Fisheries and Oceans
Science

Pêches et Océans
Sciences

C S A S

Canadian Science Advisory Secretariat

S C C S

Secrétariat canadien de consultation scientifique

Proceedings Series 2001/042

Série des compte rendus 2001/042

Proceedings of the International Harbour Porpoise Workshop

26-28 March, 2001
Bedford Institute of Oceanography
Dartmouth, Nova Scotia, Canada

Meeting Chairperson
Dr. Garry Stenson
Department of Fisheries and Oceans
P.O. Box 5667, Northwest Atlantic Fisheries Centre
St. John's, Newfoundland, Canada
A1C 5X1

December 2001

Proceedings of the International Harbour Porpoise Workshop

26-28 March, 2001
Bedford Institute of Oceanography
Dartmouth, Nova Scotia, Canada

Meeting Chairperson
Dr. Garry Stenson
Department of Fisheries and Oceans
P.O. Box 5667, Northwest Atlantic Fisheries Centre
St. John's, Newfoundland, Canada
A1C 5X1

December 2001

Table of Contents

Abstract

Serious concerns have been raised regarding the status of the harbour porpoise populations in the North Atlantic and specifically for those inhabiting Atlantic Canadian waters. In 1991 harbour porpoise in these waters were classified as "Threatened" by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Since this time, important new data have become available in some parts of their range while in others, significant data gaps continue to exist. In order to gain a clear understanding of the current state of our knowledge of harbour porpoise in Atlantic Canada, the Department of Fisheries and Oceans convened a workshop to discuss harbour porpoise in Dartmouth, Nova Scotia 26-28 March 2001. Sixteen scientists from Canada, the United States and Greenland participated. The objectives of the workshop were to 1) compile available information on the biology, abundance and by-catch of harbour porpoise in eastern Canadian waters, 2) identify gaps in our existing knowledge required to assess the status of harbour porpoise in these waters, 3) review methods for estimating harbour porpoise abundance and distribution, and 4) review methods for estimating harbour porpoise incidental mortality in fishing gear. Information on stock identity, biological parameters, abundance, distribution, ecology, by-catch, and by-catch mitigation methods were presented and discussed. It was concluded that available data on stock identity are consistent with the three putative populations (Bay of Fundy/Gulf of Maine, Gulf of St. Lawrence and Newfoundland) proposed in the 1980s, but that significant sampling gaps remain. It was agreed that data exist to construct simple population models although these models will be limited due to the absence of data on survivorship of harbour porpoise. Good estimates of abundance in the Bay of Fundy/Gulf of Maine area are available, whereas estimates of abundance in the Gulf of St. Lawrence are incomplete and non-existent in Newfoundland and Labrador waters. Obtaining estimates in these latter areas was considered to be the highest priority for research. Although diets have been examined in various areas, ecological factors affecting porpoise abundance in Atlantic Canada are unknown. Estimates of current by-catch are not available from the Gulf of St. Lawrence and Newfoundland areas; the implementation of such monitoring programs is a high priority. Monitoring programs should include a variety of methods to determine levels of by-catch and must cover all of the fisheries that may catch porpoise. A number of mitigation methods have been shown to be effective in reducing by-catch. These include the use of pingers, time-area enclosures and gear modifications. Porpoise by-catch has likely declined in a number of areas, however, due to reduced effort in gillnet fisheries.

Résumé

L'état des populations de marsouin commun de l'Atlantique Nord, en particulier celles des eaux canadiennes de l'Atlantique, est très préoccupant. En 1991, le Comité sur le statut des espèces menacées de disparition au Canada (COSEPAC) a classé le marsouin commun de ces eaux comme une espèce menacée. D'importantes nouvelles données ont été recueillies depuis dans certaines parties de l'aire de répartition de l'espèce, mais il existe encore de grandes lacunes dans les données sur les autres parties. Afin d'établir clairement l'état actuel de nos connaissances sur le marsouin commun retrouvé dans les eaux du Canada atlantique, le ministère des Pêches et des Océans a tenu un atelier de travail à cette fin à Dartmouth, en Nouvelle-Écosse, du 26 au 28 mars 2001, auquel ont participé seize scientifiques du Canada, des États-Unis et du Groenland. Les objectifs de l'atelier étaient les suivants : 1) compiler les renseignements disponibles sur la biologie et l'abondance du marsouin commun, ainsi que sur les captures accidentelles de l'espèce dans les eaux de l'est du Canada, 2) identifier les lacunes dans les connaissances actuelles nécessaires pour évaluer l'état de la population de marsouin commun de ces eaux, 3) passer en revue les méthodes d'estimation de l'abondance et de la distribution de l'espèce et 4) revoir les méthodes d'estimation de la mortalité accidentelle du marsouin commun dans les engins de pêche. De l'information sur l'identité des stocks, les paramètres biologiques, l'abondance, la distribution, l'écologie, les captures accidentelles et les méthodes de réduction des captures accidentelles a été présentée et discutée. Les participants à l'atelier ont conclu que les données disponibles sur l'identité des stocks correspondent aux trois populations hypothétiques (baie de Fundy/golfe du Maine, golfe du Saint-Laurent et Terre-Neuve) identifiées dans les années 1980, mais qu'il existe encore d'importantes lacunes dans les données. Ils ont reconnu qu'il existe suffisamment de données pour établir des modèles simples des populations, bien que l'utilité de ceux-ci sera limitée par l'absence de données sur la survie. On dispose de bonnes estimations de l'abondance de l'espèce dans la baie de Fundy et le golfe du Maine, mais aucune pour les eaux de Terre-Neuve et du Labrador, alors que celles pour le golfe du Saint-Laurent sont incomplètes. La première priorité de recherche est donc l'obtention d'estimations de l'abondance de l'espèce dans ces deux derniers secteurs. Bien que le régime alimentaire du marsouin commun dans diverses régions ait été étudié, les facteurs écologiques ayant une incidence sur l'abondance de l'espèce dans le Canada atlantique sont inconnus. Étant donné qu'aucune estimation des captures accidentelles actuelles à Terre-Neuve et dans le golfe du Saint-Laurent n'est disponible, la mise en oeuvre de programmes de surveillance de ces captures est de haute priorité. Ces programmes devraient comprendre une gamme de méthodes pour déterminer les niveaux des captures accidentelles et doivent couvrir toutes les pêches qui pouvant mener lieu à la capture de marsouins. Plusieurs méthodes se sont révélées efficaces pour ce qui est de réduire les captures accidentelles, entre autres l'utilisation d'émetteurs d'ultrasons, de fermetures de la pêche pendant une certaine période et dans certaines eaux et des modifications d'engins. Les captures accidentelles de marsouin ont probablement diminué dans certains secteurs en raison d'une réduction de l'effort de pêche aux filets maillants.

1. Opening Remarks

Garry Stenson

Serious concerns have been raised regarding the status of the harbour porpoise populations in the North Atlantic and specifically for those inhabiting Atlantic Canadian waters. Potential threats to the harbour porpoise include incidental mortality (by-catch), habitat degradation, prey depletion, illegal harvesting and climate change. Of these, the greatest concern centres on the incidental capture of harbour porpoise in gillnets, weirs and other fishing gear.

There are three putative harbour porpoise sub-populations in Atlantic Canada, i.e. the Gulf of St. Lawrence ('Gulf'), Newfoundland, and the Gulf of Maine/Bay of Fundy ('BOF/GOM'). In 1991 harbour porpoise in Atlantic Canadian waters were classified as "Threatened" by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

Considerable data are required in order to assess the status of a population and determine if a given level of removals is sustainable. A good understanding of the stock structure and seasonal movements are required to define the area being considered. Also, unbiased estimates of biological parameters are needed, preferably for each area and over time, to estimate population growth rates. Finally, quantitative estimates of removals and population size are needed on the appropriate spatial scale.
Since harbour porpoise were assessed by COSEWIC in 1991, significant new data have become available. Substantial data are now available from the BOF/GOM sub-population thanks to research by Canadian and US scientists (e.g. Read and Gaskin 1990; Read and Hohn 1995; Palka 1995a, 2000; Bisack 1997; Westgate *et al*. 1998). There are also new data on stock structure, although the samples do not cover the entire range of the species in Atlantic Canada (e.g., Gao and Gaskin 1996a,b; Westgate *et al*. 1997, Westgate and Tolley 1999; Rosel *et al*. 1995, 1999; Wang *et al*. 1996,). Less is known about the Gulf of St. Lawrence sub-population although Kingsley and Reeves (1998) recently estimated abundance. There are also limited data on the level of incidental captures of harbour porpoise in the Gulf (Fontaine *et al*. 1994) but the estimates were preliminary in nature and do not reflect current catches due to the decline in fishing the Gulf since the early 1990s. Very few data are available from porpoise found in the waters off Newfoundland and Labrador and there are no estimates of either abundance or by-catch in this area.

Given the importance of understanding the current status of harbour porpoise in Atlantic Canada and the variety of information that has been obtained since the status was last determined, it is clear that the status of harbour porpoise in Atlantic Canada should be re-examined. However, before this can be done a clear understanding of the current state of our knowledge of stock identify, biological parameters, abundance, distribution, ecology, and human induced mortality of harbour porpoise in this area is needed. Most importantly, critical gaps in our knowledge should be identified and appropriate research actions identified. With these goals, the Department of Fisheries and Oceans convened an international workshop on harbour porpoise where scientists with expertise and knowledge of harbour porpoise were invited to discuss their research, to identify gaps in knowledge and to assist in the development of a research program designed to facilitate a better understanding of the ecology of the harbour porpoise and related issues in the Canadian Atlantic Region.

The specific objectives of the workshop were:

1) Bring together current information on the biology, abundance and by-catch of harbour porpoise in eastern Canadian waters,
2) Identify gaps in our existing knowledge required to assess the status of harbour porpoise in these waters,
3) Review methods for estimating harbour porpoise abundance and distribution, and
4) Review methods for estimating harbour porpoise incidental mortality in fishing gear.

Meeting Arrangements

The workshop took place from 26-28 March, 2001 at the Bedford Institute of Oceanography in Dartmouth, Nova Scotia, Canada. A total of 16 scientists from Canada, the United States and Greenland participated. The list of participants is presented in Appendix I and the agenda is presented in Appendix II.

We wish to thank Lynn Cullen and John Loch, DFO Maritimes, for their assistance in hosting the workshop at the Bedford Institute of Oceanography.

2. Stock Identity

2.1. Harbour Porpoise Stock Structure

Patricia Rosel

Knowledge of population structure is a critical component of any management plan. To date, harbour porpoise population structure has been examined on a variety of scales using genetic data. Mitochondrial DNA sequence data have been used to examine the evolutionary relationships among porpoise populations on a global scale, within the north Atlantic, and in the NW Atlantic.

On a global scale, populations in the NE Pacific, north Atlantic and the Black Sea are significantly genetically differentiated from each other (Rosel *et al*. 1995). Not surprisingly, Black Sea and Atlantic porpoise populations are more closely related to each other than either is to the northeast Pacific.

In the north Atlantic, Gaskin (1984) proposed the existence of 14 unique harbour porpoise populations. These population designations were re-examined and modified by the IWC in 1996, leaving 13 separate populations, four in the Northwest Atlantic and nine in the NE Atlantic (IWC 1996). Two genetic studies using mitochondrial DNA sequence data have examined the degree of genetic differentiation between the northeast and Northwest Atlantic. Rosel *et al*. (1999) compared porpoises from the NW Atlantic to those from the NE Atlantic (the Baltic Sea and waters around the British Isles). This analysis revealed a significant amount of genetic differentiation between these two regions. Furthermore, porpoises in the NE Atlantic exhibited much lower levels of genetic diversity than those from the NW Atlantic suggesting that these two regions have experienced very different evolutionary histories, probably mediated by differing impacts of Pleistocene glaciations. Finally, this study indicated that porpoises from west Greenland were more similar to those from the western Atlantic than those from the eastern Atlantic, indicating that the break between the east and west Atlantic occurs to the east of west Greenland. A second study compared the genetic diversity of porpoises from the NW Atlantic to those in Iceland and Norway (Tolley *et al*. 1999). The results from this research supported the previous study. Again, genetic diversity in the NE Atlantic was lower than in the NW Atlantic. Samples from Iceland were more similar to those from the NW Atlantic than they were to the Norwegian samples, indicating that the break between the east and west Atlantic lies east of Iceland.

Within the NW Atlantic, four populations have been defined – West Greenland, Newfoundland, Gulf of St. Lawrence, and the Bay of Fundy/Gulf of Maine ('BOF/GOM'). Porpoises present during the winter months off the US mid-Atlantic states are considered to be part of the BOF/GOM population (IWC 1996). Rosel *et al*. (1999) have examined the genetic relationships among these four populations using mitochondrial DNA. An analysis of molecular variance indicated that a significant amount of genetic variation could be attributed to differences among these four populations, suggesting there is not one homogenous population of harbour porpoises in the NW Atlantic. On a pairwise basis, each pairwise population comparison revealed genetic differences that differed significantly from panmixia with the exception of the comparison of the Gulf of St. Lawrence to west Greenland. This latter result may indicate that there is genetic exchange occurring between these two populations, or that these two populations have only recently diverged from one another. In addition to mitochondrial data, these populations were also examined using nuclear microsatellite markers. These markers provide information on the contribution of both males and females to genetic exchange, whereas the mitochondrial DNA data provide information only on the female contribution to genetic exchange among populations. The microsatellite data did not reveal significant levels of genetic differentiation in the NW Atlantic, although the p–value for this analysis was "marginally significant ($P < 0.052$; Rosel *et al*. 1999). These results may indicate that male-mediated gene flow is sufficient to maintain homogeneity among the nuclear markers, while female philopatry maintains the signature of genetic differentiation in the mitochondrial DNA data. Alternatively, the microsatellite data may not be sensitive enough to detect differentiation, although with their high mutation rate and high level of polymorphism, they should be sufficiently sensitive to detect such differences.

The mitochondrial data were also used to examine the question of whether harbour porpoises present in the mid-Atlantic states during the winter could be attributed to any one summer breeding population (particularly the GOM/BOF population). A mixed-stock analysis using a conditional maximum likelihood framework was performed to examine this question (Rosel *et al*. 1999). Haplotype frequencies in the GOM/BOF differed significantly from the mid-Atlantic states sample; data for the three remaining populations did not indicate that the GOM/BOF Fundy population could account for all the mid-Atlantic sample alone. The conditional maximum likelihood analysis also indicated that the mid-Atlantic sample does not arise solely from the Gulf of Maine/Bay of Fundy, but rather is likely a mixture of the summer populations. Frequency differences between the summer populations were not significantly different from one another to accurately determine the relative contributions of each summer population to the winter aggregation.

Several questions remain and improvements may be made to the mixed-stock analysis. Do the summer samples provide accurate estimates of the haplotype frequencies in each region? For some populations, samples were collected from a restricted area and in only one year. Larger sample sizes from these areas may provide better estimates of haplotype frequencies. Second, have we sampled all potential sources of the winter animals? Eight haplotypes unique to the mid-Atlantic sample were found. What is the source of these animals? Third, most mid-Atlantic samples used were of stranded juvenile animals. Do they represent the wintering "population" as a whole? Finally, can we increase informational content available, thereby increasing the power of the mixed-stock analysis, by combining the mitochondrial DNA and microsatellite data?

2.2. Summary/Conclusions

- ❖ Available data on the stock identity of porpoise in Atlantic Canada are consistent with Gaskin's putative populations (Gulf of St. Lawrence, Newfoundland and Bay of Fundy/Gulf of Maine).
- ❖ Sampling gaps exist, especially in Newfoundland, Gulf of St. Lawrence, and Nova Scotia waters.
- ❖ Harbour porpoise from all three populations may be incidentally captured in fishing gear during the winter fisheries that occur in the US mid-Atlantic states.

3. Biological Parameters

3.1. Biological Factors Associated with the By-catch of Harbour Porpoise in Washington

Patrick Gearin

A co-operative study based on an agreement between the National Marine Fisheries Service and the Makah Indian Tribe was conducted during 1988-90 to assess the nature and magnitude of harbour porpoise (*Phocoena phocoena*) interactions in the Northern Washington Marine set-net fishery (Gearin *et al*. 1994). The fishery operates annually along the northern coast of Washington State (U.S.) in the north Pacific Ocean and in the western Strait of Juan de Fuca from 1 May to 15 September. The fishery targets on chinook salmon (*Oncorhynchus tshawytscha*) using submerged gillnets up to 100 fathoms (183 m) long. An observer program was conducted during the 1988-90 seasons and fishing effort was estimated.

One-hundred and thirty-eight harbour porpoises were observed or reported taken incidentally during the 3 years of which 100 were collected and necropsied. Harbour porpoise were primarily taken during a one month period from mid-July to mid-August at the Spike Rock fishing grounds in the Pacific Ocean. The number of harbour porpoise observed or reported taken in the fishery declined dramatically during 1989 and 1990 due to low fishing effort.

The sex of harbour porpoise collected was 55 males and 45 females. One-hundred porpoise were aged and reproductive condition was determined for 99 individuals. The maximum estimated age (based on growth layer groups within the dentine of teeth) was age 5 yr for females and age 8 yr for males. Fifty-four percent of the porpoise which were aged were 1 and 2-year-olds. A majority (62.6%) of the 99 animals examined were reproductively immature. Males were reproductively mature at age 4 yr with a body length of approximately 132 cm. Females were reproductively mature at age 3 yr with a body length of approximately 153 cm.

The principal prey of both harbour porpoise and chinook salmon were Pacific herring (*Clupea harengus pallasi*), market squid (*Loligo opalescens*), and smelt (Family Osmeridae).

The observations of the fishery from 1988-90 demonstrate that the interactions between harbour porpoise and the fishery were limited to a small area and time span relative to the total area and time fished. Harbour porpoise were taken almost exclusively at the Spike Rock fishing grounds, which was a small fraction of the overall fishing grounds. One hundred and thirty-four of 138 harbour porpoise reported or observed taken were caught at Spike Rock. The catch of harbour porpoise appeared to be confined to a small portion of the fishing season, primarily during a 1 month period from mid-July to mid-August. One hundred and ten of 138 (80%) of the porpoise taken from 1988-90 were caught between 14 July and 13 August.

The evaluation of harbour porpoise and chinook salmon stomach contents indicate that both species were actively foraging in the Spike Rock area. The similarity of prey items indicate that harbour porpoise and chinook salmon are ecological counterparts in this region and their foraging behaviour was similar. Harbour porpoise may have a more diverse prey base, yet for both predators Pacific herring appeared to be the principle prey. The results suggest that chinook salmon and harbour porpoise were feeding in the same areas and their reasons for frequenting the Spike Rock area may have been strongly correlated with prey availability, leaving both species susceptible to entanglement in gillnets.

3.2. Biology of Harbour Porpoises in the Bay of Fundy

Andrew Read

The harbour porpoise has been the object of intensive, seasonal study in the Bay of Fundy since 1969, when David Gaskin began his program of field research. Since that time, porpoises have been studied each summer from field stations located in the western approaches of the Bay. We now have more than three decades of accumulated scientific knowledge on this species from this area.

In the early days of this program, specimens were obtained primarily from a directed research collection (hunting). Some porpoises were also obtained as by-catch from herring weirs, a source of samples that has continued until the present. In the 1970s, most porpoises from herring weirs were examined post-mortem, but in the 1980s and 1990s most porpoises from weirs have been examined alive and released. Finally, a large sample of porpoises was obtained from by-catches in a sink gill net fishery for cod and pollock. Taken together, approximately 930 porpoises have been examined over the last three decades, although complete data are not available for every specimen. A large number of additional specimens from this population have been examined from the Gulf of Maine during other periods of the year.

We have been able to describe many aspects of the biology of the species in the Bay of Fundy from examination of these specimens. Recently, we have also begun to examine temporal (inter-decal) variation in these parameters. Here I describe, very briefly, some aspects of the biology of harbour porpoises in the Bay of Fundy that are relevant to assessment of their status.

Porpoises in the Bay of Fundy are relatively short-lived, compared to other odontocetes. Maximum longevity, as determined from examination of growth layer groups in the dentine in thin sections of decalcified teeth is 17, but a few individuals live into their second decade of life. Reproduction is extremely seasonal, with most ovulation and conception occurring in a few weeks in June. Gestation lasts for approximately 10.6 months before parturition in May. We are currently using observations of foetal size and growth to estimate conception date for this and other populations, to determine whether the timing of reproduction varies among populations. Females experience post-partum oestrus and most mature individuals become pregnant each year. Thus female porpoises in this population spend most of their mature lives simultaneously lactating and pregnant. Lactation lasts for at least eight months.

In this region, porpoises feed primarily, but not exclusively, on juvenile Atlantic herring of age classes 2, 3 and 4 yr. This primary prey item is augmented with juvenile gadids and other small demersal species. Herring stocks in the Bay of Fundy and Gulf of Maine have experienced dramatic fluctuations in abundance over the past three decades and we have recently examined the potential effects of this variation in prey biomass on the life history of harbour porpoises. The initial results of this analysis have yielded some surprising results; female porpoises produce the largest calves during the decade (1980s) when prey biomass was lowest. There have been no effects of variation in prey biomass on the condition or fecundity of mature females.

We have also been monitoring the long-term movements of individual porpoises using satellite-linked radio telemetry. To date, approximately 25 porpoises have been equipped with satellite-linked radio transmitters, resulting in periods of contact ranging from a few days to eight months. All but one of these individuals have remained in the Gulf of Maine or moved to the Mid-Atlantic States in winter. The movement patterns of individual animals are typical of those of other marine mammals – extended periods of intensive use in a particular area interspersed with fairly long, directional movements. The results of this monitoring are, in general, consistent with the hypothesis that porpoises from the Bay of Fundy and Gulf of Maine form a single population and should be managed as a single stock.

3.3. Research on Harbour Porpoise in the Gulf of St. Lawrence and St. Lawrence River estuary

Michael Hammill

In the early 1990's, sparked in part by the apparently high by-catch levels documented in the Bay of Fundy, there was interest in the potential impacts of commercial fisheries on harbour porpoises in the Gulf of St Lawrence. A questionnaire survey asking fishermen about by-catch levels was sent to 968, 731 and 2,433 fishermen in 1989, 1990 and 1994, respectively. Response rates varied from 17 to 33%. The surveys indicated an average catch of 1.5 (se=0.45) to 2.4 (se=0.88) porpoise per fishermen. Assuming that all licensed fishermen expended similar effort results in an estimate incidental catch of 2,000-3,600 animals (Fontaine *et al*. 1994). However, these results are likely biased because fishing effort by registered fishermen is not known and the data should probably be stratified to take into account regions of high or low porpoise abundance. Groundfish fisheries accounted for 80-85% of the catch, while pelagic fisheries, primarily herring, accounted for 15%. The Lower North shore and Gaspé/Baie de Chaleur regions accounted for 40% of total fish landings and 70% of the incidental catches. Most of the incidental catches (80%) occurred from June through August. Test fishing trials indicated that total fishing success was linked to total amount of net in the water. Increasing the string length did not necessarily lead to increased fish catch, but did lead to increases in incidental catches of porpoises.

Animals caught by fishermen had a greater asymptotic length (males=149.4 cm, SE=2.26, n=68; females=166.8 cm, SE=5.30, n=54) than by-caught animals from the Bay of Fundy (Read and Hohn 1995). Herring and capelin accounted for 85% of the energy contribution by diet, while redfish, mackerel, cod, and squid were also consumed. Capelin was the most important prey species among animals from the northeastern Gulf accounting for 98% of the diet (energy). Animals caught near Anticosti Island consumed similar amounts of capelin and herring, while among animals from the Gaspé region herring accounted for 70% of the diet (expressed as energy). Follow-up surveys were not completed. Owing to the large-scale failure and closures in the Atlantic groundfish fishery, incidental catches of harbour porpoises have likely declined, but this should be examined.

3.4. Growth and Reproduction of the Harbour Porpoise, *Phocoena phocoena*, in Eastern Newfoundland, Canada

Garry Stenson

Data on harbour porpoise in the waters of Newfoundland are extremely limited. In order to obtain some information on biological parameters of porpoise from this sub-population, 94 porpoises caught incidentally in fishing gear along the south-east coast of Newfoundland during the summers of 1990 and 1991 were examined. Most porpoises (56%) were ≤ 4 years of age. Maximum age was 9 yr for females and 12 yr for males. Growth rates were similar for both sexes until one year of age, after which females grew longer and weighed more than males of similar ages. Using the Gompertz growth model, asymptotic values for body length were 156.3 cm for females and 142.9 cm for males. Asymptotic weights were 61.6 kg and 49.1 kg for females and males, respectively. With the exception of west Greenland porpoise that were shorter and females from Norway that were lighter, Newfoundland porpoises could not be differentiated from animals collected in other areas based on growth data. However, differences in dental deposition patterns were noted suggesting that Newfoundland porpoise may belong to a separate population.

Reproduction characteristics of the 94 harbour porpoises were determined as well. The majority of mature females (76%) were pregnant; a high proportion were simultaneously pregnant and lactating (35%). Mean age at sexual maturity for females was 3.1 yr (SE=0.07) years which occurred at a mean length of 146.4 cm (SE=0.03). Younger females appear to have multiple ovulations or an increased proportion of luteinized follicles. Parturition occurred before sampling began in late June and ovulation and conception were estimated to occur from early to late July.

Sexual activity in males, as indicated by spermatogenic activity, was high during July, supporting estimates for the timing of ovulation and conception. On average, sexual maturity in males was estimated to occur at 3.0 yr at a length of 135.1 cm (SE=0.02). There was a dramatic increase in testes weight, testes volume, and seminiferous tubule diameter at the onset of age three.

3.5. Summary/Conclusions

- ❖ Sufficient data exist to construct simple population models.
- ❖ No data on the survivorship of harbour porpoise are available.
- ❖ Additional data can be used to monitor potential changes in biological parameters.
- ❖ Additional data on biological parameters are required but obtaining these data are of a lower priority than filling other data gaps such as abundance and by-catch estimates.
- ❖ A specimen database should be established among researchers to facilitate the co-operative use of samples and comparisons among regions.

4. Abundance and Distribution

4.1. Harbour Porpoise Abundance Surveys in the Bay of Fundy/Gulf of Maine

Debra Palka

Gaskin (1977) estimated that summer harbour porpoise abundance in the Bay of Fundy was about 4,000 animals. Kraus *et al*. (1983) estimated the summer harbour porpoise abundance in waters off Maine was about 15,300 animals. During the summers of 1991, 1992, 1995, and 1999, the National Marine Fisheries Service (NMFS) estimated the abundance of harbour porpoises in both the Bay of Fundy and Gulf of Maine was 37,500 (CV=0.29) during 1991 (Palka 1995), 67,500 (CV=0.32) during 1992 (Smith *et al*. 1993), 74,000 (CV=0.20) during 1995 (Palka 1996), and 89,700 (CV=0.22) during 1999 (Palka 2000). Part of the reason for the inter-annual differences stems from the fact that the area surveyed during the earlier years (1991 and 1992) was only a subset of the area surveyed during the latter years (1995 and 1999). In addition, in 1999, there were harbour porpoises detected in two areas that had not previously been surveyed. These two areas are: 1) north of St. John's, New Brunswick, Canada in the upper Bay of Fundy, and 2) on the southern flank of Browns Bank and northern flank of Georges Bank. In the region surveyed during all years, the abundance estimates were nearly constant during 1992 to 1999. It is not fully understood why the 1991 abundance estimate was lower than other years. Palka (1996) suggested sea surface temperature and distributions of herring and silver hake prey are part of the explanation.

Field and analytical methods used in all years were similar. The research ship *R/V Abel-J* was used to survey coastal waters of Maine and Nova Scotia, and the NOAA aircraft Twin Otter was used to survey the surrounding waters. Field collection methods are fully described in Palka (1995, 2000).

On the ship two teams of four people surveyed on two sighting platforms using the naked eye. Each team consisted of three people who were on-effort and one person at rest. Within a team, each person spent 30 min in one of three observation positions, and then rotated to the off-effort position; thus, a person worked for 1/2 hr and rested for a 1/2 hr. Both sighting platforms were on a forward mast, one on top of the other, where neither have obstacles in their view. The upper sighting platform was 14 m above the water surface, and the lower platform was 6 m below the upper platform. Observers recorded their own sightings using a palm-top computer. All cetaceans, seals, and turtle sightings were recorded, though the target species was harbour porpoise. Sightings data collected for each sighting included: estimated visual distance between the ship and initial location of the group, angle between the track line and line of sight to that group, best, high, and low estimated size of the group, species identification, swim direction of the group, best estimate of the number of calves in the group, behaviour of the group, and other comments. The time, recorded to the nearest second was automatically recorded whenever a sighting was entered. Other data collected included: time, location of the ship, ship's speed and bearing, wind speed and direction, water temperature and depth, cloud cover, direction and magnitude of glare, and location of each observer. To collect additional environmental data, the temperature, salinity, and depth was measured using a CTD that was deployed three times a day, before surveying started at 0600, at lunch break at 1200, and after surveying commenced at 1800. Also, at 1800, a bongo net was deployed to collect zooplankton.

On the aircraft, there was one team that consisted of one person observing through a port bubble window, one observing through a starboard bubble window, one through a belly window, one recorder, and one person in a rest position. People rotated through the three observation positions and the rest position. During the entire survey, only one person recorded data. This was done to increase the reliability of the data, and to relieve the stress of all five people learning how to cope with recording accurate data especially during times of high animal densities. Observing was performed with the naked eye. Binoculars were available when needed to assist in identifying the species and group size. The data-recording computer was connected to a GPS system to allow the aircraft's position to be recorded at least once per minute. Data recorded in the plane was similar to that recorded by the ship, as described above. Water temperature was measured by infrared and recorded on a computer every minute.

Abundance was estimated using standard line transect methods (Buckland *et al.* 1993). Three assumptions of the line transect methodology were discussed in detail. These are: 1) all animals are detected on the track line (e.g., g(0)=1), 2) the probability of detection is dependent only on perpendicular distance, and 3) animals do not respond to the sighting platform before the observers detect them. To estimate the shipboard g(0), the two-team data were used in the modified direct duplicate analytical method (Palka 1995), which uses the ideas developed in capture-recapture estimates. The aerial g(0) was determined by comparing the density estimated from the plane and ship when both platforms surveyed the same track lines during the same day (Palka 1996). In addition, during 1999 a new method was explored to determine if it could be used to estimate a shipboard g(0). This new method was in essence creating a new "team" of observers that was a hydrophone trailing behind the ship that automatically recorded vocalising harbour porpoises and other species, in particular, white-sided dolphins. This new method is still being investigated.

To insure the second assumption is valid, only data recorded in Beaufort sea states of three and less were used. Other analytical methods that could be used to account for effects of sea state, observer differences, and other covariates was developed by Borchers *et al*. (1998) and Cooke and Leaper (1998).
The present analyses assume harbour porpoises do not respond to the sighting platforms before the animals are detected. This assumption is probable valid for aerial data. However, it may not be so for shipboard data. If animals avoid the ship, then the abundance estimate will be negatively biased. Palka and Hammond (in press) estimated harbour porpoises from the Gulf of Maine and North Sea start avoiding the ship when they are about 1000 m from the ship. They also describe a method to account for this responsive movement in the abundance estimate. Further investigations are needed.

4.2. Harbour Porpoise in the Gulf of St. Lawrence: By-catch, Distribution, and Survey Estimate of Numbers

Michael Kingsley

Studies based on fisheries in the early 1990s indicated a by-catch of harbour porpoise in the Gulf of St Lawrence possibly of the order of a few thousand animals per year, mostly in bottom-set gillnets. To scale this problem against population size, line-transect aerial surveys were carried out in the Gulf in 1995 and 1996. In 1995 the study area comprised the entire Gulf stratified into north, central and southwestern areas. In 1996 only the northern part, corresponding roughly to the north stratum of the 1995 survey, was flown.

Aerial line-transect surveys of cetaceans were flown in the Gulf of St. Lawrence in late August and early September of 1995 and in late July and early August of 1996 (Kingsley and Reeves 1998). The timing of the surveys was intended to sample the peak season of cetacean residence in the Gulf, from the perspectives of species diversity, numerical abundance, and aggregate biomass. It was assumed that the migratory populations that enter the Gulf in summer would have largely arrived by the end of July and that their departure would not have begun until after mid-September. The interval of 25 July to 15 September was selected for the surveys.

Systematic north–south transects were spaced 15^{o} of longitude apart. In 1995, the study area comprised the entire Gulf, divided into three strata for analysis; 69% was flown. In 1996, a single stratum covered only the north shore shelf; 75% of the design was flown. The two surveys differed in geographical coverage and timing by approximately one month which makes it difficult to compare results from the two years. The best coverage was achieved in the northern Gulf of St. Lawrence.

The surveys were flown in a high-winged Cessna 337 “Skymaster,” with endurance of 7 hr, normal cruising speed of 155 knots (287 km/h), minimal continuous operating speed of 100–110 knots (185–204 km/h). Bubble windows had been installed at the two rear seating positions to improve the ability of observers to see animals near the transect line. The aircraft was flown at 213 m (700 ft)
Standard line-transect methods were used for collecting data. Two observers, one sitting on each side of the aircraft immediately behind the pilot, maintained a continuous watch and spoke into independent tape recorders.

Ten cetacean species were seen. Minke whales (*Balaenoptera acutorostrata*), Atlantic white-sided dolphins (*Lagenorhynchus acutus*), and harbour porpoises (*Phocoena phocoena*) yielded enough sightings to support good estimates, while fin whales (*Balaenoptera physalus*), humpback whales (*Megaptera novaeangliae*), white-beaked dolphins (*Lagenorhynchus albirostris*), and long-finned pilot whales (*Globicephala melas*) yielded few sightings and unreliable estimates. Blue whales (*Balaenoptera musculus*) and belugas (*Delphinapterus leucas*) were seen too rarely to support any analysis. The tenth species was a small delphinid, not positively identified.

The harbour porpoise was widely distributed throughout the Gulf and occurred in particularly high densities in portions of several strata. Harbour porpoises (12,000 in 1995 and 21,000 in 1996) were most numerous in the northern stratum, but were also widely distributed at lower densities in the central and southern Gulf.

Analyses were restricted to Beaufort 0–2. Porpoises were not seen well closer to the track-line than 150 m and visibility dropped off further than 300 m away; ESW was 277 m. Estimated surface-visible numbers were 12,100 total in 1995, of which 4,900 in the C and SW strata, and 21,700 in the north stratum alone (possibly 26,600 total) in 1996. Visibility corrections of the order of times 3 to times 5 have been estimated elsewhere, yielding estimates of the order 36,000 to 130,000 for the Gulf. The species was one of the more widely distributed cetaceans, and sightings were scattered throughout most of the Gulf, but a significant concentration area appeared to exist north and north-west of Anticosti Island.

Our abundance estimates for this species, if adjusted for bias along the lines proposed by Laake *et al.* (1998), would rival or exceed those for the Gulf of Maine–Bay of Fundy region, which has long been recognised as a major concentration area for the species (Gaskin 1992; Palka 1995; Palka 1996). The Gulf of St. Lawrence is clearly an important summering ground for harbour porpoises and therefore a promising area for more detailed research on their ecology, stock relationships, and abundance.

A programme of repeated vessel and aerial surveys in the Strait of Belle Isle approximately every three weeks from July through December 1998 gave irregular sightings of harbour porpoise: most sightings were made in one survey. Sightings were largely restricted to waters SW of a transect across Belle Isle Strait from Blanc Sablon, but the water further north-east was nearly always rough, which if it did not restrict the distribution of porpoises would probably restrict the distribution of sightings. (These surveys have not been fully analysed and thus it has not been possible to investigate the covariates that might account for the observed southern concentration of harbour porpoises.) A resulting line-transect estimate was about 3,000 if porpoises were assumed restricted to calm-water areas or about 6,000 if density was assumed to be the same in rough-water areas.

The small size and discreet behaviour of this species tend to induce a large and uncertain visibility bias to survey results. Furthermore, porpoises appear to be gregarious—large groups are occasionally sighted, and sightings in the Gulf aerial surveys were noticeably aggregated—and mobile, so it is difficult to design and execute precise surveys for them, and survey results become difficult to interpret without information on movements.

4.3. General Discussion

There was some discussion of the potential effect of rough surface water on the sightability of harbour porpoises and on the suitability of such areas as harbour porpoise habitat. There is no evidence to the latter effect, but satellite data might shed light on this. Opinions expressed suggested that surface conditions were unlikely to affect porpoise distribution. The observed patchiness in porpoise distribution is more likely to reflect overall differences in habitat.

The sighting curves differed considerably between the two types of aircraft used in the Gulf of St. Lawrence surveys. The aircraft were thought to differ mainly because the Cessna does not have on-wing engines and thus it offers better visibility; however, there may be other differences as well, including the size and shape of windows. Sighting curves can also differ because of biases associated with looking for large whales and thus missing the smaller cetacean species closer to the aircraft.

There was a question about the best way to design mixed species surveys and whether such surveys are possible. There seemed to be agreement that such surveys are possible, but that they may result in larger variances for the larger species than might otherwise be possible. However, in such mixed species surveys, observers cannot look for large whales at distance and hope to estimate the abundance of small species as well. Thus observer training is critical in that the sighting distances must be strictly followed to ensure unbiased estimates for all sizes of whales.

There was considerable speculation about the factors that might determine harbour porpoise abundance and distribution. While entertaining and useful for generating hypotheses, few conclusions could be reached.

Presently, there are no surveys for harbour porpoise in Newfoundland waters. But there is a project underway to analyse cetacean sightings from Platforms of Opportunities. However, as many of these were obtained during offshore groundfish surveys, they are unlikely to yield many harbour porpoise sightings. There are may also be opportunities to document broad-scale patterns using traditional ecological knowledge from coastal Newfoundland and Labrador.

4.4. Summary/Conclusions

- ❖ Good estimates of abundance are available for the Bay of Fundy/Gulf of Maine harbour porpoise.
- ❖ There are incomplete estimates available for Gulf of St. Lawrence harbour porpoise and data for Newfoundland are non-existent.
- ❖ Surveys can be conducted using aircraft and/or ships. The most appropriate platform will likley differ among areas and need to be identified.
- ❖ Simple survey designs will provide information on distribution and abundance of harbour porpoise but such simple surveys should be calibrated to more complex survey designs.
- ❖ Satellite telemetry will provide information on distribution required to design surveys.
- ❖ Obtaining abundance estimates for the Gulf of St. Lawrence and Newfoundland sub-populations are some of the highest priorities for research.

5. Ecology and Pollutants

5.1. Habitat dynamics, Feeding and Predation on Harbour Porpoise: Bay of Fundy/Gulf of Maine

Paul Brodie

The harbour porpoise is the smallest cetacean inhabiting north Atlantic waters. The capacity for this species to reproduce on an annual basis would suggest a relatively high turnover of energy reserves. This reproductive strategy may thus require a greater year-round proximity to a reliable food base. Therefore, their distribution and relative condition may more strongly reflect the distribution and energy density of their prey. Such a year-round association between porpoise and their prey may have been a confounding factor in previous attempts to assess population size, as well as growth and condition of individuals. To better understand harbour porpoise within the context of their habitat requires that we examine the factors that influence the seasonal distribution of porpoise, as well as the distribution of the demersal sink gillnet fishing effort.

Variation in the frequency of porpoise by-catch may be a consequence of the feeding strategies of: (1) the pelagic, mobile herring stocks *(Clupea harengus)* which are presemed to affect porpoise distribution, and (2) the demersal species such as cod *(Gadus morua)*, which are more site specific and which are the target of the sink gillnet fishery (Brodie 1995). The distribution of pelagic fish, such as herring, are dependent upon the distribution of mobile and shorter lived planktonic prey, such as *Calanus* spp. that can vary in biomass by an order of magnitude between years. The Bay of Fundy and Gulf of Maine (BOF/GOM) is greatly influenced by the surrounding land mass, both in terms of the generating and remarkable tidal dynamics as well as the influence of the land watershed: circa 165,000 km^2 being 2-3 times greater in area than the BOF/GOM. Year-to-year fluctuations in rainfall within this watershed can vary by an order of magnitude, affecting rates of river and stream outflow, and marine production. Distribution of herring is influenced by these seasonal changes, as well as the resulting landings of herring by fixed and active gear fisheries.

Demersal species, such as cod, feed predominately upon benthic prey whose distribution and density are strictly defined by the quality of bottom habitat (sand, gravel, etc). The diversity and generation times of benthic prey species, that can range up to several years, result in long term stability at these sites. The seasonal distribution of cod and the traditional fisheries for them using either fixed or active gear are therefore typically site-specific.

The opportunity for collision with gillnets by porpoise occurs when the distribution of the demersal and pelagic species overlap. The timing, and the duration, of residence by herring and associated porpoise in the vicinity of the demersal fishery are subject to seasonal changes in oceanographic features. Therefore, variability in year-to-year by-catch should be expected, as well as the site of these by-catches (Smith *et al*. 1993).

Harbour porpoise weigh circa 50 kg at maturity, and therefore never attain a size which would eliminate their susceptibility to predation by large sharks. Unlike seals, which have the capacity to haul out on land to conserve energy, give birth and nurse their young, or to seek refuge, harbour porpoise are restricted to an aquatic environment. They may therefore be the most susceptible or preferred prey of large predators of marine mammals on the eastern seaboard of North America. The harbour porpoise may have experienced varying levels of predation, depending upon the standing stock of shark predators, and loss of porpoise through such predation may have been sufficient to maintain the population at lower levels. Changes in the numbers of shark predators, as a consequence of directed shark fisheries, as well as by-catch in longline fisheries, and sport fishing for sharks might have substantially altered the level of predation upon harbour porpoise (Brodie and Beck 1983).

Whether this is a factor to consider with regard to other concentrations of harbour porpoise such as in the Gulf of St. Lawrence and off Newfoundland and Labrador is uncertain. However, the possibility that they could overwinter south from George's Bank would expose them to similar levels of predation for that part of the year.

Based on present understanding of the movements of the Bay of Fundy/Gulf of Maine porpoise, they range year-round through eastern seaboard fishing grounds, known to support stocks of sharks. Exploitation of sharks off the US east coast has been at such a level that there is now regulation of direct and indirect catches. Large coastal sharks are considered to be overutilized (FMP 1993). Thus, porpoise may have experienced predator release as shark stocks were diminished, resulting in an expanding population with a more youthful age structure.

Should there be limited exchange between the Newfoundland, Gulf of St. Lawrence and Bay of Fundy/Gulf of Maine populations, this may be reflected through a difference in the age structures. Such a difference would be a consequence of the BOF/GOM population experiencing a reduction in predation by sharks, a result of commercial shark catches and shark by-catches. By contrast, the more northerly populations may not experience such a level of predation and may therefore exhibit a different age distribution as a consequence (Brodie 1995).

5.2. Summary/Conclusions

- ❖ Although relatively little has been done to determine contaminant levels in porpoise, there are no obvious concerns about the impacts of contaminant levels on reproduction of porpoise ("no red flags")
- ❖ Data on diets in various places/seasons do exist; porpoise appear to feed primarily on small pelagic fish such a herring and capelin
- ❖ Diet data have been obtained primarily from animals obtained as by-catch in fishing gea. It is unknown if the source of these samples presents a potential of bias
- ❖ Ecological factors affecting porpoise abundance are unknown

6. Incidental Capture of Harbour Porpoise

6.1. By-catch in the U.S. Gulf of Maine and Mid-Atlantic States

Debra Palka

Harbour porpoise by-catch in gillnets in the U.S. Gulf of Maine ranged from 2,900 (CV=0.32) in 1990 to 270 (CV=0.28) in 1999 (Bravington and Bisack 1996; Bisack 1997; Rossman and Merrick 1999; Waring *et al*. 2000). By-catch in the drift and sink gillnets in U.S. mid-Atlantic waters ranged from a maximum of 572 in 1997 (CV=0.35) to a minimum of 53 in 1999 (CV=0.49) (Rossman and Merrick 1999; Waring *et al*. 2000).

Using the ratio method (Cochran 1977), total by-catch is estimated as the product of the by-catch rate and total effort of the fishing fleet. The by-catch rate was estimated as the number of harbour porpoises observed caught in gillnets divided by the amount of observed effort. Data to estimate the by-catch rates were collected from a sample of fishing trips that were observed by trained National Marine Fisheries Service personnel. Total effort was calculated from landings data, and data required in mandated fisher logbooks.

The sea sampling program collects the following data: date, home port, port landed, number of crew, weather conditions, depth, time soaked, target species, length of net, mesh count and size, twine size, net material, use of floats, net material, colour, use of lead and anchors, tons of ice used, fuel used, price of water, food, oil and bait, and damage costs, species id and number, condition of body, net animal caught in, body measurements, sex, types of samples taken, and pictures taken.

Observed trips have been divided into marine mammal and fish trips. Marine mammal trips are trips where the observer dedicates their time to watch the haul back process to detect all marine mammals that might fall out of the net before it is fully hauled into the boat. Fish trips are trips where the observer's primary task is to collect biological information on the fish landed and discarded, and so the haul back process is not directly observed. However if a marine mammal was observed during a fish trip, then marine mammal biological data are also collected. Before 1994, approximately half of the observed trips were fish trips and the by-catch rate from these trips was lower than the by-catch rate of marine mammal trips. To account for this fact a weighted by-catch rate was estimated (Bravington and Bisack 1996). To avoid this problem, after 1994, most (80-90%) of the observed hauls were dedicated marine mammal trips, and fish trips were not used in the by-catch estimate.

In the time span of the observer program (1990-present), both proportional and optimal allocation schemes were used to schedule the number of trips to be observed in a particular time and port (Bisack 1999). Proportional allocation means the number of trips to be observed in a month/port was proportional to the total fishing effort from that port during previous years. In contrast, optimal allocation attempts to minimise the variance of the by-catch estimate given previous spatial-temporal patterns of effort and by-catch rates of the various species that by-catch will be estimated for. For example, during summers in waters off New Hampshire there is a lot of fishing and very few porpoises in the water. So for this time/area, a proportional allocation scheme would schedule many observed trips while an optimal allocation scheme would schedule nearly none. At present, because of marine mammal take reduction plans and fish management plans that are simultaneously being implemented, the spatial patterns of fishing effort are not very predictable. Thus, optimal allocation is not practical and could result in by-catch estimates that are more imprecise than if proportional allocation had been used.

Another issue that is used to determine the number of scheduled trips in a year is the desired level of uncertainty of the by-catch estimate. There is an exponential relationship between the expected coefficient of variation (CV) of the by-catch estimate and the number of observed trips (Bisack 1999). The strategy used in US fisheries was to schedule the least number of trips that were in the flat part of the exponential relationship that resulted in low CVs (<0.3). Another way to express this relationship is that the expected probability of observing a given number of mortalities is dependent on the true by-catch and sample size of the observer program (Smith 1999; Wade 1999). It is the goal of the observer program to observe enough trips to have confidence to observe a take if they occur. Using this relationship, it was found that in the mid-Atlantic coastal gillnet fisheries, if the true total by-catch was >150 animals, then 2% coverage was sufficient to observe one or more porpoises, with 95% confidence. However, if true total by-catch were only 50 animals, then observer coverage would have to be increased to 6% to observe one or more porpoises, with 95% confidence.

For by-catch estimates in US gillnet fisheries, it was necessary to assume the unit of effort is amount of fish landed. Though, many variables were collected in the sea sampling program that could have been a proxy for effort (e.g., net-days, km-hr, or number of hauls), it has not been possible to estimate total effort of the entire fishery using any of these other variables. An inappropriate unit of effort could bias the estimate of by-catch because one of the assumptions of the ratio method is there is a linear relationship between the number of porpoises caught per haul and effort per haul. To test the validity of this assumption for two units of effort the sea sampling data collected in the Gulf of Maine from 1994 to 1999 were investigated. It was demonstrated that as the number of porpoises caught in a string increased, the median km-hr also increased, while the median tons of landed fish decreased. To investigate the effect of these two units of effort on the level of bias and precision of the estimated by-catch a simulation was conducted. It was found that the by-catch estimates that resulted when km-hr was the unit of effort was less bias and more precise than when tons landed were used. However, the difference was insignificant. This conclusion is only true because of the range of harbour porpoise by-catch rates and fishing practices that were typically used. Theoretically, if discarding fish increased greatly in only some areas and times or for only some species, then landings would not be representative as a unit of effort and then the estimated by-catch could be seriously biased.

6.2. Breaching the By-catch: Problems and Porpoises in the North Sea

Kaija Metuzals

The BYCARE program in the North Sea was carried out in 1996-1999 to estimate marine mammal by-catch in a number of selected European Union (EU) fisheries: it was a collaborative effort between the Sea Mammal Research Unit of the University of St. Andrews, (UK), the Centre for Coastal and Marine Sciences, Plymouth (UK), the University of Warwick (UK), the University of Cork (Ireland), the Danish Institute for Fisheries Research and Stockholm University (Sweden). The objective was to develop by-catch methodologies and at the same time to assess the ecological importance of these by-catches.

I describe only one aspect of this study, that of the by-catch of harbour porpoise in the Grimsby, UK fleet and make a comparison with the Danish fleet. The complete data obtained from the observer programmes, pinger experiments, and genetic studies, among others, is summarised in Harwood (1999).

The Grimsby fleet is composed of about 12 gillnet vessels that set groundfish nets on wrecks. The wrecks act as attractors for bottom-dwelling fish such as cod, and this type of fishing is called wreck netting. I used a combination of methods: 1) a retrospective analysis of fisheries data (landings and effort), 2) an analysis of environmental parameters, and 3) interviews with skippers.

A retrospective analysis of 15 years of fisheries data was made whereby individual vessel landings were plotted on ICES rectangles to identify the fishing pattern. In this way it was thought possible to describe the fisheries and to locate areas of high risk of by-catch. Risk analysis was also carried out. Furthermore, average fishing effort in trips per year was analysed. It was seen that the effort almost doubled from 1985 to the early 1990s. In addition, cluster analysis separated the early years from the later years. Both the average effort and the total area searched by the fleet increased over the years. However, the most densely fished ICES rectangle per year showed a high degree of consistency. It was evident that this area was located near a front. Using a 3-D model, the formation of a springtime front separating the North Sea into two parts and remaining in place until September was identified. Frontal parameters may be important to fishing and consequently to porpoise distribution.

Data from in-depth interviews with fishermen also provided by-catch estimates. Since the data were obtained as by-catch per trip, fishing data (average number of trips) plus data from observer programs were combined. Then, using a simple ratio method, the total number of porpoises caught by the fleet was estimated. The estimate was 95 to 202 for 1997-98. Estimates for the Danish fleet from interviews for

1998 ranged from 3,500 to 4,500. The estimate of 4,629 reported by Vinther (1994, 1995) for 1993 matched the upper level of the range. From these studies it was concluded that interviews may provide a cost-effective way to obtain initial estimates of by-catch (McGlade and Metuzals 1999).
If these estimates are now scaled up to observer reports and applied to the population estimate of porpoises obtained from the SCANS survey (Hammond *et al*. 1995) it can be seen that the total by-catch is greater than 2% of the population.

6.3. Incidental By-catch of Harbour Porpoise in Newfoundland and Labrador - As We Know It

Jon Lien

There have been only limited efforts to understand the extent of harbour porpoise (*Phocoena phocoena*) by-catch in fixed, inshore fishing gear in Newfoundland and Labrador between 1979 and 2000. Prior to and during this period there was little concern by fishermen about incidental catches of this species and minimal, sporadic interest by responsible government agencies in the nature or extent of the catch.

It was clear that harbour porpoise by-catch, especially in gillnet fisheries, was common to even a casual observer of the inshore fishery during the 1970s and 1980s. "Puffin pigs" were typically used for food, caused minimal net damage when caught, and were perceived to be plentiful. These factors were responsible for the lack of interest in studying the nature of the by-catch, or its possible conservation impacts. Resources for studies of this by-catch were lacking and compounded by the difficulty of studying up to 27,000 fishermen over 17,000 km of coastline.

Early History:

During the period from 1972-1976 morphometric data on some incidentally caught harbour porpoise were collected by fishery observers (Hood 2001). In 1979 a systematic programme which involved fishermen in reporting gear damages due the by-catch of large whales and sharks, and in reporting entrapments of whales, sharks and turtles, was initiated by Memorial University of Newfoundland in co-operation with the Newfoundland and Labrador Department of Fisheries, the "Fishermen's Union" (FFAAW), and the Department of Fisheries and Oceans (DFO). Few reports of harbour porpoise by-catch were initially submitted by fishermen (Lien 1980) but it was clear, during interviews with them to check on reliability of their by-catch reports, that large numbers of porpoise were being caught.

As our interest in porpoise by-catch was expressed to fishermen, harbour porpoise began to appear in by-catch reported to the monitoring programme by 1981 (Lien and Aldrich 1982). These reports were believed to represent a tiny fraction of actual catches. Reporting of harbour porpoise by-catch to this programme has remained low (N=3-12 per year) in relation to the level of catches we suspect, and has remained consistently low throughout the period the programme has operated. Nothing, however, has contradicted suspicions of higher than reported catches. For example, when a market (for research access) developed briefly which paid $20 for a harbour porpoise, in one community 11 animals were landed in two days (Lien *et al.* 1987).

Early summaries of harbour porpoise by-catch include Piatt and Nettleship (1987), Lien *et al.* (1988), and Lien (1989). Piatt and Nettleship (1987) sampled only in the region of four seabird colonies but estimated between 112-168 porpoise were captured each year, primarily in groundfish gillnets. Lien

(1989) indicated that by-catch could be as high as 3,000 porpoise per year but indicated that 1,800 was a more likely number. Lien (1989) and Lien *et al*. (1988) repeat the estimate of 1,800, taken primarily in gillnets. Some areas of high by-catch were identified, such as St. Mary's Bay and the Fogo Island area, but information on seasonality of catches has been difficult to obtain due to poorly-quantified fishing effort.

Several surveys have attempted to produce more information on harbour porpoise by-catch.

A 1980 Logbook Study:

In 1980 a log book programme was established to determine the extent of harbour porpoise by-catch. A total of 100 fishermen were selected from a larger group of fishermen who participated in a gear monitoring experiment during 1979. Selection was based on past co-operation with monitoring programmes and their willingness to report on harbour porpoise catches.

Prior to the fishing season, fishermen were contacted, either in person or by phone, and given logbooks in which to record by-catch data. During these contacts, data on their fishing gear, the amounts of gear and their plans for the fishing season were discussed. During the summer attempts were made to contact fishermen weekly. All of the fishermen were called successfully at least once during the fishing season after the initial contact; most were reached several times; some regularly. During phone contacts they were asked about fishing successes, small cetacean by-catch and urged to regularly record by-catch. Near the end of the fishing season (late August and September) the fishermen were again contacted, primarily by phone. All fishermen co-operated in providing data and discussing it.

Fishermen in the sample used a total of 1,755 50 ftm. groundfish gillnets, 190 cod traps and 794 50 ftm salmon nets during the 1980 fishing season. It proved impossible to calculate accurately the number of fishing days for gillnets as they were hauled, removed for repair, mated to other strings and moved frequently. Reasonably accurate days of effort could be estimated for cod traps. A total of 243 harbour porpoise and 15 white-sided dolphin (*Lagenorhychus acutus*) or white-beaked dolphin (*Lagenorhychus albirostris*) were reported taken. Virtually all animals were caught in gillnets.

Most fishermen (77%) reported they had no catches. Of the 23% who did catch porpoise, most reported catching only one animal during the monitored period. Four fishermen reported extremely large catches of 25, 29, 41, and 112 porpoise. These individuals all fished in St. Mary's Bay. All four of these fishermen were re-interviewed about their catches. The numbers reported by the first three individuals appeared to be credible and it was clear that they caught porpoise regularly in large numbers. The catches reported by the fourth fishermen could not be verified as the numbers he reported during conversations varied.

In checking the data of the four fishermen reporting high numbers of catches we conducted phone interviews of 20 additional fishermen in St. Mary's Bay that fished in adjacent areas. All reported frequent catches of porpoise but none in numbers near the four fishermen in our initial sample. Mean catches by these fishermen was 0.70 porpoise per enterprise during the season. St. Mary's Bay does appear to have higher than average (about 2 - 3 times higher) harbour porpoise by-catch but because of the extreme variations, the data of these four fishermen was used only to indicate they caught at least one porpoise.

A total of 36 harbour porpoise were reported caught by the initial sample of 100 fishermen. Most were caught in groundfish gillnets (88%) but a few were taken in salmon gillnets (8%) or cod traps (4%).

Extrapolating the percentage of fishermen who caught porpoise to all fishing enterprises in Newfoundland and Labrador resulted in an estimate of 1,368 harbour porpoises caught. Using total catches reported results in an estimate of 2,242 porpoise caught.

1990 Survey of Cetacean By-catch:

A total of 350 fishermen randomly selected from a list of chairmen of local fishermen's committees from all regions around Newfoundland and Labrador were selected to be contacted by phone in May, 1990, and interviewed about their cetacean by-catch during the 1989 fishing season. The sample was stratified based on the total number of fishermen in each fishing area of the province. Local fishermen's committee chairmen are typically among the 'best' fishermen. They do much of the local organising of fishery-related activities, and are accustomed to providing information to scientists and fishery officials.

Fishermen were assigned randomly to one of four experienced interviewers (two male; two female). Two interviewers were fishermen; two were fishery technicians; two were male, two female. Each interviewer identified himself/herself as calling on behalf of either a government fishery agency or a university department (Science Branch, DFO or Whale Research Group, MUN). A maximum of six attempts were made to reach an individual selected in the initial sample before interview efforts were discontinued. A report on the methodology of this sample can be found in Lien *et al*. (1994)

During the phone interview each fisherman was asked to describe the type of gear he used in 1989. Questions on fish catches, and incidental catches of cetaceans, pinnipeds, birds, sharks and turtles were repeated for each type of gear that the fishermen used. When by-catch was reported, questioning continued until the interviewer was satisfied with identification of the animal. During the interview fishermen were asked if they would be willing to continue reporting by-catch in the future. Based on their response, and their behaviour during the interview, the interviewer rated their "co-operativeness" on a three-point scale ("uncooperative; helpful; very helpful").

Some results from this study have been reported previously (Lien *et al*. 1994). Only 235 (67%) of the original sample were successfully reached by phone. Of those contacted 81.6% were rated as "very helpful"; 17.0% were rated as "helpful". Only three individuals were "uncooperative". A total of 62.6% of the fishermen contacted used groundfish gillnets, 22.6% of them used salmon gillnets and 35.3% used lumpfish gillnets. There was some variation in the type of fishing between marine regions but, as interview numbers were low, differences between regions were not analysed.

In total, 46 porpoise were reported caught. A total of 33 (72%) were caught in groundfish gillnets by 147 fishermen using them. Nine harbour porpoise were caught in salmon gillnets used by 53 fishermen. Four porpoise were reported as by-catch in lumpfish nets used by 83 fishermen. No small cetaceans were taken in bait nets, cod traps, capelin traps, squid traps, trawls or handlines. Effort with all these types of gear were reported as relatively minimal, except for cod traps.

Extrapolating from the present sample using catch/fishing enterprise to all fishing enterprises in Newfoundland and Labrador (N=9,876) produces a by-catch estimate of 1,931 porpoise in 1989. However, only 13.2% of fishermen reported catching a porpoise or harbour porpoise and virtually all caught only one. If all fishing enterprises similarly caught porpoise a total 1,304 porpoise were estimated to have been caught. Variation between fishermen in numbers of dolphins reported caught was greater than that in numbers of porpoise by-caught. While most fishermen reported catching only one animal, several men reported catching many.

Several points should be raised in evaluating the estimates made in this study. The first is that because chairmen of committees are generally the most successful fishermen, they may not be a representative sample of all fishermen. They were selected as we believed they would provide accurate data, but they may fish harder, more successfully, in best berths, etc. During the late l980's it became obvious that groundfish stocks, especially inshore, were becoming depleted. Inshore fishermen responded to depletion with greater fishing effort (Lien *et al.* 1994). The increase in effort resulted in a greater number of large whale entrapments (Lien 1994). There is no good documentation on the magnitude of inshore fishing effort in the province during this period, but in 1989 the amount of inshore fishing gear used by fishermen was at its peak.

We re-called 25 fishermen that participated in this phone survey. In the second call a different interviewer talked with the fishermen and requested the same information as during the first call. A total of 16 out of 25 fishermen changed their numbers on the second call, usually in the numbers of seals or seabirds they caught. Only 8.2% of fishermen changed numbers of small cetaceans caught if their by-catch was between 0–2 animals. However, 84.6% of fishermen that reported catches of three or more animals changed their estimates on the second call; 52.6% of these increased estimates while 47.4% lowered estimates.

1990 Evaluation of Motivation to Report:

A total of 54 fishermen were called in 1990 after fishing had begun and asked to call when they caught a harbour porpoise. Most were from St. Mary's Bay or the Southern Shore of the Avalon Peninsula. The fishermen were promised no payment (N=18), $10 (N=18), or $25 (N=18) for a reported porpoise. Each carcass reported was collected.

The fishermen reported a total of 10 porpoise taken prior to being called. There were no differences between groups in porpoise caught before a market was offered for carcasses. A total of eight porpoise were taken after contact and were collected; two from the 18 fishermen paid nothing; one from the fishermen paid $10; and five from fishermen paid $25. The total catch of 18 animals from 54 fishing enterprises (.33 animals per enterprise) is similar to that in the 1980 survey (0.36 animals per enterprise). All animals were captured in groundfish or lumpfish gillnets. These results, while inconclusive, suggest continued under-reporting of porpoise by-catch.

1990 Logbook Survey:

In 1990 45 fishermen who had participated in past gear monitoring and interviews were contacted and provided with log books to record their fishing activities. Included in the log books were daily questions about by-catch. Of this sample 31.8% reported by-catch of small cetaceans. The mean catch of small cetaceans during the 1990 fishing season was 0.48 animals per enterprise. Extrapolating to all fishing enterprises would estimate between 2,852-4,416 porpoise caught.

1992 Phone By-catch Survey:

Fishermen who participated co-operatively in the 1990 survey, and several volunteer fishermen, were called early in 1992 to discuss their 1991 by-catch of cetaceans, seals, turtles, seabirds and sharks. A total of 242 fishermen were successfully interviewed. Of these 144 (60%) used groundfish gillnets, 77 (31%) used lumpfish nets, 114 (47%) used cod traps.

A total of 101 large whale collisions (not necessarily entrapments) were reported, 98 dolphins were captured and 74 porpoise were taken by the fishermen interviewed. Extrapolating to the total fishery enterprises would estimate that some 550 enterprises caught large whales in groundfish gillnets involving 725 collisions/entrapments. An estimated 70 enterprises caught large whales with lumpfish nets. Some 2,249 fishing enterprises reported codtrap collisions/entrapments. There were an estimated 2,260 such incidents with codtraps. Estimates of dolphins taken as by-catch are high due to several fishermen who reported extremely large catches. Most dolphins are taken in groundfish gillnets. Most harbour porpoise by-catch occurred in groundfish gillnets. An estimated 548 fishing enterprises caught an average of four porpoise for an estimated total catch of 2,283 animals.

Summary of Present Porpoise By-catch Data:

Asking fishermen for numbers of animals incidentally captured and adding them up does not necessarily make good estimates. Fishermen count in non-linear scales when making such estimates and may be motivated to withhold or exaggerate information. Those individuals reporting substantial catches, primarily of seabirds or seals, frequently change the exact numbers they provide (Lien *et al*. 1994). As the only estimates of harbour porpoise by-catch for Newfoundland and Labrador were volunteered by fishermen, they must be regarded with caution. The fishermen were carefully selected and a majority have worked with the Whale Research Group for years. What data consistently suggest is that harbour porpoises catches occur primarily in groundfish gillnets and that, in past decades, they were very common. They may be useful for some historical considerations but, because of greatly changed effort and fishery practices, likely are not relevant to the present inshore fishery.

Post Groundfish Moratorium By-catch:

The moratorium of 2J3KL cod was initiated in 1992; other groundfish closures soon followed (FRCC 1993). Reduced groundfish quotas dramatically changed fishing patterns, effort and practices and resulted in increased fishing effort on other stocks such as lumpfish, lobsters and invertebrate resources.

Management changes, such as individual quotas, have shifted much fishing effort seasonally. Understanding the nature and extent of by-catch during the speed and magnitude of these changes is virtually impossible. Because of reduced fishing effort, and post-moratoria fishery management, it is clear that by-catch of porpoise has been dramatically reduced. That appears to have had beneficial effects on the porpoise population as now we much more commonly sight harbour porpoise, perhaps indicating some recovery in numbers.

The constriction of fishing and attendant changes in fishery practices has presented new opportunities for the systematic monitoring of by-catch. Sentinel fisheries, in which fishermen fish specified amounts of gear for specific periods and in set locations, provide a perfect means to monitor by-catch. Although we have been unsuccessful thus far in getting the Sentinel programme to record by-catch, the opportunity it represents should be vigorously pursued. Sentinel fishers that do report by-catch to us indicate very high catches of porpoise in recent years, much higher than before the moratoria. This may indicate some recovery of the porpoise population. Extending catches by Sentinel fishers to all fishing effort is now possible. As commercial fishing for both groundfish and lumpfish are now more closely managed and controlled, reasonably accurate estimates of inshore effort are possible.

Continuation of low groundfish quotas, reduced fishing effort, and management changes that shift fishing effort seasonally will persist for some time to come. Hence, reduced by-catch pressure on porpoise populations will continue. In addition, recent indications by both the Newfoundland and Labrador Department of Fisheries and the Fisheries Resources Conservation Council (2001) challenge the use of gillnets to harvest groundfish quotas. Both groups have voiced strong pressure to abandon this technology.

Recommendations Regarding By-catch Monitoring in Newfoundland and Labrador:

a) Develop an integrated by-catch monitoring programme for large and small cetaceans, seals, turtles and seabirds. A requirement for any modern fishery should be to routinely assess total removals and their environmental impact,

b) Use opportunities for by-catch monitoring presented by the Sentinel Fisheries Programme and the Observers Programme. There are no excuses for not fully using these opportunities to understand the impact of fisheries,

c) Work with managers and Statistics Branch to develop adequate estimates of total fishing effort by gear type, and

d) Awareness/education programmes on by-catch and implementation of responsible fishing practices are necessary for fishery managers.

6.4. By-catch Estimates in Three Gillnet Fisheries of the Northwest Atlantic

Catherine Hood

In order to obtain information on the incidental capture of harbour porpoise in the western North Atlantic, research was conducted in three fishing regions (St. Bride's, Newfoundland during the summer of 1993, Jeffreys Ledge in the Gulf of Maine during the fall of 1993 and Grand Manan Island in the Bay of Fundy during the summers of 1994 and 1995) where incidental capture of harbour porpoise in groundfish gillnets was occurring. Data were collected on the procedures used in fishing, the environmental conditions at the time of fishing, characteristics of the porpoise caught, and the views of the fishermen regarding the issue of harbour porpoise incidental capture in their nets.

A total of 124 harbour porpoises were captured during 465 observer days when 17,363 nets were hauled. Over three seasons, significant relationships were found between harbour porpoise capture, duration of net soak time and distance of net placement from shore. The depth at which the net was set and the number of nets in a string were related to harbour porpoise by-catch over two seasons. Target species capture varied between seasons, altering the relationship of target species fish and by-catch. For one of the two seasons where mesh size varied, it showed a relationship to harbour porpoise by-catch.

Of 85 animals retrieved, 50 were male and 35 female. Lengths and weights of females were greater than males. Estimated age of animals ranged from 0 to 7+ years. Of the total number, 61% of the porpoises were sexually mature, 26% were immature, and 13% were calves.

Newfoundland porpoise primarily foraged for capelin, sand lance and herring, while Gulf of Maine/Jeffreys Ledge animals ate pearlsides, silver hake and herring; in the Grand Manan Island/Bay of Fundy region the diet was primarily Atlantic herring and silver hake. Atlantic herring occurred in 80% of the stomachs analysed and was the longest prey fish (44-332 mm).

Environmental data were collected over the 159 days of the study. By-catch of the harbour porpoise was correlated with wind speed during both seasons in Grand Manan Island/Bay of Fundy, with cloud cover during the 1993 summer season in Newfoundland, and with water temperature during the 1994 Grand Manan Island/Bay of Fundy season.

Assessment of elapsed time since death was undertaken to examine the diagnostic usefulness of the vitreous humour and core body temperature in determining postmortem interval. Twenty-four animals from Bay of Fundy by-catches were examined for core temperature and concentrations of various constituents of vitreous humour (glucose, urea, sodium, potassium, chloride, magnesium, calcium, and phosphorus), and the data were compared with published data of rectal temperature and serum concentrations of similar elements in live harbour porpoise. Vitreous humour glucose decreased from antemortem serum values, and the level was positively correlated with core temperature. Potassium and magnesium increased from antemortem serum values. Data suggest nearly all the animals had been dead for several hours.

Seventy-one fishermen from the Gulf of Maine/Bay of Fundy region were surveyed; most believed soak time of the net, depth of net set and target species harvest are factors related with harbour porpoise capture in gillnets. In compliance or with survey results, these results are in agreement with results in Newfoundland (Hood 2001).

6.5. Summary/Conclusions

- Various methods can be used to estimate by-catch including independent observers, sentinel fishermen, logbooks and interviews,
- Using multiple methods of estimation may be the best approach to ensure that all the various types of data and fisheries are included,
- Data from independent observers should be used to ground-truth other methods,
- Any monitoring program must have coverage of all fisheries that may catch porpoise,
- Sentinel fisheries may be a good place to begin estimating by-catch in the Gulf of St. Lawrence and Newfoundland regions, and
- Total landings and/or numbers of enterprises provide some indication of effort but other measures are needed to provide more accurate estimates of by-catch.

7. By-catch Mitigation

7.1. The US Management Scheme and Mitigation Measures Developed to Reduce By-catch of Harbour Porpoise in Gillnet Fisheries

Debra Palka

The management scheme used in the US was developed under the Marine Mammal protection Act (MMPA) of 1972 with amendments from 1994. The goals of the MMPA are: 1) maintain a population level above its optimum sustainable population (OSP) level, 2) restore populations that have been reduced, 3) approach a zero mortality incidental catch rate by commercial fisheries, and 4) minimise unnecessary disruption of fishing activities. To achieve these goals all marine mammals that inhabit US waters are assessed using information on stock structure, abundance, and human-induced mortalities. To assess the status of a population, estimates of human-induced mortalities are compared to the Potential Biological Removal (PBR) level. PBR is defined as the produce of the minimum population abundance estimate, half of the maximum productivity rate, and a recovery factor. The minimum population abundance estimate is defined as the number of animals in a stock, based on the best available scientific information on abundance, and also on the precision and variability of the abundance estimate. The maximum productivity rate is defined as the maximum theoretical or estimated net productivity rate of the stock when the stock size is small. The maximum productivity rate is defined as 0.04 for cetaceans, and 0.12 for pinnipeds and sea otters (default values), or a reliable stock specific estimate from a peer-reviewed journal, or from a review group, such as a Scientific Review Group or the Scientific Committee of the International Whaling Commission. The intent of the recovery factor is to compensate for effects of undefined uncertainties on the recovery of a stock to its OSP level, and to ensure the time to recovery is not significantly increased, especially for stocks listed as endangered, threatened, and depleted. The recovery factor, a factor between 0.1 and 1.0, is defined as 0.1 for stocks listed as endangered, and 0.5 for stocks listed as depleted, threatened, or of unknown status (default values). This factor is also adjusted depending on the coefficient of variation of the mortality estimate. The Potential Biological Removals (PBR) is estimated as $N_{min} \cdot 1/2R_{max} \cdot RF$ where N_{min} is the lower 20th percentile of the population estimate, R_{max} is the maximum reproductive potential (assumed to be .004 for cetaceans) and RF is the recovery factor. Using the 1999 abundance estimate, the proposed value of PBR for the Gulf of Maine/Bay of Fundy harbour porpoise population is $747 = 74{,}695 \cdot 1/2 \cdot 0.04 \cdot 0.5$.

Because the by-catch of this stock was larger than its PBR, two “Take Reduction Teams” (TRT) were created in 1996 and 1997 to develop a plan to reduce the by-catch to a level below PBR within six months. The TRTs were composed of 20-30 individuals that represented all stakeholders, including fishing industry representatives, government managers, and environmentalists. These two teams recommended a plan that was implemented in 1999.

The take reduction plan for the Gulf of Maine sink gillnet fishery established times and areas that were closed to all gillnet fishing, and other time/areas where gillnets had to use pingers (Federal Register 63 FR 66464). The complete time/area closures were times and areas of predicted high by-catch. However, because of inter-annual variability and incomplete data, times and areas of highest by-catch varied. To capture this variability, the pingered time/areas were times and areas surrounding the complete closures. The plan also included required training and certifying pinger users and other outreach programs.

The take reduction plan for the mid-Atlantic coastal gillnet fisheries established times and areas that were completely closed to gillnet fishing, and times and areas where gillnets were required to use specific gear characteristics (Federal Register 63 FR 66464). The required gear characteristics were specific twine sizes, string lengths, and use of tie downs that depended on the net’s mesh size. Nets with mesh sizes ≤5 in (127 mm) had no restrictions. The plan also included required outreach programmes. These required gear characteristics were chosen by investigating the statistical correlations between harbour porpoise by-catch rates and gear characteristics as recorded on observed hauls. It was unknown if these statistical correlations were either indicators of a cause-and-effect relationship or simply a statistical relationship.

During the first year of the plan, 1999, the by-catch estimate (323) was below PBR (747). Preliminary analyses indicated the reasons for the reduced by-catch are both the harbour porpoise take reduction plan and fish management plans that were simultaneously imposed on the fishers. These fish management plans included measures to reduce fishing effort. Thus, with lower fishing effort, even if there were no measures to reduce harbour porpoise by-catch, the predicted by-catch would be lower.

In the Gulf of Maine during the winter of 1999, few fishers used the time/areas that were open only to gillnets with pingers. Thus, in the times and areas where it was predicted the highest harbour porpoise by-catch would be, there was very little fishing effort. This can be interpreted as the reduced by-catch in this season was primarily due to the annual fish limits imposed by the fish management plans. However, because of the fish management plans, it was impossible to determine if the plan would have been effective in this season if there had been fishing. In contrast, in the Gulf of Maine during the fall of 1999, the time/areas that were open only to pingered nets were utilised by the fishers and the by-catch rate of these nets were lower than the historical by-catch rates of nets that did not use pingers. This can be interpreted as the reduced by-catch during this season was primarily due to the harbour porpoise take reduction plan. It was observed that the number of non-compliant observed nets (nets without pingers) had increased during 1999 and 2000.

In the mid-Atlantic coastal gillnet fishery, the same conclusion can be made. The reduced by-catch was due to both the fish management and harbour porpoise by-catch reduction plans. During 1999, the only observed by-catch was in nets with mesh sizes ≤5 in, that is, nets not regulated under the take reduction plan. As in the Gulf of Maine, total fishing effort was reduced as a result of fish management plans. However, a large percent of those gillnets that did fish were using gear characteristics that were statistically correlated to low harbour porpoise by-catch. Given the statistical models used to develop the take reduction plan and the observed inter-annual variability, the low by-catch rate observed in 1999 was in the predicted range. The single gear characteristic that had the highest predictability of a low by-catch rate was twine size. That is, larger twine sizes (≥0.81 mm) were correlated with low by-catch rates.

In conclusion, because the by-catch of harbour porpoises in US waters was greater than PBR, a take reduction plan was developed by a team of fishing industry representatives, government managers, and environmentalists. The plan they developed was at least partially responsible for a reduced by-catch in years when the plan was implemented.

7.2. The Use of Various Types of Alarms Including a New High Frequency Pinger

David Potter

Acoustic Deterrent Devices (ADD's or Pingers): A Brief History

In 1991 Dr. Jon Lien (Memorial University) reviewed the utility of employing acoustic transmitters ("Cod Balls") to fishing gear as a means to deter cetaceans and thus prevent entanglement. He concluded that these devices might be potentially useful, and in 1992 Lien initiated a demonstration project with the Portsmouth COOP Fishermen. Although there was great interest in this technology by the fishermen, the acoustic gear was bulky and difficult to work with. In 1993 Lien continued experiments using observers and Memorial students. During these experiments the results were more promising, and again, a low-tech approach was used with pingers made out of dump truck back-up beepers (2-4 kHz, sound pressure level (SPL) unknown), PVC pipe and Radio Shack battery packs. It was hoped fishers would build their own, but this approach had technical problems. However, these experiments cleared the way for the well-known Kraus and Read Study.

In 1994, a full scale experiment was funded by NFWF (National Fish and Wildlife Foundation) and NOAA Fisheries (with $250,000 from NFWF and $250,000 from NOAA). There was a problem finding a source for the pingers, although Dukane were able to provide hundreds of pingers "off the shelf". These units operated at approximately 10 kHz and 132 dB re 1 μPa-m, with a 300 millisecond transmission every four seconds. These pingers were at a different frequency than Lien used previously. The experiment consisted of approximately 840 sets (a set was a single string of 12 gillnets) both with (423) and without (421) working pingers. There was a double blind experimental design with 100% observer coverage. A highly significant reduction in harbour porpoise by-catch was observed; 25 porpoise were caught in control nets (no pingers) and 2 taken in experimental (pinger) sets.

Debi Palka's presentation (see previous section) presents data on the continued use of pingers and the resultant by-catch reduction seen in the fisheries following their mandatory use in closed areas. Observer data suggests that pingers work better in the experimental setting than during actual fishing situations, but they do appear to work.

At present it is unknown how pingers achieve their deterrent effect; there are several theories, but no firm evidence of a cause and effect:

a) The pingers might alert the porpoise to the presence of the net, after which the porpoise echolocate to avoid it. However, Read and Kastelien both demonstrated this is not the case. In fact, external acoustic stimuli tend to make porpoise quiet.

b) The pingers displace porpoise from the area of the ensonified nets. During field experiments porpoise were caught in control nets co-located with the experimental nets so if pinger-induced displacement is occurring, porpoise are not displaced a great distance.

c) The pingers may provide the porpoise with a means to image the net acoustically (via the so-called "ambient noise imaging" or "acoustic daylight" process). John Potter of the Acoustic Research Laboratory in Singapore has demonstrated this effect. Harmonics in the pinger signal would reflect from the nets in such a way that to an animal capable of hearing the sound and creating a perceptual three-dimensional acoustic map of their surroundings (such as it is presumed the harbour porpoise is capable) could see the size and orientation of the net independent of visible light cues. Further research on this effect is ongoing.

Limitations of Acoustic Deterrent Devices

The current pinger device, the Dukane Netmark 1000, is part of the recovery mechanism in commercial aircraft black boxes.

There is work underway by URI Ocean Engineering Students to deal with some current problems. For example, the batteries last only about a month and so the pingers require constant maintenance. In addition, opening the pingers' pressure housing increases the likelihood of flooding resulting in high failure rates, and the possibility taking of porpoise in nets with such flooded pingers.

Many people cannot hear the signals from the current 10 kHz units, and the 47 kHz units are well above human hearing range. Thus there is no way for a fisherman to know if his/her pingers are operative during deployment. Therefore, we have been developing a "pinger tester"; these units will be available shortly and we hope to test a prototype within the month.

A functional problem for pinger technology is that the sounds from the pingers may be perceived as a cue by hungry marine mammals that learn to (positively) associate pingers with fishing nets from which they can remove caught fish. Our first clue that this might be a problem came when the fishermen wanted to try a pinger operating at a higher frequency above the pinniped hearing threshold. We are currently examining an alternative pinger—the Airmar. It has the advantage of working at different frequencies (10 or 47 kHz), is a similar cost to current pingers ($50-55 US), and has a battery that can last a year to allow for a certification program. A different pinger is used on the Pacific coast but I am not aware of its specifications.

7.3. Testing of Acoustic Alarms to Reduce the By-catch of Harbour Porpoise in the Pacific Northwest

Patrick Gearin

We conducted experiments using acoustic alarms in the Northern Washington Marine Set-net Fishery from 1995 to 1997 (Gearin *et al*. 2000). Observer programs in the fishery since 1988 indicated that most harbour porpoise were taken during July and August (Gearin *et al*. 1994). Most of the harbour porpoise (99%) observed or reported taken in the fishery from 1988 to 1997 (N=205) were caught in the Spike Rock area, a small bay on the Pacific coast. Catch rates of harbour porpoise at Spike Rock are among the highest reported in the world ranging from 0.10 to 0.70 porpoise taken per net day (Gearin *et al*. 1994). Our goal was to determine if alarms would reduce harbour porpoise by-catch in this fishery, and to learn more about how the alarms function. In addition, we conducted studies on observations of harbour porpoise in relation to alarmed nets and made field measurements of alarms at the fishing grounds where the studies were conducted.

Design of Alarms

The alarms used were slightly modified designs of Jon Lien's as described by Fullilove (1994). The alarm unit consisted of a piezo buzzer that operated on four 9 volt batteries, ABS pipe, screw caps, end caps and adapters. The central housing tube was cut from 5 cm diameter ABS to lengths of 15-18 cm. We used rubber sealant and silicon instead of O-rings to seal the screw caps. Our devices did not have a salt water switch but remained constantly active. Because the nets stayed in one location for long periods of time and remained in the water except for the brief period when they were checked, it was not necessary to save battery life by installing a salt water switch. Due to the short duration of the experiments, the four batteries installed were adequate to power the alarms for 6-8 weeks.

Field Testing Alarms

The attenuation and sound source levels of three alarms were tested before the 1995 experiment began to determine optimal spacing patterns and required distances between nets (Bain, unpubl. data). The alarms produced a broad band signal at intervals of 4 s centred at 3 kHz with a second peak near 20 kHz . Minimum source levels were 90 dB re 1 µPa at 30 cm (in air) according to manufacturer's specifications. We also contracted with acousticians from *Hubbs Sea World Research Institute* to conduct field measurements of the ambient noise parameters and alarm attenuation at the Spike Rock study site in 1996 (Bowles *et al*. 1997). Transmission loss and ambient noise levels in the area were measured using a broadband calibrated recording system including an *ITC 6050C* hydrophone and a *Nagra IV-SJ* recorder. The transmission loss was estimated using a shallow water loss model (spherical [20 log R] spreading out to bottom depth and approximately cylindrical spreading [10 log R] thereafter). The shallow water model was used to estimate the detection range of alarms at the two frequency peaks. As background noise appeared to have a large effect on the empirical data, the transmission loss was also modelled using decline in signal-to-noise ratio (SNR) of the alarms, or the difference between tonal level and ambient noise level in the appropriate bands (SNR >0 dB). A simple logarithmic decay model was used to fit the data.

Experimental Design and Net Configuration

The experiments were conducted in the Spike Rock Fishing grounds in depths ranging from 8 to 18 m. One tribal gillnet vessel was used during the fishing experiments which were conducted from 27 July to 28 August 1995, and from 7 July to 9 August 1996. In 1997, alarms were placed on all nets used in the fishery (except for the first two days) which was conducted over 47 days from 30 June to 16 August. Four tribal nets were constructed to be used in the experiments, in order to control for net size, mesh size and condition. The nets were 19.5 cm stretched mesh and 183 m long. In 1995-96, two nets were composed of three-strand green nylon and were 50 meshes deep and two were three-strand white nylon and 80 meshes deep. The 50 mesh nets fished approximately 7.5 m deep and the 80 mesh nets fished 12 m deep. In 1997 the nets were re-hung with new 19.5 cm stretched mesh green color web and each was 183 m long and 50 mesh deep. The nets were checked once each day, weather permitting, and typically soaked for 24 hours. Each net was set and aligned so as not to overlap the other. Minimum distances between nets was 300 m in order to reduce the chance of sound overlap between nets. Alarms were rotated between different nets in an attempt to balance alarmed and control fishing effort through the season. The rotation schedule however could not be strictly adhered to as a result of inclement weather which prevented checking the nets on several occasions or large swell conditions which prevented changing alarms. Two nets were set on the north side of the bay and two in the center of the bay acting as identical paired sets. Nets were set in only four positions during each season and were not moved until pulled out of the water at the end of the season. Nets were set in approximately the same locations during each of the three fishing seasons. Each net acted as a control (without alarms) and as an experimental net when alarms were in place, except during 1997 when all nets were alarmed. The alarms were placed on the cork line of the nets using nylon tie wraps. When in position, the alarms were horizontal, parallel to the cork line. When fishing, the alarms were 4-7 m below the surface. Each net was fitted with 11 alarms, spaced at intervals of 16.6 m. When the nets were checked, observers recorded data on harbour porpoise catch, salmon and sturgeon catch and by-catch of other fish and marine mammals.

Observational Studies

Shore-based observations were made from a 47 m high cliff above the Spike Rock fishing grounds to observe the behaviour and distribution of porpoise around the experimental nets in 1996. A three member observer team recorded porpoise sightings in relation to Net 1 and calculated the positions of sightings and distances from the net. The observer team was unaware of whether Net 1 was a control or alarmed net. Theodolite bearings to the buoys marking each end of Net 1 were recorded at low and high tides each day, providing a record of net locations relative to porpoise sightings. Searching for porpoise was conducted through 7 × 50 reticle binoculars, which have a 5.44 × optical field of view with 14 reticle marks which measure vertical angle from the horizon. An internal magnetic compass provided 360^{o} horizontal bearings. More detail on the methodology is provided in Laake *et al*. (1998).

Harbour Porpoise By-catch

The results of these studies indicate that acoustic alarms significantly reduce the probability of harbour porpoise entanglement in bottom set gillnets in the fishery without reducing the catch of target fish species. In 1995, only one harbour porpoise was caught in an alarmed net and 19 were caught in control nets, over nine different ND. Alarmed and control net CPUE were 0.019 and 0.365 per ND, respectively. The CPUE was 19 times greater in control nets than alarmed nets. This represents a 95% reduction in harbour porpoise by-catch. However, the porpoise catch was not uniformly distributed over time during the duration of the 1995 experiment; the majority of porpoise were taken in the first half of August and only one was taken in the second half of August. All harbour porpoise were caught on seven days between 30 July and 18 August. Twelve harbour porpoise were taken on one day during the fishery, in three different nets, including seven in one net. The probability of an entanglement in an alarmed net (P_{active} = 0.019) was significantly lower than the probability of an entanglement in a control net (P_{control} = 0.173) (χ^2 = 5.28 df = 1, P = 0.02). The odds ratio was 10.5 (95% CI:1.78-61.4) which implies the odds are 10.5 times greater that a porpoise entanglement occurred in a control net than an alarmed net. The expected number of porpoise which would have been caught if alarms were not used was 38 (0.365 × 103 ND), as compared to the 20 which were observed taken. During 1996, only one harbour porpoise was taken in an alarmed net and 28 were taken in control nets in 13 different ND. In 1996, the CPUE of harbour porpoise for alarmed and control nets was 0.016 and 0.467 per ND, respectively. The CPUE was 29 times greater in control nets than alarmed nets. This represents a 97% reduction in harbour porpoise by-catch. The alarmed and control effort and harbour porpoise catches were more evenly distributed in 1996 than in 1995. The chi-square analysis revealed that the probability of a porpoise entanglement in an alarmed net (P_{active} = 0.016) was significantly lower than the probability of an entanglement in a control net (P_{control} = 0.217) (χ^2 = 11.2 df = 1, P = 0.001). The odds ratio was 16.6 (95% CI: 2.9-93.5) implying that the odds of a porpoise take in a control net was 16.6 times greater than in an alarmed net. We would have expected 56 harbour porpoise to have been taken in the fishery had no alarms been used in 1996. In 1997, 12 harbour porpoise were taken during 180 ND of fishing effort using alarmed nets. We would have expected 79 harbour porpoise to be taken in the fishery had no alarms been used, based on extrapolating from control catch rates from 1995 and 1996 (CPUE = 0.42 per ND). The observed by-catch reduction was 85% for 1997. We collected 59 harbour porpoise during the fisheries; two porpoises dropped out of the nets before they could be retrieved. All sex and relative age categories were represented in the animals collected. Eleven of 14 (78.6%) of the harbour porpoise taken in alarmed nets were reproductively immature, which is higher than the percentage in the overall population. Ten of the porpoises caught in alarmed nets were single entanglements of only one individual. The porpoises entangled in the control nets appeared to be uniformly distributed along the length of the nets but most were located near the lead line or bottom third of the net.

Observational Studies

We present only the primary findings of the 1996 field observations. The complete details of the study are presented in Laake *et al*. (1998). Over the 27-day period of observations in 1996, 503 positions of harbour porpoise groups were recorded at Spike Rock during 136 hours of observation. Although group size varied from 1 to 10 porpoise, groups of 1 or 2 individuals comprised 72% of the sightings. Harbour porpoise sightings were primarily clustered to the north of Net 1, but when Net 1 was unalarmed, porpoises were seen closer to the net. The distribution of distances between porpoise and Net 1 suggested that porpoises were displaced 100 to 150 m from the net when it was alarmed. Laake *et al*. (1998) chose 125 m as the radius of the displacement region for testing the significance of an alarm effect. Harbour porpoises were seen within the displacement region on 5 of the 13 days when the net was not alarmed but on only 1 of the 14 days when the net was alarmed. This demonstrated that porpoise were less likely to surface within 125 m of the displacement region when the net was alarmed ($P < 0.05$) (Laake *et al*. 1998).

The observations of harbour porpoise around the nets during 1996 (Laake *et al*. 1998) indicated that harbour porpoise were displaced a minimum distance of 125 m from alarmed nets. Many porpoise were sighted in the general area to the north within 200-300 m indicating that the alarms did not displace porpoises from a large area away from the alarm source. We propose that the alarms function in an aversive manner by scaring or displacing porpoises away from the sound. If the alarms functioned by alerting animals to the presence of the net, we would expect porpoises to approach closer to the nets than the 125 m minimum. The fact that porpoise do not approach closer suggests that they are deterred by the sound rather than by being alerted to the presence of the net.

The field measurements of the alarms at the Spike Rock fishing grounds (Bowles *et al*. 1997) provide information on the effective range of an alarm and alarmed net. The effective range under typical conditions of ambient background noise would be between 113 to 293 m. This effective range falls within the bounds of the 125 m exclusion zone demonstrated by Laake *et al*. (1998). This finding provides further evidence that alarms function by excluding harbour porpoise from a certain area in an aversive manner, and not necessarily by alerting porpoises to an object.

We do not suggest that acoustic alarms will function in all types of net fisheries or be effective for other cetacean species. We recommend caution in applying acoustic alarm technology to management situations until they are adequately tested to determine if they will be effective in that particular situation. Furthermore, we do not recommend large-scale usage of acoustic alarms until more is known about the possible effects of large-scale sound transmission and habituation.

7.4. Mitigation of Harbour Porpoise By-catch in Fishing Gear: How to Effectively and Efficiently Save Porpoise Without Pissing Off Fishermen, Managers, Conservationists or Politicians!

Jon Lien

Developing an Approach for By-catch Reduction

There are three main levels of responsibility for by-catch of marine mammals during fishing activity:

1) Fishermen are responsible for by-catch and must be held responsible for any environmental harm, such as by-catch,

2) The Department of Fisheries and Oceans is the licensing agency which authorises fishing and are therefore responsible for insuring that the environmental harm that this activity causes, such as by-catch, is mitigated, and

3) Academics, conservationists, and other “nice guys” are not directly responsible for by-catch, but can help in developing mitigation methodologies.

Overall, our first responsibility is to ensure the protection of the marine mammals. For harbour porpoise in particular, even relatively minor by-catch is likely not good for their populations as they, on considered scientific opinion, are considered threatened.

While we can develop a threatened species "science industry" which attempts to show how deleterious by-catch is, there will never be enough data to be very precise. In addition, both fishermen and scientists are potentially self-serving and have vested interests in by-catch and its management.
Canada has committed to using the precautionary principle which means we take action to prevent harm before it is demonstrated. It also means permitting development of activities only as knowledge of their impact is understood. Therefore, a thorough discussion of the precautionary principle as applied to species at risk is necessary before the SARA programme initiates a new Species at Risk science programme.

When developing mitigation approaches, several considerations should exist:

- Mitigation efforts should proceed knowledge of populations, the nature and abundance of by-catch, and its impact—thus a precautionary approach,
- Mitigation of by-catch should strive to anger as few stakeholders as possible, and
- Mitigation costs should be borne by responsible groups.

Consultation among interested stakeholders is desirable but the involvement of responsible stakeholders (fishermen and managers) in achieving solutions is essential. Fishermen and managers need to become involved in SARA concerns and discussions at an early date as they will be the ones to implement any mitigation measures.

Mistakes of the past, such as micromanagement of fisheries, should be avoided. Rather, give fishermen a by-catch quota or goal and the opportunity to develop their own solutions. Or, provide them with possible solutions and give them the latitude to select those most practical. Further, negotiations of Conservation Harvesting Plans should include non-target by-catch issues.

Harbour porpoise by-catch should not be considered in isolation but with a holistic examination of the total impact of any method of fishing, including other by-catch of non-target species, the total mortality on target species that the fishing method inflicts, and any habitat impacts of the gear.

In summary, don't let the "perfect" stand in the way of the "good"!

Mitigation Opportunities

At present we have an outstanding opportunity to mitigate harbour porpoise by-catch. This is due to a number of factors, mainly related to groundfish depletions and gillnet fishery moratoriums or minimum quotas:

- DFO has changed its ways (some) through:
  - Individual Quotas
  - Non-competitive fisheries
  - Conservation Harvesting Plans

- 100% Dock side monitoring
- 100% quality grading
- Sentinel Fisheries
- Oceans Act

➢ Fishermen have changed their ways (some) through:
  - The Canadian Code of Responsible Fishing
  - Seasonal shifts to increase quality/price
  - Index Fisheries

➢ FRCC (2001) and fishing recommendations:
  - MPAs and time/area closures
  - Emphasis on quality and total mortality
  - Concern over use of gillnets

Changes in fishing practices/technology offer many opportunities for by-catch reduction through improved gear technology (e.g., pingers, modifications to the acoustic properties of nets) and modifications to standard fishing practices (e.g., gear substitution, trawl and handlines to improve quality, cod "pots"). Studies of total mortality caused by any gear can be used to modify IQs (and encourage gear substitutions).

7.5. Summary/Conclusions

❖ The major reason for reduced by-catch of porpoise in recent years has been reduced gillnet fishing effort.

❖ The use of pingers has been shown to be effective in a number of fisheries.

❖ Time are closures and gear modifications (e.g. twine size) appear to have some effects.

❖ Reflective nets may result in reduced catches, but the reason for this is not clear and more work is needed to understand how they may work.

❖ "Stiff nets" may also reduce by-catch which may be the mechanism by which reflective nets work.

❖ The use of alternate gear (e.g. cod pots) could potentially be used to reduce takes in future fisheries.

❖ Fishermen and managers must be involved at the planning stages in any efforts to reduce porpoise by-catch.

❖ In order to reduce by-catch, a holistic view of the fishery and ecosystem must be taken.

Appendix I - List of Participants

Don Bowen
Department of Fisheries and Oceans
1 Challenger Drive
Dartmouth, Nova Scotia, Canada B2Y 4A2
Email: BowenD@mar.dfo-mpo.gc.ca
Tel: 902-426-8909
Fax: 902-426-9683

Paul Brodie
6215 Coburg Road
Halifax, Nova Scotia, Canada B3H 1Z8
Email: pbrodie@HFX.eastlink.ca
Tel: 902-422-1053
Fax: 902-422-1053

Jerry Conway
Department of Fisheries and Oceans
1 Challenger Drive
Dartmouth, Nova Scotia, Canada B2Y 4A2
Email: ConwayJ@mar.dfo-mpo.gc.ca
Tel: 902-426-6947
Fax: 902-426-9683

Patrick Gearin
National Marine Mammal Laboratory
7600 Sand Point Way NE
Seattle, Washington, USA 96115
Email: Pat.Gearin@noaa.gov
Tel: 206-526-4034
Fax: 206-526-6615

Michael Hammill
Department of Fisheries and Oceans
P.O. Box 1000
Mont-Joli, Quebec, Canada G5H 3Z4
Email: hammillm@dfo-mpo.gc.ca
Tel: 418-775-6500
Fax: 7418-775-6542

Catherine C. Hood
Department of Fisheries and Oceans
P.O. Box 5667
St. John's, Newfoundland, Canada
Email: hoodc@dfo-mpo.gc.ca
Tel: 709-772-5693
Fax: 709-772-4105

Michael Kingsley
Greenland Natural Resources Institute
P.O. Box 570
DK-3900
Nuuk, Greenland
Email: mcsk@natur.gl
Tel: +299-32-1095
Fax: +299-32-59-57

Veronique Lesage
Department of Fisheries and Oceans
Mont-Joli, Quebec, Canada 65H 3Z4
Email: LesageV@dfo-mpo-gc.ca
Tel: 418-775-0739
Fax: 418-775-0740

Jon Lien
Whale Research Group
Memorial University
Mt. Scio Road IS there a PO box?
St. John's, Newfoundland, Canada A1B 3X9
Email: jlien@morgan.ucs.mun.ca
Tel: 753-5495
Fax: 709-737-2450

Kaija Metuzals
Department of Fisheries and Oceans
200 Kent Street
Ottawa, Ontario, Canada KIA OE6
Email: MetuzalsK@dfo-mpo.gc.ca
Tel: 613-990-0273
Fax: 613-954-0807

Debra Palka
National Marine Fisheries Service
166 Water Street
Woods Hole, Massachusetts, USA
Email: dpalka@whsun1.wh.whoi.edu
Tel: 508-495-2000
Fax: 508-495-2258

David Potter
National Marine Fisheries Service
166 Water Street
Woods Hole, Massachusetts, USA
Email: Dpotter@whsum1.wh.whoi.edu
Tel: 508-495-2000
Fax: 508-495-2258

Andrew Read
Nicholas School of the Environment
Duke University Marine Laboratory
135 Duke Marine Lab Road
Beaufort, North Carolina, USA 18516
Email: aread@mail.duke.edu
Fax: 252-504-7648
Tel: 252-504-7590

Patricia Rosel
219 Fort Johnson Road
NOAA
Charleston, South Carolina, USA 29412
Email: patricia.rosel@noaa.gov
Tel: 843-762-8579
Fax: 843-762-8700

Patrice Simon
Department of Fisheries and Oceans
200 Kent Street
Ottawa, Ontario, Canada K1A 0E6
Email: SimonP@dfo-mpo.gc.ca
Tel: 613-990-0289
Fax: 613-954-0807

Garry Stenson (Chair)
Department of Fisheries and Oceans
P.O. Box 5667
St. John’s, Newfoundland, Canada A1C 5X1
Email: stensong@dfo-mpo.gc.ca
Tel: 709-772-5998
Fax: 709-772-4105

Appendix II - Workshop Agenda

March 26-28, 2001

Bedford Institute of Oceanography

Dartmouth, Nova Scotia, Canada

MONDAY 26 MARCH

09:30-10:00 Garry Stenson – Welcome, introduction, review agenda, objectives and goals of workshop.

STOCK IDENTITY

Rapporteur: Mike Hammill

10:00-10:30 Patricia Rosel – Stock structure of harbour porpoise in the NW Atlantic

10:30-11:00 Break

11:00-12:00 General discussion

12:00-13:00 Lunch at Bedford Institute of Oceanography

BIOLOGICAL PARAMETERS

Rapporteur: Catherine Hood

13:00-13:30 Patrick Gearin – Pacific

13:30-14:00 Andrew Read – Bay of Fundy

14:00-14:30 Michael Hammill - Gulf of St. Lawrence

14:30-15:00 Break

15:00-15:30 Garry Stenson/Shelly Richardson – Newfoundland

15:30-17:30 General Discussion

TUESDAY MARCH 27

ABUNDANCE AND DISTRIBUTION

Rapporteur: Don Bowen

09:00-09:30 Debi Palka – Shipboard surveys in the Bay of Fundy/Gulf of Maine

09:30-10:00 David Potter – Aircraft surveys in the Bay of Fundy/Gulf of Maine

10:00-10:30 Break

10:30-11:00 Michael Kingsley – Harbour porpoise in the Gulf of St. Lawrence: by-catch, distribution, and survey estimates of numbers

11:00-12:00 General Discussion

12:00-13:00 Lunch

13:00-14:00 General Discussion (con't.)

ECOLOGY AND POLLUTANTS

Rapporteur: Patrice Simon

14:00-14:30 Paul Brodie – Ecological considerations for harbour porpoise

14:30-15:00 Break

15:00-17:00 General Discussion

WEDNESDAY MARCH 28

INCIDENTAL CAPTURE

Rapporteur: Veronique Lesage

09:00-09:30 Debi Palka – By-catch estimates in the Gulf of Maine and mid-Atlantic States

09:30-10:00 Kaija Metuzals – North Sea By-catch

10:00-10:30 Break

10:30-11:00 Jon Lien – Incidental by-catch of harbour porpoise in Newfoundland and Labrador - as we know it

11:00-11:30 Catherine Hood – By-catch estimates in three gillnet fisheries of the Northwest Atlantic

11:30-12:00 General Discussion

12:00-13:00 Lunch

13:00-14:00 General Discussion (con't.)

BY-CATCH MITIGATION

Rapporteur: Kaija Metuzals

14:00-14:30 Debi Palka – How the US has attempted to mitigate by-catch of harbour porpoise in gillnet fisheries: time/area closures and gear modifications and the US management scheme

14:30-15:00 Break

15:00-15:30 David Potter – The use of various types of alarms including a new high frequency pinger

15:30-16:00 Patrick Gearin – Harbour porpoise fishery interactions and mitigation regimes in Washington State

16:00-16:30 Jon Lien - Mitigation of harbour porpoise by-catch in fishing gear: How to effectively and efficiently save porpoise without pissing off fishermen, managers, conservationists and politicians!

16:30- General Discussion

Workshop closure: Garry Stenson

Appendix III – References

Bisack, K. 1999. A five-step stratified optimum allocation scheme. Pp. 11-14 *In*: Didier, A.J. Jr., and V.R. Cornish (Eds.). Development of a process for the long-term monitoring of MMPA Category I and II commercial fisheries. Proceedings of a workshop held in Silver Spring, Maryland, 15-16 June 1998. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-OPR-14, 46 p.

Bisack, K.D. 1997. Harbor porpoise bycatch estimates in the US New England multispecies sink gillnet fishery: 1994-1995. *Rep. int. Whal. Commn*. **47**:705-714.

Borchers, D.L., S.T. Buckland, P.W. Goedhard, E.D. Clarke, and S.L. Hedley. 1998. Horvitz-Thompson estimators for line transect surveys. *Biometrics* **54**:1221-1237.

Bowles, A.E., R. Anderson, and H. Stinson. 1997. Harbor Porpoise Net Entanglement Study: Ambient Noise and Propagation of Pinger Sounds. Final Report to the National Marine Mammal Laboratory., Seattle, WA. P.O. No. 40ABNF601357; Copies available at NMML, 7600 Sand Point Way NE, Seattle, WA. 98115.

Bravington, M.V. and K.D. Bisack. 1996. Estimates of harbor porpoise bycatch in the Gulf of Maine sink gillnet fishery, 1990-1993. *Rep. int Whal. Comm.* **46**:567-74.

Brodie, P.F. 1995. The Bay of Fundy/Gulf of Maine4 harbour porpoise (*Phocoena phocoena*): Some considerations regarding species interactions, energetics, density dependence and bycatch. *Rep. int. Whal. Commn. Spec. Issue* **16**:181-187.

Brodie, P.F. and B.E. Beck. 1983. Predation by Sharks on the Grey Seals (*Halichoerus grypus*) in Eastern Canada. *Can. J. Fish. Aquat. Sci*. **40**:267-271.

Buckland, S.T., D.R. Anderson, K.P. Burnham, and J.L. Laake. 1993. *Distance Sampling: Estimating abundance of biological populations.* Chapman & Hall, New York. 446 p.

Cochran, W.G. 1977. Sampling techniques. 3rd ed. Wiley, New York, NY. 428 p.

Cooke, J.G. and R. Leaper. 1998. A general modelling framework for the estimation of whale abundance from line transect surveys. Paper SC/50/RMP21 submitted to the IWC Scientific Committee, May 1998.

FMP. 1993. Fisheries Management Plan for Sharks of the Atlantic Ocean. NMFS/NOAA, U.S. Department of Commerce. February 25, 1993.

Fontaine, P.M., Barette, C., Hammill, M.O. and Kingsley, M.C.S. 1994. Incidental catches of harbour porpoises (*Phocoena phocoena*) in the Gulf of St. Lawrence River Estuary and the St. Lawrence River Estuary, Quebec, Canada. *Rep. int. Whal. Commn. Spec. Issue* **15**:159-163.

FRCC (1993). 1994 conservation requirements for Atlantic groundfish. Report to the Minister of Fisheries and Oceans, Ottawa, Ont. 70 p. + appendix.

FRCC (2001). 2001 conservation requirements for groundfish stocks in sub-areas 0, 2 + 3., FRCC.2001.R2. Report to the Minister of Fisheries and Oceans, Ottawa, Ont. 39 p. + appendix.

Fullilove, J. 1994. How to make a gillnet “Pinger”. *Nat. Fisherman* **75**:29-30.

Gao, A. and D. Gaskin. 1996a. Geographical variation in metric skull characteristics among proposed subpopulations and stocks of harbor porpose, *Phocoena phocoena*, in the western North Atlantic. *Mar. Mamm. Sci*. **12**:516-527.

Gao, A. and D. Gaskin. 1996b. Nonmetric morphometry of the skull of the harbour porpoise, *Phocoena phocoena*, in the western North Atlantic and eastern Pacific. *Can. J. Zool.* **74**:2199-2205.

Gaskin, D. E. 1977. Harbour porpoise, *Phocoena phocoena* (L.), in the western approaches to the Bay of Fundy 1969-75. *Rep. Int Whal. Commn.* **27**:487-492.

Gaskin, D.E. 1984. The harbour porpoise *Phocoena phocoena* (L.): regional populations, status, and information on direct and indirect catches. *Rep. Int. Whal. Commn.* 34: 569-586.

Gaskin, D.E. 1992. Status of the harbour porpoise, *Phocoena phocoena* in Canada. The Canadian Field-Naturalist 106:36-54.

Gearin, P., S. Melin, R.L. DeLong, H. Kajimura, and M. Johnson. 1994. Harbor porpoise interactions with a chinook salmon set-net fishery in Washington State. *Rep. Int. Whal. Commn*. *Special Issue* **15**:427-38.

Gearin, P.J., M.E. Gosho, J.L. Laake, L. Cooke, R.L. DeLong and K.M. Hughes. 2000. Experimental testing of acoustic alarms (pingers) to reduce the bycatch of harbour porpoise, *Phocoena phocoena*, in the state of Washington. *J. Cetacean Res. Manage* **2**:1-9.

Hammond, P.S., H. Benke, P. Berggren, D.L. Borchers, S.T. Buckland, A. Collet, M.P. Heide-Jorgensen, S. Heimlich-Boran, A.R. Hiby, M. Leopold, and N. Øien. 1995. Distribution and abundance of the harbour porpoise and other small cetaceans in the North Sea and adjacent waters*.* SCANS Final Report October (1995). LIFE 92-2/UK/027. 240 p.

Harwood, J. (Ed.) 1999. BYCARE EU Report, unpublished final report. 282 p.

Hood, C. 2001. Investigations of harbour porpoise bycatch. Ph.D. Thesis, Queen Elizabeth II Library, Memorial University of Newfoundland, St. John’s, Newfoundland.

International Whaling Commission. 1996. Report of the Sub-Committee on Small Cetaceans. Report of the International Whaling Commission 46:160-179.

Kingsley, M.C.S. and R.R. Reeves. 1998. Aerial surveys of cetaceans in the Gulf of St. Lawrence in 1995 and 1996. *Can. J. Zool*. **76**:1529-1550.

Kraus, S. D., J.H. Prescott and G.S. Stone. 1983. Harbour porpoise, *Phocoena phocoena*, in the U.S. coastal waters of the Gulf of Maine: A survey to determine seasonal distribution and abundance. Report to the Director, National Marine Fisheries Service, Northeast Region, Woods Hole, Massachusetts. 15 p.

Laake, J., D. Rugh, and L. Baraff. 1998. Observations of Harbor Porpoise in the Vicinity of Acoustic Alarms on a Set Gill Net. U.S. Dep. Comm., Alaska Fisheries Science Center, NOAA Tech. Memo. NMFS-AFSC-84. 40 p.

Lien, J. 1980. Whale entrapment in inshore fishing gear in Newfoundland. Report to the Department of Fisheries and Oceans, St. John's, Newfoundland. 315 p.

Lien, J. 1989. Incidental catch of harbour porpoise (*Phocoena phocoena*) in waters off Newfoundland and Labrador: Some estimates based on present data and a request for further study. CAFSAC WP/89/168, 6 p.

Lien, J. 1994. Entrapments of large cetaceans in passive inshore fishing gear in Newfoundland and Labrador (1979-1990). *Rep. Int. Whal. Commn. Special Issue* **15**:149-158.

Lien, J. and D. Aldrich. 1982. Damage to inshore fishing gear in Newfoundland and Labrador by whales and sharks during 1981. CAFSAC WP/82/104 38 p.

Lien, J., J. Papineau, and L. Dugan. 1987. Incidental entrapments of cetaceans, sharks and marine turtles in inshore fishing gear reported during 1987 in Newfoundland and Labrador. Report to the Department of Fisheries and Oceans, St. John's, Newfoundland. 43 p.

Lien, J., G.B. Stenson, S. Carver, and J. Chardine. 1994. How many did you catch? The effects of methodology on bycatch reports obtained from fishermen. *Rep. Int. Whal. Commn. Special Issue* **15**:535-540.

Lien, J., G.B. Stenson, and I.H. Ni. 1988. A review of incidental entrapment of seabirds, seals and whales in inshore fishing gear in Newfoundland and Labrador: A problem for fishermen and fishing gear designers. Pp 67-71 *In* J. Huntington (Ed.) Proceedings of the World Symposium on Fishing Gear and Fishing Vessel Design, Marine Institute, St. John's, Newfoundland.

McGlade, J. and K. Metuzals. 1999. A governance framework for the assessment and reduction of the bycatch of harbour porpoises (*Phocoena phocoena*) in the North Sea and surrounding areas based on the principles of responsible fishing. Chapter 17 *In* 'BYCARE' EU Report. Harwood, J. *et al*. (Eds). Unpublished Final Report. Brussels. 282 p.

McGlade, J. and K. Metuzals. 2000. Options for the reduction of bycatches of harbour porpoises *Phocoena phocoena* in the North Sea. Chapter 22 *In* Kaiser, M. and S. de Groot (Eds.). Effects of fishing on non-target species and habitats. Blackwell Science. 394 p.

Palka, D. 1995. Abundance estimate of the Gulf of Maine harbor porpoise. *Rep. int Whal. Commn. Special Issue* **16**:27-50.

Palka, D. 1996. Update on abundance of Gulf of Maine/Bay of Fundy harbor porpoises. NOAA/NMFS/NEFSC Ref. Doc. 96-04. 37 p. Available from: National Marine Fisheries Service, 166 Water Street, Woods Hole, MA 02543-1026.

Palka, D. 2000. Abundance of the Gulf of Maine/Bay of Fundy harbor porpoise based on ship-board and aerial surveys during 1999. NOAA/NMFS/NEFSC Ref. Doc. 00-07; 29 pp. Available from: National Marine Fisheries Service, 166 Water Street, Woods Hole, MA 02543-1026.

Palka, D. and P. Hammond. (In press). Accounting for responsive movement in line transect estimates of abundance. *Can. J. Fish. Aquat*.

Piatt, J.F., D.N. Nettleship. 1987. Incidental catch of marine birds and mammals in fishing nets off Newfoundland, Canada. *Mar. Pollut. Bull*. **18**(**6B**):344-349.

Read, A.J., and Gaskin, D.E. 1990. Changes in growth and reproduction of harbour porpoises, *(Phocoena phocoena),* from the Bay of Fundy. Canadian Journal of Fisheries and Aquatic Sciences 47:2158-2163.

Read, A.J. and Hohn, A.A. 1995. Life in the fast lane: the life history of harbor porpoises from the Gulf of Maine. *Mar. Mamm. Sci.* **11**:423-440.

Rosel, P.E., Dizon, A.E. and Haygood, M.G. 1995. Variability of the mitochondrial control region in populations of the harbour porpoises, *Phocoena phocoena*, on interoceanic and regional scales. *Can. J. Fish. Aquat. Sci*. **52**:1210-1219.

Rosel, P.E., France, S.C., Wang, J. and Kocher, T.D. 1999. Genetic structure of harbour porpoise *Phocoena phocoena* populations in the Northwest Atlantic based on mitochondrial and nuclear markers. *Molecular Ecol*. **8**:S41-S54.

Rossman, M.C. and R.L. Merrick. 1999. Harbor porpoise bycatch in the Northeast multispecies sink gillnet fishery and the Mid-Atlantic coastal gillnet fishery in 1998 and during January-May 1999. Northeast Fish. Sci. Cent. Ref. Doc. 99-17. 36 p. Available from: National Marine Fisheries Service, 166 Water Street, Woods Hole, MA 02543-1026.

Smith, S.J. 1999. Comments on using the Binomial distribution to model marine mammal encounter rates. Pp. 20-21 *In*: Didier, A.J. Jr., and V.R. Cornish, (Eds.). Development of a process for the long-term monitoring of MMPA Category I and II commercial fisheries. Proceedings of a workshop held in Silver Spring, Maryland, 15-16 June 1998. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-OPR-14, 46 p.

Smith, T., D. Palka and K. Bisack. 1993. Biological significance of bycatch of harbor porpoise in the Gulf of Maine demersal gillnet fishery. NOAA, NMFS, Northeast Fisheries Science Center Ref. Doc. 93-23, Woods Hole, Massachusetts. 15 p.

Tolley, K.A., P.E. Rosel, M. Walton, A. Bjøre and N. Øien. 1999. Genetic population structure of harbour porpoises (*Phocoena phocoena*) in the North Sea and Norwegian waters. *J. Cet. Res. Manage*. **1**:2655-274.

Vinther, M. 1994. Investigations on the North Sea gillnet fisheries. Landbrugs- og Fiskeriministeriet. Danmarks Fiskeriundersogelser. DFU-rapport 485-95. 26 p.

Vinther, M. 1995. Incidental catch of the harbour porpoise (*Phocoena phocoena*) in the Danish North Sea gill-net fisheries: preliminary results. Proceedings of the Scientific Symposium in the North Sea Quality Status Report, Ebeltoft 1994. 210-213.

Wade, P. 1999. Planning observer coverage by calculating the expected number of observed mortalities. Pp. 18-19 *In*: Didier, A.J. Jr., and V.R. Cornish (Eds.). Development of a process for the long-term monitoring of MMPA Category I and II commercial fisheries. Proceedings of a workshop held in Silver Spring, Maryland, 15-16 June 1998. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-OPR-14, 46 p.

Wang, J.Y., Gaskin, D. and White, B.N. 1996. Mitochondrial DNA analysis of harbour porpoise, *Phocoena phocoena*, subpopulations in North American waters. *Can. J. Fish. Aquat. Sci*. **53**:1632-1645.

Waring, G.T., J.M. Quintal, and S.L. Swartz (Eds). 2000. US Atlantic and Gulf of Mexico marine mammal stock assessments – 2000. US Dep. Commerce., NOAA Tech. Memo. NMFS-NE-@.

Westgate, A.J. and K.A. Tolley. 1999. Geographical differences in organochlorine contaminants in harbour porpoises (*Phocoena phocoena*) from the western North Atlantic. *Mar. Ecol. Progr. Ser*. **177**:255-268.

Westgate, A.J., D.C.G. Muir, D.E. Gaskin, and M.C.S. Kingsley. 1997. Concentrations and accumulations patterns of organochlorine contaminants in the blubber of harbour porpoises, *Phocoena phocoena*, from the coast of Newfoundland, the Gulf of St. Lawrence and the Bay of Fundy/Gulf of Maine. *Environ. Pollution* **95**:105-119.

Westgate, A.J., A.J. Read, T.M. Cox, T.D. Schofield, and B.R. Whitaker. 1998. Monitoring a rehabilitated harbor porpoise using satellite telemetry. *Mar. Mamm. Sci*. **14**:599-604.