips by month and statistical area for 1989

	511	513	514	515	521	522	Total
Jun					1		**1**
Jul					1		**1**
Aug	2	2	5		4		**13**
Sep	1	14	11	1	4	1	**32**
Oct		7	11		4		**22**
Nov		8	6		3		**17**
Dec		5	8		3		**16**
Total	**3**	**36**	**41**	**1**	**20**	**1**	**102**

Table B.2 Observed harbor porpoise by-catch for 1989 (zero indicates sampling but no by-catch)

	511	513	514	515	Total
Aug	0	0	0		**0**
Sep	0	0	0	0	**0**
Oct		1	2		**3**
Nov		1	1		**2**
Dec		2	0		**2**
Total	**0**	**4**	**3**	**0**	**7**

Table B.3 Observed sea sampling trips by month and statistical area for 1990

	511	512	513	514	515	521	Total
Jan			3	6			**9**
Feb				2	1	1	**4**
Mar			4	6	2	1	**13**
Apr			8	9		3	**20**
May		2	6	9		2	**19**
Jun		3	3	2		2	**10**
Jul	2		3	1	1	2	**9**
Aug		1	6	4		1	**12**
Sep		1	4	2	1	1	**9**
Oct		1	5	5		3	**14**
Nov			7	4		1	**12**
Dec			3	5	1	1	**10**
Total	**2**	**8**	**52**	**55**	**6**	**18**	**141**

Table B.4 Observed harbor porpoise by-catch for 1990 (zero indicates sampling but no by-catch)

	511	512	513	514	515	Total
Jan			2	0		**2**
Feb				1	0	**1**
Mar			0	2	0	**2**
Apr			3	1		**4**
May		0	0	0		**0**
Jun		0	0	0		**0**
Jul	0		0	0	0	**0**
Aug		0	0	0		**0**
Sep		1	0	0	0	**1**
Oct		0	1	3		**4**
Nov			1	1		**2**
Dec			0	1	0	**1**
Total	**0**	**1**	**7**	**9**	**0**	**17**

Table B.5 Observed sea sampling trips by month and statistical area for 1991

	464	511	512	513	514	515	521	522	538	561	Total
Jan				2	3		1				**6**
Feb				1	1						**2**
Mar				3	5						**8**
Apr				5	4	1	3				**13**
May		1	1	6	6		3				**17**
Jun		7	13	59	31	5	30	1		1	**147**
Jul		16	16	64	59	6	28	1	1		**191**
Aug		15	23	55	40	6	33				**172**
Sep	1	7	18	49	31	2	22				**130**
Oct		1	6	50	33	2	12				**104**
Nov			1	48	51	3	7				**110**
Dec	1			25	32		7				**65**
Total	**2**	**47**	**78**	**367**	**296**	**25**	**146**	**2**	**1**	**1**	**965**

Table B.6 Observed harbor porpoise by-catch for 1991 (zero indicates sampling but no by-catch)

	511	512	513	514	515	Total
Jan			1	1		**2**
Feb			0	1		**1**
Mar			1	0		**1**
Apr			2	0	1	**3**
May	0	0	3	0		**3**
Jun	2	0	0	0	2	**4**
Jul	2	1	0	0	0	**3**
Aug	0	0	0	0	0	**0**
Sep	0	2	0	0	0	**2**
Oct	0	1	2	0	0	**3**
Nov		0	22	2	0	**24**
Dec			2	2		**4**
Total	**4**	**4**	**33**	**6**	**3**	**50**