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Estimating Harbor Porpoise Bycatch in the Gulf of Maine Sink Gillnet Fishery

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INTRODUCTION

The Northeast Fisheries Science Center (NEFSC) has previously prepared estimates of harbor porpoise bycatch in the Gulf of Maine for 1990-1992 (Bisack 1993; Smith, *et al.* 1993). In February 1994, at an international workshop on harbor porpoise, attention was drawn to evident under-reporting of bycatch in some instances, implying that these estimates were likely to be too low. The workshop concluded that an improved estimation method should be developed to address this problem, and that bycatch estimates should then be recalculated with the new method (Palka [Ed.] 1994). After the workshop the NEFSC developed a new method of estimating bycatch; this was reviewed and accepted by members of the workshop. The NEFSC used the improved method to prepare revised estimates of harbor porpoise bycatch in the Gulf of Maine sink gillnet fishery for 1990-1993, which were reported in June 1994.

In this document, we review reasons for changing the old method, and the new procedures used for calculating revised estimates of bycatch. We have also included summaries of the data and of the new estimates. The descriptions are meant to be non-technical, so we have simplified or omitted details to keep the document reasonably concise. Full technical details will be provided in a more comprehensive manuscript now being prepared.

There are basically three distinct steps required for management of harbor porpoise: (1) estimating current bycatch, and the likely range of error; (2) determining an acceptable bycatch level (the Potential Biological Removal, or PBR); and (3) if current bycatch exceeds the PBR, then deciding how to go about reducing bycatch. This document only deals with the first step, which is comparatively straightforward.

OVERVIEW OF THE FISHERY AND DATA COLLECTION

Many readers will be familiar with the fishery and sampling procedures, but it is useful to give a brief overview. The sink gillnet fishery comprises mostly small boats, which usually make one-day trips. In each trip, several (usually four or five) strings of sink gillnets are set. Each string is usually left in the water for about 24 hours before being hauled. Fishery observers accompany about 10% of the trips, recording bycatch of porpoise, fish catch, and other information, as each string is hauled. Groups of observers are recruited and trained once or twice a year. Depending on the area and time of year, an observer might expect to see one harbor porpoise about every thirty hauls.

In addition to watching for marine mammals, observers are expected to carry out other duties (*e.g.* monitoring discards) during some hauls. There are two types of hauls: dedicated marine mammal observation ("on-watches"), and hauls where other duties may distract an observer from watching for harbor porpoises ("off-watches"). If a porpoise reaches the boat while still entangled, an off-watch observer should still see it, but dead porpoises sometimes fall out of a net before reaching the deck. Observers' written comments indicate that porpoises falling out of the net are often only briefly visible, and could easily be overlooked during off-watches.

The data from the observer program are part of the NEFSC sea sampling database, and can be used to estimate the average bycatch of harbor porpoise per haul, or BPH. In addition, NEFSC operates a weighout data program, whereby port agents collect information on landings and fishing activities. Together, these data are used to estimate total hauls in the sink gillnet fishery. By multiplying average bycatch per haul by total hauls, we can estimate the total bycatch of harbor porpoise.

There have been minor amendments to the database since bycatch estimates were last published (August 1993), as part of the routine process of identifying and correcting errors. Table 1 shows summary data for 1990-1993 from the sea sampling and weighout databases. Because of the seasonal patterns of the fishery and the migration patterns of porpoise, we have stratified (organized) the data into three regions and three seasons per year, as shown in the Table. With four years of data, there are 36 strata in all, one for each combination of year, season and region. We estimated total hauls and BPH in each stratum independently, then multiplied them to estimate total bycatch for that stratum. To get annual totals, we added the totals over all strata within each year.

ESTIMATING TOTAL HAULS

We have no direct measures of the total number of hauls, but there are two other possible starting points in the weighout data: total trips and total landings. Total trips is the obvious choice, but cross-checking the total trip data

Table 1a. Summary of sea sampling data on harbor porpoise bycatch[1]

Block	Year[2]	Watch	Southern Gulf of Maine Take	Hauls	Ratio	Northern Gulf of Maine Take	Hauls	Ratio	South of Cape Cod Take	Hauls	Ratio
Block 1	90W	OFF	4	110	0.036	0	5	0.000	-	-	-
		ON	5	151	0.033	0	4	0.000	-	-	-
	90S	OFF	0	39	0.000	0	16	0.000	-	-	-
		ON	0	42	0.000	0	11	0.000	-	-	-
	90F	OFF	5	87	0.057	0	6	0.000	-	-	-
		ON	2	83	0.024	1	4	0.250	-	-	-
	91W	OFF	4	90	0.044	0	6	0.000	-	-	-
		ON	6	94	0.064	0	6	0.000	-	-	-
	91S	OFF	2	1383	0.001	5	423	0.012	0	1	0.000
		ON	0	2	0.000	-	-	-	-	-	-
	91F	OFF	17	1199	0.014	3	146	0.021	0	1	0.000
		ON	10	275	0.036	-	-	-	-	-	-
	92W	OFF	9	754	0.012	1	41	0.024	0	186	0.000
		ON	5	529	0.009	0	4	0.000	2	141	0.014
Block 2	92S	OFF	0	506	0.000	1	367	0.003	0	61	0.000
		ON	0	492	0.000	11	313	0.035	0	66	0.000
	92F	OFF	5	445	0.011	3	83	0.036	0	144	0.000
		ON	10	451	0.022	4	79	0.051	0	125	0.000
	93W	OFF	7	556	0.013	0	15	0.000	1	172	0.006
		ON	12	563	0.021	0	15	0.000	1	182	0.005
Block 3	93S	OFF	0	33	0.000	7	328	0.021	0	33	0.000
		ON	0	43	0.000	4	278	0.014	0	36	0.000
	93F	OFF	13	465	0.028	0	20	0.000	0	129	0.000
		ON	7	452	0.015	1	24	0.042	0	134	0.000

[1] Southern Gulf of Maine = Stat. Areas 513, 514, 515; Northern Gulf of Maine = Stat. Areas 511, 512; South of Cape Cod = Stat. Areas 537, 538, 539

[2] Seasons: W = winter, January - May; S = summer, June- August; F = fall, September - December

with other sources reveals numerous omissions, because detailed trip information is unavailable for many smaller ports. To quote the Stock Assessment Review Committee (SARC) on harbor porpoise bycatch at its December 1991 meeting: "The SARC believes that, at present, total landings in the sink gillnet fishery are more completely and accurately monitored than total effort [trips]" (SARC 1992). The SARC went on to recommend instead the use of total landings as a starting point in estimating total effort, which we have done as follows.

The sample average fish catch per haul ought to be close to the true average, which is (by definition):

$$\frac{\text{total fish catch in stratum}}{\text{total number of hauls in stratum}} \qquad (1)$$

So, to estimate total hauls, we divided the total fish catch (from the weighout data) by the sample average fish catch per haul (from the sea sampling data). This step estimates total hauls and does not involve porpoise, so it is irrelevant whether porpoise bycatch and fish catch are correlated in individual hauls.

ESTIMATING BYCATCH PER HAUL

If the observers recorded every porpoise killed during sampled trips, this step would be very simple: we would divide the total observed bycatch by the total observed hauls. However, data in Table 1a show that substantially fewer porpoises were recorded per off-watch than per on-watch, at

Table 1b. Sink gillnet effort and landings data[1]

		Southern Gulf of Maine			Northern Gulf of Maine			South of Cape Cod		
	Year[2]	Weighout Tons	Sampling Tons	Sampling Trips	Weighout Tons	Sampling Tons	Sampling Trips	Weighout Tons	Sampling Tons	Sampling Trips
Block 1	90W	2916	20.71	56	186	3.54	2	780	-	0
	90S	7669	46.15	20	1269	5.22	6	905	-	0
	90F	5564	37.04	37	392	2.15	2	1234	-	0
	91W	2229	18.56	37	215	5.29	2	1507	-	0
	91S	5483	565.37	327	1975	149.06	90	317	0.10	1
	91F	3005	263.31	328	668	40.91	33	1160	0.13	1
	92W	1909	106.71	241	97	5.65	7	2163	90.36	73
Block 2	92S	5347	323.07	228	2073	195.26	131	711	34.02	26
	92F	3718	163.77	200	579	35.11	35	2889	60.02	50
	93W	2187	87.83	226	100	1.35	5	1261	43.71	63
Block 3	93S	7982	24.28	9	1769	160.78	121	1115	19.95	16
	93F	5434	215.90	191	225	10.33	13	1527	61.08	54

1 Southern Gulf of Maine = Stat. Areas 513, 514, 515; Northern Gulf of Maine = Stat. Areas 511, 512; South of Cape Cod = Stat. Areas 537, 538, 539

2 Seasons: W = winter, January - May; S = summer, June- August; F = fall, September - December

least in some time periods. This is consistent with the possibility that porpoises may fall out of the net before reaching the boat, and therefore are not be seen.

To confirm this possibility, we checked the written comments of on-watch observers, which show whether or not a porpoise reached the deck. In 1992 and 1993, there were 57 incidents of porpoise bycatch during on-watches. In the 36 cases where a comment was made, 21 (58%) indicate fallout. This cannot be taken as a direct estimate of the percentage fallout, because the rate may have been different in the other 21 hauls on which no comments were made. Nevertheless, these comments indicate considerable opportunity for off-watches to under-record bycatch because of missed fallout. A figure of 50% porpoise fallout compared to 50% reaching the boat has been reported in a study of a European sink gillnet fishery (N. Tregenza, personal communication).[1]

To allow for this off-watch effect, which depends largely on the observers and their instructions, the period 1990-1994 can be broken into blocks. The boundaries of the blocks should coincide with observer training and/or recruitment, and with big changes in relative on-off watch BPH in Table 1a. Accordingly, we used the three blocks shown in Table 1: pre-summer 1992, summer 1992 through winter 1993, and summer/fall 1993. We considered various alternative arrangements of blocks, but the eventual bycatch estimates were not greatly affected.

In summer and fall 1993, there is no evidence that on-watch BPH exceeds off-watch BPH. Before summer 1992, there is some evidence, but it is not definitive. However, for the summer 1992 through winter 1993 block, there is only about a 1 in 100 chance that sampling variation alone could produce the discrepancy between on-watch and off-watch BPH shown in Table 1. Together with the observers' fallout comments, this clearly indicates that the amount of bycatch missed in off-watches is sometimes substantial.

One way to allow for off-watch problems would be to discard the off-watch data altogether: we would then estimate BPH by dividing total bycatch in on-watches by the number of on-watch hauls. This procedure is unbiased; in other words, it will on average give the "right" answer whether or not there is a real on-off watch discrepancy. However, it is also wasteful, because it completely ignores a lot of data that was costly to collect and that can still be useful. There is a better approach.

Within each of the three time blocks in Table 1, the ratio of on- to off-watch BPH is fairly constant across the different strata. We can

1 Nick Tregenza, Cornwall Trust for Nature Conservation, Allet, Truro, Conrwall, U. K.

therefore estimate a single overall ratio, called the off-watch efficiency, to use for all the strata in the block. If this estimate turns out to be 0.73, then the data are suggesting that observers in off-watches on average record only 73% of the real harbor porpoise bycatch during the time block in question. (We have assumed that observers in on-watches do not miss any gillnet-related deaths).

We used a standard statistical technique ("maximum likelihood") to get the best estimates of off-watch efficiency. The details are beyond the scope of this document, but in simplified cases the estimate produced is intuitively sensible. For instance, if the number of off-watches equalled the number of on-watches in every stratum, then the maximum likelihood estimate of off-watch efficiency would just be:

$$\frac{(\text{total OffWB})}{(\text{total OnWB})} \qquad (2)$$

where: OffWB = off-watch bycatch and
OnWB = On-watch bycatch

In reality, the numbers of off- and on-watches are rarely exactly equal, and more analysis is needed to get the best estimate of off-watch efficiency.

It would be unrealistic to suggest that off-watches can be systematically more efficient than on-watches at observing bycatch; in other words, true off-watch efficiency can never be more than 1. However, due to sampling variability, the estimated off-watch efficiency may sometimes happen to exceed 1. If so, we make the estimate exactly equal to 1. Apart from this common-sense constraint, the model makes no prior assumption about off-watch efficiency; the estimate is determined purely by what the data show, and if there is no apparent difference between off-watch and on-watch rates (i.e. if estimated off-watch efficiency is 1, as in summer and fall 1993), then the model will treat data from all watches the same.

Once we have an estimate of off-watch efficiency (limited to a maximum of 1, if necessary), the maximum likelihood BPH estimate in a stratum is just:

$$\frac{(\text{total bycatch})}{(\text{total OnWH} + \text{OffWE X total OffWH})} \qquad (3)$$

Where: OnWH = On-watch hauls;
OffWE = Off-watch efficiency; and
OffWH = Off-watch hauls

This is a sensible estimate, as the following extreme examples show. If the estimated off-watch efficiency is 1, then the BPH estimate is just total bycatch divided by total hauls. If the estimated off-watch efficiency is 0 (*i.e.* if no bycatch was seen during any off-watch), then the BPH estimate is total on-watch bycatch divided by total on-watch hauls.

PRECISION OF THE ESTIMATES

Sampling coverage is between 5 and 10% of trips or landings in most strata. While this is enough to estimate BPH, there is inevitable uncertainty in the estimates. We can also use the data to say how large this uncertainty is likely to be. For each stratum, we can produce an approximate 95% confidence interval; that is, a pair of numbers such that there is about a 1 in 20 chance of the true bycatch for the stratum being outside the interval. The NEFSC's current harbor porpoise assessment work is based on the estimates, not on confidence intervals. However, the upper confidence limit might be used by managers to build a safety margin in some situations (PBR Workshop 1994).

To find confidence intervals, we used a standard statistical technique called bootstrapping. The details don't belong here, but the basic idea is simple: just as the average in the sample should be similar to the average in the stratum, so the average variability in the sample should be similar to the average variability in the stratum. Bootstrapping entails repeatedly simulating alternative possible samples based on the original set of samples, re-estimating total bycatch (and off-watch efficiency, total effort, *etc.*) for each alternative sample, and setting the 95% confidence interval so it contains the middle 95% of the re-estimates.

Bootstrapping has many advantages over the formulas used in previous reports to get approximate 95% confidence intervals. Its results are determined almost entirely by the data, rather than by what assumptions are made about the data. It is more accurate, because it avoids the approximations that are necessary to get such formulas, and it automatically adjusts for unanticipated "quirks" in the data such as correlation (if any) between fish catch and porpoise. Also, bootstrapping makes it easier to find accurate confidence intervals for combined strata (such as for annual totals), and automatically gives confidence intervals for other quantities of interest such as off-watch efficiency.

Table 2. Revised harbor porpoise bycatch estimates, with measures of uncertainty. Numbers have been rounded to the nearest hundred.

Year	Estimate	95% Confidence Interval Bounds		CV
		Lower	Upper	
1990	2900	1500	5500	32
1991	2000	1000	3800	35
1992	1200	800	1700	21
1993	1400	1000	2000	18

ESTIMATING TOTAL BYCATCH

We applied these methods to the data in Table 1, to get the estimates of total bycatch shown in Table 2. These estimates are 20 to 30% higher than NEFSC's previous estimates, depending on the year. The increase would be less for 1993 (for which no prior estimate is available), because off-watches seem to have been as efficient as on-watches in the second half of that year. The increases are a direct result of allowing for possible missed bycatch in off-watches. As a check, we also tried using just the on-watch data to produce estimates. The average increase over previous estimates by the NEFSC is similar to that indicated by the data in Table 2; the uncertainty in the estimates is higher, however, which is to be expected given the loss of data.

The table also presents confidence intervals and coefficients of variation (CVs); this is another measure of uncertainty calculated by bootstrapping, and is useful for comparing the relative uncertainty in different years or areas. Lower CVs correspond to relatively narrower confidence intervals and more precise estimates. The higher the sampling coverage, the less uncertainty there will be (note how the CV decreases as sampling coverage increases from 1990 to 1993). Similarly, the confidence intervals move closer to the estimate. If coverage drops for any reason, the uncertainty will increase, the lower confidence limit will decrease, and the upper confidence limit will increase.

We produced estimates and confidence intervals for off-watch efficiency in the three time blocks, as follows:

Pre-summer 1992: 0.72 [0.38-1.00]
Summer 1992-winter 1993: 0.43 [0.23-0.83]
Summer and fall 1993: 1.00 [0.70-1.00]

The upper 95% confidence interval for the middle block is well below 1, emphasizing that chance alone is most unlikely to have produced an on-off watch discrepancy as large as observed.

There are several sources of bias in these estimates and confidence intervals. For instance, some dead porpoises drop out of the nets and sink before becoming visible even to on-watch observers. This means that the estimates are probably too low, but there is currently no reliable way to say by how much. The estimates presented in this document are the best given the present state of knowledge.

REFERENCES

Bisack, K. 1993. Estimates of total by-catch in the Gulf of Maine sink gillnet fishery. Woods Hole, MA: NOAA/NMFS/NEFSC. *Center Ref. Doc.* NEFSC Lab. Ref. Doc. 93-11.

Palka, D., (ed.) 1994. Results of a scientific workshop to evaluate the status of harbor porpoises, *Phocoena phocoena*, in the western North Atlantic. Woods Hole, MA: NOAA/NMFS/NEFSC. Center Ref. Doc. No. 94-09.

PBR [Potential Biological Removal] Workshop. 1994. Report of the PBR Workshop. Held June 27-29, 1994, Scripps Institution of Oceanography, La Jolla, California, convened by the National Marine Fisheries Service and the U. S. Fish and Wildlife Service.

SARC. 1992. Consensus summary of assessments. *In* Report of the Thirteenth Northeast Regional Stock assessment Workshop, p. 23-142. Woods Hole, MA: NOAA/NMFS/NEFSC. *Center Ref. Doc.* 92-02.

Smith, T., D. Palka, and K. Bisack. 1993. Biological significance of bycatch of harbor porpoise in the Gulf of Maine demersal gillnet fishery. Woods Hole, MA: NOAA/NMFS/NEFSC. Center Ref. Doc. 93-23.