INCIDENTAL CAPTURE OF HARBOUR PORPOISE, PHOCOENA PHOCOENA, IN THREE GILLNET FISHERIES OF THE NORTHWEST ATLANTIC: AN INVESTIGATION OF POSSIBLE FACTORS

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INCIDENTAL CAPTURE OF HARBOUR PORPOISE, *PHOCOENA PHOCOENA*, IN THREE GILLNET FISHERIES OF THE NORTHWEST ATLANTIC: AN INVESTIGATION OF POSSIBLE FACTORS

by

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ABSTRACT

There is increased concern for harbour porpoise (*Phocoena phocoena*) susceptibility to incidental mortality in commercial fisheries throughout their range. 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 bycatch over two seasons. Target species capture varied between seasons, altering the relationship of target species fish and bycatch. For one of the two seasons where mesh size varied, it showed a relationship to harbour porpoise bycatch. 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, 64% of the porpoises were sexually mature, 23% 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 analyzed and was the longest prey fish (44-332 mm).

Environmental data were collected over the 159 days of the study. Bycatch 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 bycatches 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.

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"So in human relations with porpoises, let us first recognize that they are part of enormously complicated systems in the sea, whose intricacy we can scarcely hope to understand fully. Next, let us gain enough wisdom about their basic biology for us to lay guidelines that will let us tamper with them in such a way that their integrity, both as species and as parts of the living web of the sea, remains intact and responsive to the flux and flow of the world. Finally, let us look with wonder at all the capabilities of these superbly adapted marine mammals, for themselves, and not for any relation they may have to human affairs."

Dr. Kenneth Norris
The Porpoise Watcher (1974)

CHAPTER 1: INTRODUCTION

1.1 OVERVIEW

The unintended capture of small cetaceans (odontocetes) by gillnets used in coastal fisheries is a global phenomenon with substantial implications for the conservation of many species (Northridge and Pilleri 1986; IWC 1994; Tregenza *et al.*1997; Perrin 1999). During the past several decades small cetaceans have suffered appreciable mortality due to such incidental captures as fishery effort by commercial gillnets has intensified world wide (Jefferson and Curry 1994; IWC 1994; Kinze *et al.* 1994; Perrin 1999).

Small cetaceans are particularly susceptible to gillnet mortality because unlike larger whales, they are often unable to pull nets to the surface, or to free themselves. Of all the small cetaceans, the harbour porpoise *Phocoena phocoena*, is believed to be one of the most vulnerable to incidental capture due to its particularly small size and affinity for coastal habitats which overlap commercial net fisheries. In many areas throughout the harbour porpoise's range, its capture in gillnets is considered to be a major human-induced mortality factor (Northridge 1988; Donovan and Bjorge 1995; Trippel *et al.* 1996; Tregenza *et al.* 1997). In the United States for instance, the Gulf of Maine/Bay of Fundy stock is currently classified as "strategic," and is presently being considered for listing as a "threatened" species under the Endangered Species Act (National Marine Fisheries Serrvice (NMFS) 1993; Waring *et al.* 1999). In Canada, the Northwest Atlantic population has been designated as threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (Gaskin 1992).

Recognizing the threat to harbour porpoise populations posed by incidental fishing mortality, the International Whaling Commission (IWC) identified the harbour porpoise and several other species as small cetaceans currently suffering high levels of incidental mortality in passive fishing gear. The IWC urged that anthropogenic mortality due to incidental capture should be reduced, or eliminated immediately for nine cetacean populations (IWC 1994). These species include:

1. Harbour porpoise throughout their range in the northern hemisphere;
2. Baiji (*Lipotes vexillifer*) of the Yangtze River;
3. Indo-Pacific hump-backed dolphins (*Sousa teuszii*) of the Natal coast of South Africa;
4. Striped dolphins (*Stenella coeruleoalba*) in the Mediterranean Sea;
5. Vaquita (*Phocoena sinus*) in the Gulf of California, Mexico;
6. Hector's dolphin *(Cephalorhynchus hectori)* in New Zealand;

7. Bottlenose dolphin *(Tursiops truncatus)* in South Africa;
8. Dusky dolphins (*Lagenorhynchus obscurus)* in the eastern South Pacific;
9. Northern right whale dolphins (*Lissodelphis borealis*) in the central North Pacific.

The Scientific Committee of the IWC first recommended that research be initiated to investigate a possible world wide decline in harbour porpoise in 1983. Because of population dynamics, feeding ecology, and existing bycatch estimates, the IWC issued a *Resolution On Harbour Porpoise In The North Atlantic and the Baltic Sea* which gave priority to the reduction of harbour porpoise entrapment mortality in the North Atlantic (IWC 1994; Appendix 3). Despite research programs to better understand this problem and develop mitigation methods, scientists postulate that harbour porpoise bycatch mortality has not shown the decreases necessary throughout its distribution to insure sustainability for most populations (IWC 1994; De Conti 1996; Caswell *et al.* 1998).

Although there is widespread concern about its impact, knowledge about how harbour porpoise bycatch occurs is limited. The issue of cetacean mortality in gillnets is biologically and sociologically intricate with no consensus regarding solutions for their conservation and management (Perrin 1999). The challenge is to integrate biological assessments of each harbour porpoise population affected by incidental captures with a rigorous impact monitoring program in order to minimize any negative effects to the commercial fishing effort and to porpoise populations. Incidental capture of cetaceans may involve a singular parameter or a combination of several factors that include operational, biological and environmental variables. Additionally, causal factors for entrapments may vary between different fisheries and regions.

As there were few quantitative data to help assess factors which may contribute to incidental capture, in 1995 the IWC sub-committee on small cetaceans recommended that a multidisciplinary programme be conducted to improve our knowledge of harbour porpoise bycatch. The Scientific Committee of the IWC recommended that particular priority be given to research that examines the operational and behavioural processes underlying harbour porpoise incidental capture (IWC 1995). The objective of this study is to address this need by investigating factors related to incidental capture. The approach taken in this research is to conduct a comprehensive study of the dynamics of harbour porpoise bycatch.

1.2 OBJECTIVES OF STUDY

This study was undertaken to understand the dynamics of harbour porpoise entanglement in groundfish gillnets. It was predicated on the assumption that a better understanding of the circumstances which contribute to the incidental mortality of harbour porpoise is necessary to develop constructive management actions. The objectives of the study were to obtain (1) operational, (2) ecological, and (3) sociological information on gillnet fisheries in the Northwest Atlantic that capture harbour porpoise incidental to their operations, and to (4) gather biological information about the captured harbour porpoise.

The four components of the study were: (1) to monitor the observed take of harbour porpoise from several fisheries in the Northwest Atlantic; (2) to examine this bycatch for operational, biological and environmental regularities, and where possible, to interpret their biological and statistical significance; (3) to estimate the time since death of harbour porpoise as it relates to fishery practices; and, (4) to gather and evaluate fishermen's observations of factors that were correlated with harbour porpoise capture in coastal gillnets. To achieve these objectives I examined factors that contributed to harbour porpoise entrapment in demersal gillnets and that have not been adequately quantified in past investigations. In summary, relationships between bycatch and the context in which they occurred were evaluated.

1.3 THE HARBOUR PORPOISE

The harbour porpoise is the smallest cetacean that inhabits temperate and subarctic coastal shelf waters of the Northern Hemisphere in a near circumpolar distribution (Figure 1.1). It is an upper trophic level predator that feeds mainly on aggregations of high-lipid content fish less than 25 cm in length (Yasui and Gaskin 1986; Recchia and Read 1989). Harbour porpoise often feed on the prey of commercially important fish species, or on commercially important fish species, but usually when the fish are younger in age and shorter in length than those caught by commercial fishermen.

In the western North Atlantic, harbour porpoise occur from Nunavut Island south to North Carolina (Read and Hohn 1995). Three sub-populations have been identified in eastern American and Canadian waters through studies employing mitochondrial DNA, life history parameters and monitoring of tagged animals. These include: (1) eastern Labrador and Newfoundland, (2) Gulf of St. Lawrence, and (3) Gulf of Maine/Bay of Fundy (Figure 1.2). Research for this study focused on Gulf of Maine/Bay of Fundy and eastern Newfoundland harbour porpoise as no research was conducted in the Gulf of St. Lawrence.

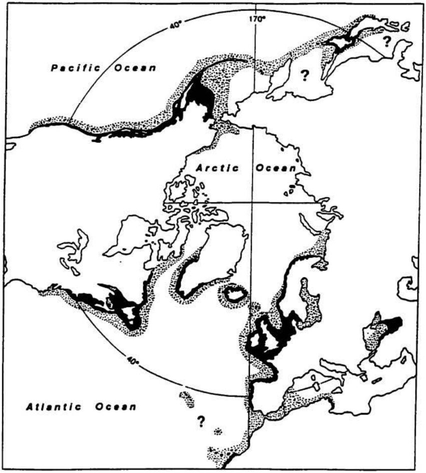


Figure 1.1: Global distribution of harbour porpoise. Blackened areas indicate known consistent occurrence; stippled sites are peripheral or probable range. Based on Klinowska (1991).

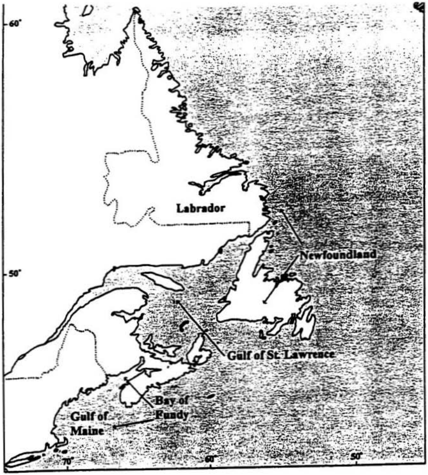


Figure 1.2: Location of three sub-populations of harbour porpoise identified by Gaskin (1992).

The Newfoundland and Labrador sub-population is considered distinct from that of the Gulf of Maine (Wang *et al.* 1996). There is no population estimate, and there are few data on the number of harbour porpoise incidentally caught in Newfoundland and Labrador. Catches occur in surface fishing nets set for herring and mackerel and in bottom fishing nets set for a variety of species. A study by Lien *et al.* (1994) which employed five methodologies for obtaining bycatch information from fishermen, estimated that the catch of harbour porpoise was probably in the low thousands per annum in traditional fishery areas of Newfoundland and Labrador during the 1980's.

In the past mortality due to bycatch in Newfoundland and Labrador waters may have been a major threat to this population (Lien 1989). However, for the past several years a fishery moratorium has drastically reduced net effort (Fisheries Resources Conservation Council 1997) and presumably bycatch. However, a net fishery for lumpfish, *Cyclopterus lumpus*, and bait nets for herring, *Clupea harengus*, continue, and there is some renewed fishing for groundfish. Presumably, all result in some continuing but undetermined bycatch of harbour porpoise.

The Gulf of Maine/Bay of Fundy transboundary harbour porpoise sub-population consists of approximately 54,300 (CV=0.14, 95% CI=41,300-71,400) animals (Waring *et al.* 1999). Incidental catches from this population occur in both Canadian and United States commercial fisheries (Trippel *et al.*1996). Incidental catches of harbour porpoise have been recorded in the Gulf of Maine since 1990 (Trippel *et al.* 1996). The combined 1993 Canadian and United States bycatch of Gulf of Maine/Bay of Fundy harbour porpoise in gillnets was estimated to be 1,824 with 424 caught in Canadian waters and 1,400 in United States waters. During the 1994 groundfish gillnet fishing season, a combined bycatch of 2,201 harbour porpoise was estimated; of this amount, 101 were entangled in Canadian nets and 2,100 in American nets. The combined 1995 bycatch was estimated to be 1,487; 1,400 of these occurred in United States waters (Bisack 1997).

These current annual bycatch estimates exceed the 483 bycatch mortality limit recommended by the Marine Mammal Protection Act as the Potential Biological Removal (PBR) rate for the Gulf of Maine/Bay of Fundy sub-population (Trippel *et al.* 1996; Waring *et al.* 1999; Table 1.1). The PBR rate is defined as "the maximum number of animals, not including natural mortalities, that may be removed from a marine mammal stock while allowing that stock to reach or maintain its optimum sustainable population" (Waring *et al.* 1999). The PBR is

Table 1.1: Estimates of harbour porpoise population size and bycatch for the Gulf of Maine and Bay of Fundy (1990-1995).

Year	Population size	Bycatch	USA	Canada	Source
1990	unknown	2,900	1,500-5,500[a]	unknown	Bravington and Bisack (1996)
1991	37,500 (26,700-86,400)[a]	2,000	1,000-3,800[a]	unknown	Palka (1995); Bravington and Bisack (1996)
1992	67,000 (32,000-104,600)[a]	1,200	800-1,700[a]	unknown	Palka (1995); Bravington and Bisack (1996)
1993	unknown	1,400	1,000-2,000[a]	424 (200-648)[b]	Bravington and Bisack (1996); Trippel *et al.* (1996)
1994	unknown	2,201	1,400-2,900[a]	101 (80-122)[a]	Bisack (1997)
1995	54,300 (41,300-71,400)[a]	1,487	900-2,500[a]	87[a]	Waring *et al.* (1999)

[a] = Ranges are 95% confidence limits. [b] = Range is ± 1 SE.

calculated by three functions: (1) the minimum population estimate; (2) one-half the estimated net productivity rate; and, (3) a recovery factor of between 0.1 and 1.0 for stocks whose status is unknown with respect to optimal sustainable population levels (Wade 1998; Waring *et al.* 1999).

This study examines the incidental fishing mortality of both the Newfoundland and Labrador and the Gulf of Maine/Bay of Fundy harbour porpoise. Data were collected aboard groundfish gillnet vessels in St. Bride's, Newfoundland, from Jeffery's Ledge in the Gulf of Maine and from waters adjacent to Grand Manan Island in the Bay of Fundy.

1.4 POSSIBLE FACTORS AFFECTING HARBOUR PORPOISE BYCATCH

1.4.1 Operational factors

The gillnets used for harvesting groundfish in which harbour porpoise become entangled are a major factor influencing rates of harbour porpoise bycatch (Dawson 1994; Perrin 1999). Gillnets are fixed, rectangular nets deployed in the form of a wall which entangle or ensnare fish in their webbing. Tautness is achieved by floats on the headline, a weighted leadline on the bottom and anchors at each end of the net. Gillnet fishing is believed to represent the single most significant threat to odontocete populations and this threat is exacerbated by gillnets' common use in coastal ocean habitat frequented by small cetaceans

(Jefferson and Curry 1994; IWC 1994; Perrin 1999).

Traditionally, gillnets were constructed of multifilament natural fibers. It appears that these nets are both visually and acoustically detectable by marine mammals (Au 1994). Modern gillnets are constructed of monofilament fibre which has a density range similar to that of water. The sonar echo from a modern gillnet is weak but it is considered above the acoustic detection thresholds of cetaceans under most conditions (Hatakeyama *et al.* 1990; Au and Jones 1991; Dawson 1991; Au 1994).

Harbour porpoise are able to detect monofilament nets of 0.1 mm diameter or greater. However, animals are frequently captured in nylon filaments as large as 0.8 mm (Au and Jones 1991; Dawson 1991; Au 1994). This discrepancy suggests that capture is not due simply to a failure to detect the gillnets but may be a consequence of multiple behavioural and environmental factors, including the following. (1) Porpoise echolocate only periodically to interrogate their environment which may result in reduced ability to detect nets. (2) The animal may not perceive the net as a barrier but rather as a penetrable object, or may exhibit other inappropriate barrier behaviour. (3) The animal may be inattentive while foraging or engaged in other activities. (4) The net may be occluded by prey or water conditions. (5) Behaviours such as exploration, curiosity, or typical escape patterns may result in entrapment. In addition, factors such as a lack of familiarity and experience with nets may contribute to entrapments (Cockcroft 1992; 1994).

Operational factors contributing to incidental entrapment of harbour porpoise include net characteristics and spatial and temporal fishing patterns (Dawson 1991; Cockcroft 1994). Circumstantial evidence suggests that increases in the length of strings (individual nets tied together at a bridle area to form a wall of nets) of gillnets are associated with increased capture rate (Lien *et al.* 1995). Capture rate per net also increased with the amount of time nets were left in the water (Richter 1998; Vinther 1999).

The issue of when the harbour porpoise is caught has important practical implications. A primary question regarding harbour porpoise captures in bottom fishing nets is whether entrapment occurs during net deployment, while the net is fishing, or during net retrieval. Sinking and retrieval times of nets fishing at depths of $\geq$ 30 m may be in excess of 30-60 mins. Thus, there is a reasonable percentage of time (perhaps as high as 10-15%) that nets could catch porpoise at less than target depths (Hood *et al.* 1996). During this period porpoise may have greater difficulty detecting clean nets as they are first placed in the water, or they could be attracted by nets full of fish as they are hauled. Thus, captures which occur during either deployment or retrieval are possible.

If captures occur as the net descends, then heavier anchors which sink the net more quickly may minimize harbour porpoise catches. If captures occur as the net is being hauled, then, shorter strings requiring less hauling time may reduce catches. Captures which occur as the net fishes at depth might be reduced by enhancing the detectability of the net (Lien *et al.* 1995). Thus, modifying fishing methods may help to mitigate incidental captures.

Depth has also been indicated as an important factor in incidental captures. Gaskin (1992) and Richter (1998) reported that harbour porpoise have a preference for deeper depths in the Bay of Fundy. Porpoise were less abundant in shallow waters and more abundant in water depths of greater than 72 m. Westgate *et al.* (1995) utilized time and depth recorders attached to harbour porpoise in the Bay of Fundy to show that harbour porpoise dive to depths of 20-130 m. Richter (1998) found that the greatest number of harbour porpoise were captured in Bay of Fundy waters deeper than 70 m. Similar results were reported by Kraus *et al.* (1995) for harbour porpoise captured in the Gulf of Maine.

1.4.2 Environmental factors

Previous studies have postulated that water column temperature and water clarity may be related to harbour porpoise distribution and incidental capture (Cockcroft 1994). Harbour porpoise in the Gulf of Maine/Bay of Fundy are found in waters of 10-13.5°C (Trippel *et al.* 1996). Gaskin (1992) located harbour porpoise in a range of temperatures from 7-15°C with most in 11-14°C water. The reason for a correlation between temperature and harbour porpoise distribution remains unclear. A possible explanation advanced by Brodie (1995) is that water temperature may be correlated with the distribution of prey species.

A number of investigators (Murison and Gaskin 1989; Cockcroft 1991; Smith and Whitehead 1993; Brodie 1995) document a relationship between sea water temperature and the abundance of prey species for cetaceans. In particular, herring, silver hake and capelin are found in temperatures preferred by harbour porpoise (Scott and Scott 1988; Recchia and Read 1989; Gaskin 1992). These relationships lend credence to the hypothesis that temperature may correlate with fish abundance and thus with harbour porpoise capture, though a causal relationship has yet to be demonstrated.

Cockcroft (1994) reported that distribution and occurrence of bottlenose dolphins from the Natal coast of South Africa is linked to water clarity, though the reason for such a correlation is not clear. Turbidity, or lack of clarity of the water column, is affected by the amount, size, and properties of suspended particles present in the water column. Additionally, oceanographic and atmospheric conditions such as storms, currents, tides, wind and sediments from continental erosion transported to the ocean by rivers, may influence turbidity. A resultant lack of water clarity from any or a combination of the above factors may limit light penetration and reduce the abilities of animals to detect gillnets.

Since vision may be a primary sense for orientation in cetaceans (Mobley and Helweg 1990; Wartzok and Ketten 1999), swimming in highly turbid waters may diminish the ability to detect objects. Coastal areas are especially vulnerable to human activities affecting turbidity, such as dredging, bilge pumping from vessels, dragging and sewage and storm drain effluent. To date there is a paucity of information on the effect of turbidity on cetacean entrapment in gillnets. As well, there are no data that document the activity of harbour porpoise at night, and since time of capture is generally unknown, it is unclear if the animals are predisposed to higher rates of capture during night darkness.

Noise generated by high winds and sea state may cause nets to be less acoustically detectable and thus, net detection may be more difficult. Lien *et al.* (1990) suggested that high levels of ambient noise may create high risk areas for entrapment of humpback whales. Likewise, a turbulent sea state during rough weather conditions may mask noises produced by gillnets, causing harbour porpoise to swim in an acoustically opaque environment and become entangled more frequently.

Fluctuations in environmental parameters which directly impact the abundance and distribution of prey species may initiate spatial and temporal behaviour in harbour porpoise foraging which predispose them to bycatch. For instance, the time and distance a harbour porpoise has to forage before locating prey influences the number of nets it will encounter. Fluctuations in oceanographic or atmospheric factors such as salinity, turbidity or coastal influences may diminish abundance, distribution or energy density of prey available for the harbour porpoise (Brodie 1995). A consequent reduction in density of prey populations may result in loss of fitness. Fitness has historically been defined as being favoured physically in the struggle for existence. In current biology terms, fitness is defined as "the success of an individual in leaving copies of its genotype in the next generation relative to that of other individuals with their genotypes" (Immelmann and Beer 1989).

1.4.3 Biological factors

Biological parameters which are possible factors involved in harbour porpoise capture include: occurrence of fishery target species, presence or absence of prey species and harbour porpoise behaviour near nets (IWC 1994; Brodie 1995). Prey-related seasonal abundance and the distribution patterns of harbour porpoise have been hypothesized as factors in the Northwest Atlantic (Brodie 1995), Pacific (Silber *et al.* 1994) and Swedish Skagerrak, Kattegat and Baltic Seas (Berggren and Arrhenius 1995). Spatial and temporal aspects of net mortality indicate the largest numbers of harbour porpoise are incidentally captured when commercial gillnet fisheries co-occur with prey species and foraging porpoise (Piatt and Nettleship 1987; Brodie 1995; Trippel and Conway 1995). If feeding is correlated with captures it may follow that parameters related to prey abundance and distribution, for example, salinity, temperature and turbidity, are important contributing conditions and certainly predictive factors (Cockcroft 1994; Carscadden *et al.* 1997).

In each of the three study sites I examine the roles that net characteristics, water temperature, water clarity, target species landings and prey abundance play in harbour porpoise bycatch.

1.5 ELAPSED TIME SINCE DEATH

Studies to estimate elapsed time since death in humans have been carried out by human forensic pathologists (Coe 1989; DiMaio and DiMaio 1989; Henssge *et al.* 1995; Knight 1991; 1997), in wildlife by wildlife scientists (Johnson *et al.* 1980; Pex *et al.* 1983; Cox *et al.* 1994), and by veterinarians working with domestic animals (Hanna *et al.* 1990). A wide variety of techniques have been used, the most common being calculations based upon postmortem changes in ocular fluid and decreases in body temperature.

Few research data are available on postmortem decline in temperature of marine mammals (Cockcroft 1991; McLellan *et al.* 1995). In addition, only antemortem levels of chemical elements in harbour porpoise serum have been reported (Kastelein *et al.* 1990; Koopman *et al.* 1995). Currently, no measures of postmortem change in harbour porpoise vitreous humour fluid rates have been reported. Such measurements may provide valuable clues in evaluating the time of death in harbour porpoise. Moreover, examination of body cooling and ocular fluids in conjunction with operational variables, such as the time the net was placed in the water, may provide valuable evidence as to the time of death and may facilitate identification of reasons for capture. For this study, vitreous fluid and core body temperature were collected from retrieved porpoise during the

1994 and 1995 research seasons in an attempt to estimate the time since death of the animals.

Human forensic scientists have found that chloride, calcium, phosphorus, urea, sodium and the sodium-potassium ratio remain stable in the vitreous humour for prolonged postmortem intervals. However, potassium, magnesium, and glucose may prove useful as ancillary chemicals in order to determine time since death (Henssge *et al.* 1995). The levels of increase in potassium and decrease in glucose show definite changes with increase in the postmortem interval making estimation of elapsed time since death possible (Knight 1991; Henssge *et al.* 1995), and when the body has been in ocean water, magnesium has been shown to increase (Sturner *et al.* 1976; Knight 1991; Henssge *et al.*1995). These biochemical variables which have proven useful in human, wild and domestic animal forensic science, may be useful for estimating time since death in harbour porpoise as well.

1.5.1 Vitreous humour constituents

Chemical tests to determine the postmortem interval in humans have been widely used and are considered to have clinical value for the forensic pathologist. The postmortem chemistry of vitreous humour shows distinct advantages for use in forensic pathology (Coe 1989; Knight 1991; Henssge *et al.* 1995). Chemical changes in the ocular fluid such as fluctuations in potassium or glucose values provide accurate quantitative results toward the estimation of time since death (Cox *et al.* 1994). Biochemical postmortem changes occur at a slower rate in vitreous fluid since it remains relatively intact, protected from autolytic change during the early postmortem period. Vitreous fluid has slight contact with cells undergoing postmortem autolysis and is least subject to postmortem changes of all body fluids (Henssge *et al.*1995). In addition, it is easy to extract from the ocular socket (Sebag 1989; Knight 1991).

Vitreous potassium which diffuses postmortem from the retina into the vitreous body as autolysis proceeds is considered by Henssge *et al.* (1995) to be the best parameter for study of time of death. This breakdown of cells causes a gradual increase of potassium with elapsed time since death (Sebag 1989; Knight 1991; Henssge *et al.* 1995). Potassium content of the vitreous humor shows a linear rise with time after death in humans until approximately 100 hrs postmortem (Coe 1989) and is essentially independent of external factors (Henry and Smith 1980; Henssge *et al.* 1995). Several authors (Adelson *et al.* 1963; Sturner 1963; Sturner and Gantner 1964; Coe 1972; Stephens and Richards 1987; Coe 1989; DiMaio and DiMaio 1989; Madea *et al.* 1990; Cox *et al.* 1994; Henssge *et al.* 1995; Knight 1997) have documented a time dependent rise in vitreous potassium.

Johnson *et al.* (1980) found a 0.1 mmol/L postmortem increase of potassium concentration in mule deer over a 10 hr test span. Hanna *et al.* (1990) extracted vitreous fluid from euthanized cattle. A biochemical profile showed the mean potassium concentrations increased by 60% in a 24 hr period. The value for potassium in serum of live harbour porpoise is 3.1-8.3 mmol/L, mean 4.64 (SD= 1.30; n=27; Koopman *et al.* 1995).

Magnesium level of the vitreous is fairly stable in postmortem adult humans (Henry and Smith 1980; Knight 1991). However, magnesium levels in the vitreous of humans drowned in salt water are reported to increase after death (Sturner *et al.* 1976; Knight 1991). Adjutantis and Coutselinis (1974) and Farmer *et al.* (1985) found in cases of salt water immersion at death, magnesium ions diffuse into human eye fluid. Magnesium content does not reach equilibrium with the surrounding water, or 100% magnesium saturation, for approximately 24 hrs (Henssge *et al.* 1995). Sturner *et al.* (1976) studied bovine eyes immersed in salt water and found a steady increase of magnesium over time with saturation complete within 24 hrs. If the rate of diffusion of magnesium occurs in relationship to the length of the immersion period, postmortem measures of magnesium may be used as a time dependent indicator of elapsed time since death. Mean magnesium levels in live harbour porpoise serum are; 0.75 (SD= 0.16 mmol/L; range 0.51-1.28, n=27; Koopman *et al.*1995).

Knight (1991) reports that levels of glucose in fresh samples of vitreous humour are similar to those in human serum. Glucose has been found to decrease after death through the process of glycolysis (breakdown of the glucose molecule) (Guyton 1991). In bovine, canine, and feline samples, mean glucose concentrations in vitreous humor between 0-24 hrs after death displayed a continuous decrease of the glucose concentration over the postmortem interval (Hanna *et al.* 1990). Antemortem mean levels in harbour porpoise reported by Koopman *et al.* (1995) are 10.87 $\pm$ 1.46 (range=8.2-13.8 mmol/L, n=27).

1.5.2 Body cooling

Theoretically, cooling of the body commences as soon as life ceases, with a progressive decline until body temperature reaches that of the surrounding environment (Knight 1997). After death circulation transferring heat from the inner core to the surface stops, causing heat within the inner core organs including the liver, to remain constant for a period of time. Rate of cooling is affected by a variety of factors such as, the difference between body temperature and ambient temperature, body mass and condition and blubber thickness. Additionally, the high thermal conductivity of water causes a submerged body to lose heat at a rate approximately twice that in air, i.e. 2-3 ^{0}C/hr (Gee and Watson 1989; Knight 1991; 1997).

There are few data on postmortem temperature changes in cetaceans. Kastelein (1994; unpublished data) recorded 36.2°C (range 35.0-37.1°C) as the average rectal temperature taken from two captive harbour porpoise maintained in 18°C pool water. These rates are within the normal mammalian range of 35-38°C (Norris 1966). McLellan *et al.* (1995) observed that a harbour porpoise dead for approximately ten minutes had a core temperature of 34°C in an ambient air temperature of 14-16°C. The carcass remained out of the water for approximately 60-120 minutes while being fitted with metal thermocouples, it was then returned to sea water. Core temperatures were taken every half hour for 24 hrs. The carcass temperature decreased for approximately 500 minutes (8.3 hrs) at an average rate of 2.5°C per hr until it reached ambient water temperature. Cockcroft (1991) recorded similar results with postmortem body temperatures from a striped dolphin (*Stenella coeruleoalba*); temperature decreased for up to 500 minutes until ambient temperature was reached.

1.5.3 Elapsed time since death research criteria

This segment of research had two objectives: (1) to develop and evaluate a time of death index for harbour porpoise from one-time measurements of value changes in ocular fluid and deep core temperature; (2) determine the time required for a net to sink to fishing depth and compare time profiles with nets that caught harbour porpoise and those which did not in order to evaluate if sink time is a contributing factor to the incidental capture of these animals.

In order to accomplish the above, this research examined the relationships between deep core temperature, water temperature and ancillary chemicals of individual animals against changes in the three primary determinants: potassium, magnesium and glucose in an attempt to answer the following questions:

1. Are biochemical parameters alone, or in combination, useful diagnostic tools for determining elapsed time since death in harbour porpoise?
2. Is there a relationship between chemical values or core temperature and ambient temperature, or the soak time of a net in the water?
3. How do postmortem values compare to antemortem values?

1.6 SOCIOLOGICAL DATA

1.6.1 Fishermen's traditional knowledge

Historically, the perception has been that scientists and fishermen have not consistently exchanged information related to bycatch issues (Lien and Hood 2000). Consequently, fishermen have not always been well represented, or on occasion, have been excluded from decision making processes in fisheries management (Lane and Stephenson 1995; Richter 1998). Lack of involvement from user groups has been problematic resulting in divisiveness between fishermen and scientists with each group maintaining their own agenda with little or no integration of knowledge from the two groups. Fishermen, through their daily experience, have intricate knowledge concerning the spatial and temporal distribution of fish stocks and harbour porpoise. It follows that an effective way to determine the number of animals captured and to collect data pertinent to nets which capture and those which do not is to be an active member of the fishing crew.

In this study, I use direct observation (observers were active volunteer crew members), collaborative study designs, consultations and surveys, to incorporate fishermen's traditional knowledge into an assessment of the factors influencing harbour porpoise bycatch in their gillnets. This cooperative-based approach was used to link the underutilized knowledge of fishermen with scientific data in hopes of expanding the understanding of and facilitating a practical solution to the problem of harbour porpoise incidental capture in gillnets.

1.7 MANAGEMENT AND MITIGATION

A variety of management measures have been investigated to reduce and or mitigate the incidental capture of harbour porpoise in gillnets, including time and/or area closures and bycatch quotas (a method which limits the number/weight of the bycatch of one or more species) (Polacheck 1989; De Conti 1996). Modifications in net-setting procedures, such as a reduction in net length, decrease in soak duration, relocation of nets further from shore, decrease in numbers of nets set to reduce fleet effort, decrease in setting time, and net modification to make nets more species specific have also been identified as possible management regimes for the conservation of harbour porpoise (IWC 1994; Jefferson and Curry 1994; Silber *et al.* 1994).

Closures that prohibit commercial fishing either year round or during seasonal abundance or critical activities, have also been legislated. For example the United States closes significant regions of the California coast to gillnet fishing as a conservation measure to protect sea otter and harbour porpoise populations (Dawson 1991). Some scientists advocate a total elimination of gillnets as the only answer (Dawson 1991; Silber *et al.* 1994). Evaluation of the likely effectiveness of all but the last measure suffers from a lack of information regarding the behaviour of porpoise near the nets and the scenarios which result in capture (Lien *et al.* 1995).

In response to the capture problem several scientists have investigated the concept of demarcating gillnets with acoustic devices to render them acoustically more detectable to the animals, or to warn of the nets presence (Kraus *et al.* 1995; Lien *et al.* 1995; Richter 1998). To date most harbour porpoise bycatch mitigation studies have focused on the use of acoustic alarms. Experiments to test the efficacy of acoustic alarms have been conducted in the Gulf of Maine/Bay of Fundy region with results to date strongly supporting the efficacy of alarms to act as a deterrent to bycatch (Lien and Hood 1994; Kraus *et al.* 1995; 1997; Lien *et al.* 1995; Trippel *et al.* 1995;1996; Richter 1998). Evidence from these studies suggests that harbour porpoise actively avoid alarmed nets but alarms should not be regarded as the only potential solution to the cetacean bycatch problem (Dawson 1991;1994; Kraus *et al.* 1995;1997). Alarms may help but it is still not clear why captures occur and such devices may have unintended impacts on harbour porpoise and other marine mammals present in the water.

This study investigates the incidental capture of harbour porpoise in three regions of the Northwest Atlantic where the incidental capture of harbour porpoise have historically and are presently occurring. It examines which operational, biological or environmental parameters relate to the bycatch of harbour porpoise in groundfish gillnets. It provides a cooperative methodology with fishermen including a survey of their opinions surrounding this issue. Finally, it discusses the results of the research and makes recommendations for the reduction of incidental capture of harbour porpoise. By ascertaining which aspects of groundfishing most affect harbour porpoise bycatch, the results of this study could guide managers to make informed decisions about how to reduce or possibly eliminate incidental mortality.

CHAPTER 2: STUDY LOCATIONS AND METHODS

2.1.1 STUDY SITES

The bycatch of harbour porpoise was investigated in three regions of the Northwest Atlantic where incidental catches have historically and are presently occurring. These were St. Bride's, Newfoundland during the summer of 1993, Jeffreys Ledge in the Gulf of Maine USA, during the fall of 1993 and Grand Manan Island in the Bay of Fundy during the summers of 1994 and 1995 (Figure 2.1).

In order to gain an accurate account of bycatch, a cooperative approach with fishermen who frequently caught harbour porpoise was implemented at the onset of the project. Prior to commencement of field trials, fishermen who had experienced harbour porpoise bycatch were contacted by telephone and mail and asked to participate in the research. All the fishermen who chose to participate collaborated in the design and implementation of the research protocol in order to achieve standardized and agreeable methods and objectives toward the facilitation of the research goals.

Figure 2.1: Study areas in three regions of the Northwest Atlantic, St. Bride's, Placentia Bay, (1993), Gulf of Maine/Jeffreys Ledge, (1993), Grand Manan Island/Bay of Fundy, (1994-1995).

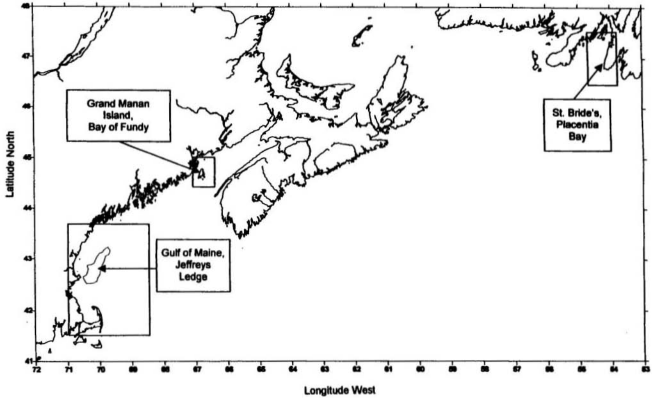


Figure 2.1: Study areas in three regions of the Northwest Atlantic, St. Bride's, Placentia Bay, (1993), Gulf of Maine/Jeffreys Ledge, (1993), Grand Manan Island/Bay of Fundy, (1994-1995).

Participating fishermen, as well as others active in the local fishery, were surveyed individually in order to collect their observations of harbour porpoise captures in gillnets. The objective of the survey was to systematically compile fishermen's knowledge of porpoise bycatch. The survey was viewed as a tool to combine fishermen's biological assessments with operational considerations. *In situ* interviews were used as they were considered to be more reliable compared to telephone interviews or mailed questionnaires (Lien *et al.* 1994).

2.1.2 St. Bride's, Newfoundland

St. Bride's is located on the eastern coast of Newfoundland at the entrance of Placentia Bay (46° 55' N, 54° 10' W; Figure 2.1). Mean depth on the surrounding fishing grounds is approximately 43 m (range 20-73 m). The summer ocean climate in June through August is characterized by a mean air temperature of 15°C (range 9-21°C) and mean sea surface temperature of 12°C (range 6-13.5°C). Tides are semi-diurnal with a range of 2-3 m. Prevailing winds are southwest to southerly at 10-25 km/hr. Southerly winds are accompanied by dense fog. Low visibility due to fog occurs 20-30 percent of the time during spring and early summer (Environment Canada 1993).

2.1.3 Gulf of Maine/Jeffreys Ledge

Monitored fishing effort occurred in the waters of Jeffreys Ledge. Jeffreys Ledge, located in the Gulf of Maine, is an elliptical, semi-enclosed sea, bordered by three New England states (New Hampshire, Massachusetts, and Maine), and by the Canadian provinces of New Brunswick and Nova Scotia. The surface area of the Gulf of Maine measures 79,000 square km with a mean depth of 150 m (range 40-200 m). Surface temperatures over Jeffreys Ledge are among the warmest in the gulf, averaging 12-18 °C during the summer (Conkling 1995, Figure 2.1).

2.1.4 Grand Manan Island/Bay of Fundy

The Bay of Fundy is a shallow funnel shaped lowland trough approximately 240 km long and 80 km wide at the mouth. It is located at the Northern edge of the Gulf of Maine. Due to its funnel shape, rapid narrowing, and shallow water depth, tides are funnelled to escalating heights as they surge forward to the head of the bay. Tidal amplitude varies from 4-5 m at the mouth of the Bay to 15 m at the head of the Bay (Environment Canada 1992). Grand Manan Island is situated near the mouth of the Bay of Fundy (44° 48' N, 66° 43' W) and is approximately 21 km long and 10 km at the widest point (Figure 2.1). Off the northeast coast of Grand Manan Island the mean water depth is 60 m. Monthly mean water temperatures are 10-13 °C from July to September (Environment Canada 1992).

2.2 SELECTION OF PARTICIPANTS

2.2.1 St. Bride's, Newfoundland

During the summer of 1992, a harbour porpoise study was conducted to determine biological (reproductive and growth) parameters of harbour porpoise in Newfoundland (Richardson 1992). Bycaught animals were retrieved and brought to shore by fishermen, anatomical measurements were taken and reproductive organs and teeth collected for age and sexual maturity determination. Six fishermen from St. Bride's, Newfoundland, who had either participated in the Richardson (1992) study, or were aware of it, were contacted during the winter of 1993 and asked to participate in this study. Individual meetings were held with each fisherman during the spring of 1993 to explain the goals of the research and solicit their suggestions for methodology and participation. All six fishermen agreed to participate in the research.

2.2.2 Gulf of Maine/Jeffreys Ledge

Study in the Gulf of Maine was preceded by research conducted in 1992 by the Whale Research Group of Memorial University, St. John's, Newfoundland (Lien *et al.* 1995). Five captains who had taken part in this previous experiment were contacted by telephone during the summer of 1993 for an initial introduction to the Fall 1993 research project. A letter containing research objectives and rationale followed this initial contact. Subsequently, individual meetings with each fisherman took place to discuss methodology. These meetings were followed by a group meeting with all participants in which research objectives were reiterated and final consensus reached on procedures.

2.2.3 Grand Manan Island/Bay of Fundy

An initial meeting took place in September of 1993 on Grand Manan Island, during which the fishermen requested acoustic deterrents in an effort to decrease or eliminate the capture of harbour porpoise in their nets. Additionally, they requested scientists to study the current groundfish bycatch situation by monitoring their fishing effort for the entire season. All the fishermen expressing interest in the research project were contacted by telephone in January of 1994. In April of 1994, a meeting with all participating fishermen was held on Grand Manan Island to discuss research objectives and goals.

2.3 DATA COLLECTION

2.3.1 Data classification

Data for all research seasons were collected under five headings: (1) operational (vessel characteristics, gear information, set and haul times, placement of net, and target species catch composition): (2) biological (catches of harbour porpoise, commercial fish and prey species): (3) environmental (oceanographic and atmospheric variables): (4) elapsed time since death of harbour porpoise: (5)

sociological (survey by structured interviews of fishermen at two research areas, fishermen from St. Bride's, Newfoundland were not surveyed). Details of specific parameters examined at each research location are presented in Table 2.1.

2.3.2 Operational data

All research was conducted *in situ* from fishing vessels harvesting groundfish. Vessels participating in this study ranged in length from 9-14 m. They fished with monofilament fibre gillnets ~90-100 m long which were tied together at the bridle area to form a vertical tie area where one net is tied to another end to end, (forming a string of nets), and hung in a wall ranging from 3-25 individual nets. Weather permitting, nets were hauled every 24 hrs and reset upon completion of hauling. Trained observers collected data by direct observation onboard participating vessels during every day of fishing effort for each study period.

For each gillnet set, the time of deployment, retrieval and soak time were recorded to the nearest hour. Fishing location of each set was determined using the Global Positioning System (GPS) or Loran tracking equipment on the vessel. Depth, defined as the maximum depth in metres at which the net was set, was obtained from electronic equipment (fish finders) on the vessel. The number of nets per string was counted. The distance of net placement from shore was

Table 2.1: Summary of data and samples collected in three regions of the Northwest Atlantic from 1993-1995; (Nfld.=Newfoundland; GOM=Gulf of Maine; BOF=Grand Manan Island).

Research locations

Operational data	Nfld. 1993	GOM 1993	BOF 1994	BOF 1995
set and haul date (d/m/y)	x	x	x	x
anchor weight (kg)	x	x	x	x
number of nets set	x	x	x	x
number of strings set	x	x	x	x
length of strings set (m)	x	x	x	x
proximity of bycatch to bridle	x	x	x	x
location of net set (latitude and longitude)	x	x	x	x
location of haul (latitude and longitude)	x	x	x	x
duration of soak time to nearest hour	x	x	x	x
depth of net set	x	x	x	x
distance of net from shore (km)	x	x	x	x
total catch of fish per species	x	x	x	x
Biological data from harbour porpoise				
gender	x	x	x	x
girth (cm)	x	n/a	x	x
standard length (cm)	x	x	x	x
body mass (kg)	x	x	n/a	n/a
stomachs for content analysis	x	x	x	x
teeth for age determination	n/a	x	n/a	x

Table 2.1: (continued)	Nfld. 1993	GOM 1993	BOF 1994	BOF 1995
Biological data from fish caught in net				
stomachs for content analysis	n/a	x	x	x
Environmental				
temperature profile	x	x	x	x
salinity profile	x	x	x	n/a
probe reading (net sink speed)	n/a	n/a	x	x
water visibility (Secchi disk)	x	n/a	x	x
wind speed (Beaufort scale)	x	x	x	x
sea state (Beaufort scale)	x	x	x	x
cloud cover (%)	x	x	x	x
weather (rain, fog, clear)	x	x	x	x
Elapsed time since death (ETSD)				
deep core temperature (^{0}C)	n/a	n/a	x	x
vitreous humour (ocular fluid)	n/a	n/a	x	x
intestine sample	n/a	n/a	x	n/a
liver specimen	n/a	n/a	x	n/a
Sociological data				
survey (oral/written)	n/a	x	x	x

measured in kilometres using radar equipment on the vessel. Anchors used to stabilize the nets were classified by weight (kilogram).

Catch per unit of effort (CPUE)

In order to address the effect of differences in the number of nets on a string, individual nets were used as the unit of effort. Fishing effort was defined in net days (ND) where one net day equalled a single net set for 24 hours. Harbour porpoise bycatch rate was calculated as the capture of porpoise per unit of fishing effort (CPUE), or as the number of porpoise caught per net day fished. In addition, the bycatch of harbour porpoise was calculated as the capture of porpoise per net and affiliated operational, biological and environmental parameters.

St. Bride's, Newfoundland

From 1 July-30 July, 1993 research was conducted from six vessels harvesting cod (*Gadus morhua)*, flounder (*Limanda ferruginea*), and/or lumpfish in coastal fishing grounds near St. Brides, Newfoundland (Figure 2.1). Three scientists from the Whale Research Group of Memorial University, St. John's, Newfoundland monitored a total of 469 strings (nets tied together) during 72 observer days (one observer per vessel per day=one observer day). Vessels fishing for lumpfish utilized 23.1 cm mesh nets which were hauled by hand.

Vessels harvesting flounder employed 17.6 cm mesh nets, while cod was harvested in nets with a mesh size of 12.1 cm. These nets were typically hauled mechanically. Two vessels harvested only lumpfish. Upon completion of the lumpfish fishery on 19 July, the remaining four vessels employed 12.1 cm mesh gillnets to target cod.

Strings consisting of 3-10 nets were set at a mean distance from shore of 2 km, and a mean depth of approximately 32.3 m. Strings were anchored at each end with large rocks weighing 13.5-18 kg and both ends were marked with a buoy.

Gulf of Maine/Jeffreys Ledge

From 13 October-18 December, 1993 research was conducted from five vessels based at the Portsmouth Fishermen's Cooperative, Pierce Island, New Hampshire, USA. The participating vessels targeted cod and pollock (*Pollachius virens)* at Jeffreys Ledge, approximately 45.4 km from shore in the western Gulf of Maine (42^0 50' N, 70^0 13' W) at a mean depth of 73 m (Figure 2.1).

Five observers were hired by the National Marine Fisheries Service (NMFS) Sea Sampling Observer Program for the fall/winter 1993 research season. A total of 565 strings (mesh size 15.2, 16.5, or 20 cm) were observed for 133 observer days. Nets were set and anchored at each end with steel bars (railroad rails) weighing approximately 13.5-18 kg. Five to twenty-five nets were tied together to form a string. Each end of the string was marked with an identifiable buoy. A daily set included four to five strings of nets. Hauling was accomplished with the assistance of a hydraulic lifter.

Grand Manan Island/Bay of Fundy

Two research seasons were completed on Grand Manan Island. The first lasted from 7 July-10 September, 1994 and the second from 3 July-26 September, 1995. Observer coverage was concentrated in the Swallowtail region of the Bay of Fundy on vessels departing from North Head Harbour (Figure 2.1). Observers were trained volunteers comprised mainly of university and/or college students with an interest in marine mammals.

In 1994 and 1995, seven fishermen participated in research. Fishing effort in both years consisted of day trips during which fishermen set four to five strings of three or four nets constructed of monofilament fibre with a mesh size of 15.2 cm. All vessels were equipped with a hydraulic lifter for hauling. Anchors weighed 15 -27 kg.

2.3.3 Biological data

All observed porpoise bycatch was counted and recorded. Those animals which were not lost as the fishing gear was retrieved were retained for further data collection. Retained animals were measured onboard for standard length in centimetres (defined as the straight line distance between the tip of the rostrum and the fluke notch in a straight line parallel to the body) using a flexible two metre measuring tape. Girth in centimetres was measured midway between the pectoral flipper and the dorsal fin. The measuring tape was held securely but not tightly, to avoid compressing the tissue.

Harbour porpoise retrieved in Newfoundland, and in the Gulf of Maine were brought to shore intact and frozen at -20°C. No biological sampling was done on board the vessels. Carcasses of retrieved animals from the 1993 St. Brides, Newfoundland porpoise bycatch were transported to the Department of Fisheries and Oceans in St. John's, Newfoundland, Canada for necropsy. Harbour porpoise incidentally caught in the Gulf of Maine/Jeffreys Ledge fall gillnet fishery were necropsied at the National Marine Fisheries Science Centre Laboratory in Woods Hole, Massachusetts, USA. Morphological data for animals retrieved from the Grand Manan Island/Bay of Fundy fishery were obtained in the field in response to a request by fishermen that retrieved animals would not be retained and brought to shore. Time since death samples (retrieved during 1994-95 only) were collected before returning the animal to ocean water. Upon return to land the samples were frozen at -20°C for examination at a later date.

Stomach content analysis

Harbour porpoise stomachs were collected for analysis in order to investigate the relationship between harbour porpoise and their prey. Harbour porpoise stomachs consist of a series of three chambers. Recchia and Read (1989) and Fontaine *et al.* (1994) advise sampling contents from the first chamber (known as the fore-stomach) since digestive glands are thought to be absent and contents of the two remaining chambers are usually too digested for identification and measurement. Therefore, only contents from the fore-stomach were used for analyses.

To prevent loss of contents and insure complete removal, each stomach was ligatured at the base of the esophagus and at the beginning of the duodenum before being excised. Cuts were made through the esophagus and duodenum, several centimetres away from the ligatured site at ends distal from the stomach. The stomach was then extracted.

Whole stomachs were weighed. Fore-stomachs were excised carefully and weighed before opening by longitudinal incision along the greater curvature. Stomach contents were emptied into a tray and rinsed throughly. Emptied stomachs were re-weighed to obtain the total weight of stomach contents by subtraction (g). Prey items were washed through three sieves with a mesh size of 2 mm, 1 mm and 0.25 mm in order to recover identifiable remains. Sagittal otoliths and cephalopod beaks were retrieved. All otoliths were stored dry in vials. Prey items were identified to the lowest taxonomic level possible. Standard length (cm) and mass (g) of prey specimens which were sufficiently undigested and identifiable were measured. Prey length was not measured in the 1993 samples from St. Brides and mass was not collected for prey sampled from Jeffreys Ledge or the Bay of Fundy (1993, 1994-95).

Otoliths were not collected from the stomachs of harbour porpoise captured during the summer of 1993 in St. Bride's. Otoliths from harbour porpoise stomachs collected during the fall 1993 in the Gulf of Maine were identified at the Northeast National Marine Fisheries Science Centre located in Woods Hole, Massachusetts. Otoliths collected in harbour porpoise stomachs from the Bay of Fundy during the summers of 1994 and 1995 were identified by the author using a Department of Fisheries and Oceans reference collection specific for the region. Findings were checked for accuracy by technicians from the Department of Fisheries and Oceans who were experienced in otolith identification.

For identifiable otoliths, length (defined as the longest dimension between the anterior and posterior edges of the otolith; Hunt 1992) was measured to the nearest 0.01 mm using a computer-based image analysis system or digital calipers (see Lawson *et al.* 1995 for description). Ingested fish lengths were calculated from regressions on otolith size for the three most common prey species: Atlantic herring, silver hake *(Merluccius bilinearis)* and Weitzman's pearlsides *(Maurolicus weitzman)*. Whole specimens with obvious evidence of deterioration, or those found to be unidentifiable, were counted but not analysed. The number of fish present in a stomach was estimated by dividing the total number of sagittal otoliths by two (Table 2.2).

The relative importance for each prey item in the harbour porpoise diet was estimated and recorded using the following three indices described by Hyslop (1980): (1) frequency of occurrence, defined as the percentage of harbour porpoise stomachs containing each specific prey species; (2) proportion of numerical abundance, defined as the total number of individual prey determined by counting identifiable whole prey, cephalopod beaks, and fish otoliths, divided by the total number of all identifiable prey items found in stomachs of all the animals sampled and (3) each major prey species, expressed as length of prey

Table 2.2: Equations used to estimate length of harbour porpoise prey from otolith lengths (OL) collected in the Gulf of Maine/Bay of Fundy during 1993-1995. FL=fork length in millimetres.

Prey species	Equations	Source
Clupea harengus (Atlantic herring)	FL=69.23 OL-27.48	Recchia and Read (1989)
Maurolicus weitzmani[1] (Weitzman's pearlsides)	FL=9.82+28.75 OL	Harkonen (1986)
Merluccius bilinearis (silver hake)	FL=20.9 OL-0.41	Recchia and Read (1989)

or mass of prey for St. Bride's, 1993 (Hyslop 1980; Recchia and Read 1989; Gannon *et al.* 1998).

For cephalopods, the maximum number of either upper or lower beaks found in the stomach was recorded. The numbers of broken or partially digested euphausiids were determined by counting the number of pairs of eyes present. No lengths or weights were calculated for these samples.

Fish diet

To further explore a relationship between harbour porpoise capture and the presence of prey in the water, stomachs of target species were collected at the rate of ten per day in the Gulf of Maine/Jeffreys Ledge, and twenty per day when possible during the 1994 and 1995 Grand Manan Island/Bay of Fundy research seasons. After fish were identified, the stomachs were removed and stored in plastic bags. Upon returning to land the stomachs were weighed (in grams), opened and the contents weighed (in grams) and examined. Prey items were identified to the lowest taxon possible and counted. Variety and number of prey items were analysed for a correlation with harbour porpoise bycatch.

Age Determination

Age and predicted corresponding sexual maturity were estimated for harbour porpoise collected during the fall 1993 Gulf of Maine and the 1995 Bay of Fundy research seasons from independent counts of dentinal growth layer groups (GLGs) without the reader having access to biological data (gender, length, or girth) for the specimen (Read and Hohn 1995). Five to ten teeth were extracted from the mid-portion of the mandible and fixed in 10% buffered formalin. Teeth extracted during 1993 were processed at the Northeast National Marine Fisheries Science Centre, Woods Hole, Massachusetts, and those from the 1995 research season at the Histology Laboratory of the Memorial University Health Science Centre, St. John's Newfoundland. Preparation of teeth for aging followed Hohn and Lockyer (1995). Teeth were decalcified for 24-48 hours in a 5% solution of nitric acid, subsequently frozen in petroleum ether in an acetone carbon dioxide bath, and sectioned longitudinally on a cryostat through the centre axis of the pulp cavity and apex of the crown to a thickness of 20-25 microns. A minimum of four sections from each tooth were stained in Ehrlich's haematoxylin, and blued in Scott's Tap Water. The sections were subsequently dehydrated and mounted permanently on microscope slides using Surgipath Micromount. All tooth sections from animals captured during 1995 were aged initially by the author and checked for accuracy by two experienced readers.

No teeth were collected during the summers of 1993 (St. Bride's) or 1994 (Grand Manan Island/Bay of Fundy). Age of harbour porpoise for these seasons was estimated using length and back calculations from parameter values for length at age, mass at age and for mass from length for Gompertz growth curves for male and female harbour porpoise from Newfoundland by Richardson (1992; Table 2.3) and for animals from Grand Manan Island/Bay of Fundy by Read and Tolley (1997; Tables 2.4 and 2.5). Sexual maturity was predicted by fitting length and mass parameters to estimated ages at sexual maturity to length and weight values from Richardson (1992 Table 2.3) and Read and Tolley (1997; Table 2.4) and Lockyer (1995) and Lockyer and Kinze (1999).

2.3.4 Environmental data

Environmental data were collected daily from the vessels at each fishing net location. Vertical profiles of water column temperature (^{0}C) and salinity (ppt=parts per thousand) as a function of depth in metres were measured by using a Seabird SBE-19 conductivity (salinity) and temperature at depth recorder (CTD) (Sea-Bird Electronics, Inc., Bellevue, WA, USA) during the summer and fall 1993 and summer 1994 research seasons. The CTD was immersed just below the sea surface to equilibrate with the ambient environment for five minutes and then lowered to the sea bottom at a profiling speed of approximately 1 m per second.

Table 2.3: Estimated parameter values for length at age and mass at age and standard errors (SE) for Gompertz growth curves for male and female harbour porpoise from Eastern Newfoundland. Length is total body length from tip of snout to fluke notch, measured in a straight line in centimetres (cm). Cited from Richardson (1992).

Length	*A* (SE)	*b* (SE)	*k* (SE)
Males	142.9 (1.2)	0.419 (0.03)	0.747 (0.09)
Females	156.3 (2.9)	0.558 (0.06)	0.735 (0.13)
Mass			
Males	49.1 (1.3)	1.069 (0.15)	0.658 (0.13)
Females	61.6 (3.6)	1.284 (0.18)	0.554 (0.15)

Note: *A*=the asymptotic value where length= (cm), and mass (weight) =kg, *b*=fitted constant (no units), *k*=growth rate constant (years^{-1}), age= age (years).

The regression equation for the Gompertz model for male length at age is:

Length = 142.9 * exp (- 0.419 * exp (-0.747 * age))

and for females is: Length = 156.3 * exp (- 0.558 * exp (-0.735 * age))

The Gompertz equation for weight to age in males is:

Weight = 49.1 * exp (-1.069 * exp (-0.554 * age)

and for females is: Weight = 61.6 * exp (-1.284 * exp (-0.554 * age)).

Table 2.4: Estimated parameter values for length at age and mass at age and standard errors (SE) for Gompertz growth curves for male and female harbour porpoise from the Grand Manan Island/Bay of Fundy area. Length is total body length from tip of snout to fluke notch, measured in a straight line in centimetres (cm). Cited from Read and Tolley (1997).

Length	*A* (SE)	*b* (SE)	*k* (SE)
Males	143 (1.25)	0.3 (0.01)	0.6 (0.07)
Females	158 (1.56)	0.4 (0.01)	0.5 (0.04)
Mass			
Male	50 (1.05)	0.7 (0.04)	0.5 (0.07)
Females	65 (1.87)	0.9 (0.04)	0.4 (0.05)

Note: *A* is the asymptotic value where length = (cm), and mass (weight) = kg, *b* = constant of integration, and *k* = growth rate constant.

Table 2.5: Body mass from length equations for harbour porpoise from the Gulf of Maine/Bay of Fundy.

Equations for determining body mass from length in harbour porpoise from Read and Tolley (1997). For females:

$$\log mass = (1.42 * \log m\ 14) + (1.21 * \log length) - 3.70.$$

For males the equation is:

$$\log mass = (1.61 * \log m\ 14) + (1.12 * \log length) - 3.88,$$

where m14 = girth anterior to the dorsal fin (in cm),

mass is in kg and length is in cm.

Data were collected at a rate of two samples per second. Once at maximum depth the CTD was returned to the surface and removed from the water, and the data downloaded.

Temperature and depth versus time for the net to sink

During the 1994 and 1995 research seasons vertical water column temperatures (^{0}C) as a function of depth in m, temperature and time at fishing depth of nets were recorded using a Sealog-TD temperature/depth logger (Vemco LTD; Halifax, NS, Canada). The logger was attached approximately one m from the bottom of the anchor line to prevent it from settling on the ground and becoming clogged with sediment. The Sealog recorded temperature changes $\geq$ 0.1^{o}C, or if depth changed by an amount $\geq$ 0.5 m. The Sealog also recorded the time it took the net to sink to the fishing depth. At depth, the Sealog monitored temperatures while the net was fishing. Data were stored within the memory unit and downloaded to a personal computer for inspection and processing upon retrieval. The amount of time for the net to reach fishing depth was defined as the net sink time (range 10-40 minutes). This net sink time was then divided into seven time intervals. These intervals were compared to the number of harbour porpoise bycatch occurring in each time interval. Harbour porpoise bycatch was examined in relationship to the time the net took to sink to fishing depth.

Upon the setting and hauling of nets wind force was recorded according to Beaufort scale criteria (Appendix 4). Cloud cover was measured as the percent of sky obstructed by clouds; and weather conditions (rain, fog, clear) were recorded.

Water clarity

To determine water clarity at each net setting site, Secchi Discs were secured to ropes which were marked at one metre intervals. At each set and haul, the discs were placed overboard and lowered to the depth at which the disc was first lost to sight. The depth at which the disc disappeared was recorded to the nearest 0.5 m. Water clarity measurements were taken at the setting of nets exclusive of the Gulf of Maine/Jeffreys Ledge season. Those in which a harbour porpoise was entangled were compared with nets which did not have a bycatch.

2.4 ELAPSED TIME SINCE DEATH

During the 1994/1995 Grand Manan Island/Bay of Fundy seasons, 24 porpoise that were incidentally captured were examined for time since death. Data collected included standard length and girth measurements. Body temperature (in °C) was taken immediately upon retrieval of the animal. A lateral incision was made at the ventral site of the liver in order to place a thermometer (Canlab BI-

Metal 12 centimetre stem) into the left lobe of the liver. The thermometer was left in place a minimum of 3 minutes to stabilize and then read *in situ.*

Vitreous humour samples were collected immediately following placement of the thermometer into the liver. Fluid was collected by lateral insertion of a 16 or 20 gage needle through the outer canthus of the eye into the central region of the vitreous body, followed by gentle aspiration of 1-2 cc of ocular fluid into a 5 cc syringe using a separate syringe for each eye (Knight 1991). Nine animals had one eye with advanced deterioration making collection of fluid from both eyes impossible. For the remaining 15 animals, left and right ocular fluid values were analysed independently. Upon return to the research station vitreous humour samples were centrifuged for ten minutes. The supernatant fluid was then frozen at -20°C for further processing. Biochemical values for the supernatant fluid were determined with a BM/Hitachi 911 blood chemistry multianalyser.

Measurements of glucose, sodium, chloride, phosphorus, urea, deep core body temperature, ambient temperature, body length, and girth were determined. Data from 1994 and 1995 were pooled together for statistical analysis. Potassium, magnesium, sodium potassium ratio, and calcium measurements were collected in 1995 only.

Liver and intestine samples

In 1994, 4x4 cm sections of liver from porpoise were excised and collected in order to determine if postmortem changes in this organ would be a useful diagnostic tool in estimating time since death in harbour porpoise. These samples were frozen at -20°C until processed. For each sample a swab was taken from the middle of the tissue, plated on blood agar and on McConkey agar, and incubated at 35°C and 5% CO_2 for 48 hours. Liver samples were then examined under a microscope for evidence of bacterial flora from the digestive tract which had invaded the blood vessels and colonized the liver.

Intestinal samples were collected in 1994 to investigate the degree of postmortem decomposition undergone at the time of retrieval from the net. Two cm long samples were taken at approximately 1 m from the pylorus and placed in 10% buffered formalin until they could be embedded in paraffin, sectioned and stained with haematoxylon and eosin. Four sections of tissue from each sample were examined. In order to obtain a relative index of the degree of postmortem decomposition of the rows of epithelial cells lining the villi of the intestinal mucosa, the integrity of cell rows and the integrity of individual cells forming the rows were rated on an ordinal scale (i.e. 0 {no change} to 4+ {severe change}). A rating value was assigned to each of the four sections of intestine excised from individual animals and averaged.

All postmortem elapsed time since death samples for 1994/95 were processed at the Department of Pathology and Microbiology, Atlantic Veterinary College, Charlottetown, P.E.I., Canada.

2.5 SOCIOLOGICAL DATA

2.5.1 Fishermen's traditional knowledge

Fishermen's knowledge and beliefs about harbour porpoise bycatch were assessed at each study site through daily communication. In addition, all fishermen who participated in research from the Gulf of Maine/Bay of Fundy as well as active fishermen in the region surrounding areas (Maine and Massachusetts), were formally interviewed *in situ* (n=71). Seventy-one fishermen participated in the harbour porpoise bycatch survey. Respondents hailed from the following locales: New Hampshire (NH; n=15), Massachusetts (MA; n=9), Maine (ME; n=24), Grand Manan Island/Bay of Fundy (GM; n=23). The respondents who did not answer a specific question are listed as "did not respond" (DNR).

Responses were analyzed by calculating separately for each locale the number of answers to the individual questions and determining the percent of responses for each. Answers were then pooled, and the cumulative responses from all respondents were calculated by percent answer. Fishermen completed a survey in which the interviewer presented a series of questions clustered into four general topics: 1) live sightings; 2) the entanglement issue; 3) possible causes for entanglement; and, 4) searching for solutions. The survey included multiple choice, ranking, agree and disagree statements, and discussion questions (Appendix 5). Each interview was completed in confidence and required 1.5-2 hour(s). Survey protocol followed that of Lien *et al.* (1994). Responses were analysed by calculating separately for each locale the number of answers to the individual questions and determining the percent of responses for each. Answers were pooled and the cumulative responses from all respondents were calculated by percent answer.

2.6 DATA ANALYSIS

Descriptive statistics were the first calculated to obtain information from and to organize and summarize the numerical data collected. All data were then checked to ascertain if the they met the assumptions required for specific statistical tests.

For operational and environmental data, univariate Logistic Regression analysis that reported the Wald statistic depicted as the Z score was employed to test for statistical significance where the dichotomous outcome took two possible responses (bycatch occurred or no bycatch occurred) represented by values of 1 or 0 respectively (Dytham 1999; Hosmer and Lemeshow 1989; 2000). The Wald statistic was used to determine how significant the independent variable was for predicting the dependent variable. The level of statistical significance is noted by the Z score and the P value associated with it. Tolerance for type 1 error was set at the 0.05 level.

Operational and environmental data were analysed for both daily and weekly (six day interval) relationships to the incidental capture of harbour porpoise. Six day intervals were chosen because this number was the best fit for the majority of data collections.

In addition, to compare a measure of association, harbour porpise bycatch and operational variables were calculated as the capture of porpoise per unit of fishing effort (CPUE), or as the number of porpoise caught per net day fished and affiliated operational parameters. These parameters were also grouped into operational categories. The resultant categorical divisions were examined and are presented as the incidental capture of harbour porpoise per unit of effort (CPUE) for each operational category.

Elapsed time since death data were measured for strength of association by Pearson Product Moment Correlation (Sokal and Rohlf 1981).

Two statistical packages were used for analysis of data; Abacus Concepts, StatView. (Abacus Concepts, Inc., Berkeley, California 94704;1992) and SYSTAT 8.0 Statistics/SPSS Inc., 233 South Wacker Drive, Chicago, IL 60606-6307.

CHAPTER 3: RESULTS

3.1 OPERATIONAL AND FISHERY EFFORT

3.1.1 St. Bride's, Newfoundland, 1993

Total observer coverage for the 1993 summer research conducted in waters adjacent to St. Bride's, Newfoundland was 72 observer days; (one observer day being equivalent to one day of vessel effort). Fishing effort targeted cod, lumpfish or flounder. A total of 5,822 nets were hauled with a mean of 193 nets per day of fishing effort/observer day; (SD=99.5; range 35-318 nets) for 6,461 net days of fishing effort during a total of 27 days of fishing (Figure 3.1). Strings consisted of 3-10 nets (274.5-915 m) tied together. Nets were ~91.5 m in length, with a mesh size variation of 12.1, 17.6, or 23.1 cm. Total metres of net fished was 532,713 m. The mean metres of net fished per day of observed fishing effort was 19,730 m (SD=7,080; range 3,202-29,097 m per day). Effort data are reported in Appendix 6.

The mean soak time for all nets was 34.4 hrs (SD=15.8; range 24-72 hrs). Nets soaked at a mean depth of 32.3 m for the season (SD=18.4; range 20-90 m). The mean distance from shore for net settings was 2.2 km (SD=1.0; range 0.5-4.5 km).

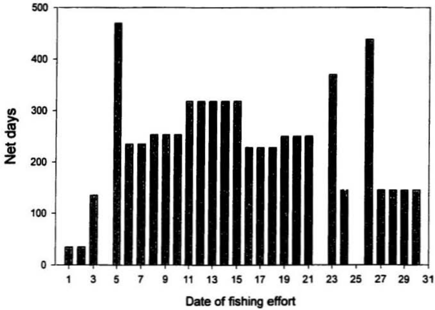


Figure 3.1: Daily effort for 27 days of fishing effort during July, 1993 in waters adjacent to St. Bride's, Nfld. Lumpfish nets were in the water from 3 July-19July. Cod and flounder nets fished for 27 days.

Total landed harvest of cod for 27 days of effort was 163,545 kg (93% of total harvest) (mean 5,451; SD=5,723; range 0-23,324 kg per day of effort). Lumpfish roe total harvest for 12 days of fishing was 7,266 kg (4.1% of total harvest) (mean 419; SD = 457; range 0-1,591 kg per day of effort). Flounder total catch for 11 days of fishing was 5,051 kg (2.9% of total harvest) (mean 174; SD=344; range 0-1,327 kg per day of effort). The total season harvest for fish and lumpfish roe combined was 175,862 kg.

3.1.2 Gulf of Maine/Jeffreys Ledge, 1993

A total of 10,995 net days were monitored during 133 observer days for the 1993 fall research conducted in the Gulf of Maine/Jeffreys Ledge region. The fishery targeted cod and pollock. Research was conducted from 13 October-18 December. Nets had a mesh size variation of 14.0, 15.2, 16.5 or 20 cm. A total of 7,934 nets, each 90 m long, were hauled in strings which averaged 14 nets (SD=5.45; range 5-25 nets) per string for a total of 714,060 m of nets fished (mean 1,263; SD=493) during 46 days of fishing effort. The most concentrated fishing effort occurred in November when observers monitored 67 or 50.4% of the total trips for 5,651 net days. There were 39 trips monitored or 29.3% of total effort and 3,094 net days in October, and 27 trips monitored or 20.3% for 2,250 net days in December (Figure 3.2; Appendix 7).

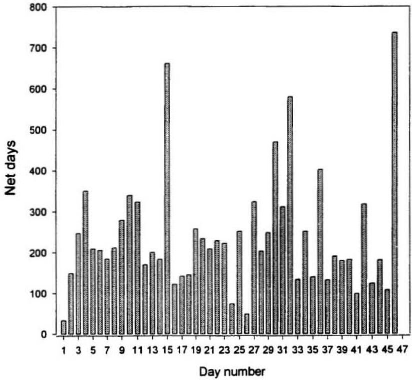


Figure 3.2: Daily effort for 46 days of fishing in waters adjacent to Jeffreys Ledge in the Gulf of Maine during 1993. Days 1-14 occurred in October, days 15-36 occurred in November; and days 37-46 represent fishing effort in December.

The mean soak time for all nets was 34 hrs (SD=28.0; range 7-216 hrs). Nets soaked at a mean depth of 73 m (SD=21; range 42-161 m). The mean distance from shore for net settings was 45.5 km (range 43.2-48 km).

Cod harvest for 46 days of effort was 42,061 kg (58% of total harvest; mean 914; SD=64.2; range 25-1,665 kg per day). Total landed harvest of pollock was 30,061 kg (42% of total harvest; mean 654; SD=54.4; range 140-1,350 kg per day). The total season harvest for both target species was 72,122 kg of fish.

3.1.3 Grand Manan Island/Bay of Fundy, 1994

Total observer coverage for the 1994 summer research conducted in the Bay of Fundy was 150 observer days during 49 days of fishing effort. Data were collected from the beginning of the fishing effort on 7 July to completion of the season on 10 September. The fishery targeted cod and pollock. The most concentrated coverage was in August when observers monitored 92, or 61.4% of the total trips, for 1,605 or 57% of the total net days. There were 41 (27.3%) observed trips in July and 761 (27%) net days. During September there were 17 (11.3%) observed trips for a total of 462 (16%) net days (Appendix 8; Figure 3.3). All nets had a mesh size of 15.2 cm. A total of 2,104 nets each 100 m long (total of 210,400 m of net) were hauled during 2,828 net days.

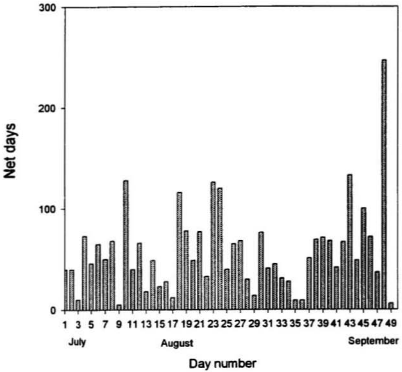


Figure 3.3: Daily effort for 49 days of fishing in waters adjacent to Grand Manan Island/Bay of Fundy. Days 1-15 occurred in July; days 16-42 occurred in August; and days 43-49 represent fishing effort in September 1994.

Each string consisted of three (98%) or four nets (2%) and was 300 or 400 m in length. The nets soaked an average of 32.8 hrs (SD=17.7; range 10-102 hrs). Mean depth at net set was 102 m (SD=17.4; range 50-170 m). The mean distance from shore for net settings was 3.1 km (SD=2.6; range 0.5-17 km).

Per request of the fishermen the landed target fish harvest was counted per individual fish according to species for the 49 days of observed fishing effort. In order of prevalence, Atlantic herring harvest was 18,048 fish (54.2% of total harvest for all species) with a mean of 384 (SD=412; range 0-2,327) fish per day. Cod harvest was 7,196 fish (21.5% of total harvest for all species) the mean was 153 (SD=126; range 13-591) fish per day. Total pollock harvest was 5,305 fish (15.8% of total harvest for all species) with a mean of 113 (SD=108; range 13-655) fish per day. The total landed catch of hake was 2,870 (8.5% of total harvest for all species), the mean was 61 (SD=57; range 1-254) fish per day. The combined total harvest for these target fish species during the observed fishing effort was 33, 419 individual fish.

3.1.4 Grand Manan Island/Bay of Fundy, 1995

There were 112 observer days during 36 days of fishing effort for the 1995 summer research conducted in waters adjacent to Grand Manan Island. A total of 1,503 nets (mean 41.7; SD=27.2) each 100 m in length (total m=150,300) were hauled for 1,849 net days. All nets had a mesh size of 15.2 cm. Ninety-eight percent of the strings consisted of three nets, two percent had four nets tied together to form a string.

Fishing effort commenced on 3 July and concluded on 26 September. The 1995 fishing season was divided into trimesters each of which had an allocated quota for total catch of cod and pollock based on bi-monthly calculations of catch. The quota system resulted in a reduction of gillnetting effort and a complete closure once the allocated quota was reached. In compliance with the quota system, effort during the second trimester ceased from 21 July-31 August when the allotted amount of target species had been landed. Fishing effort resumed on 1 September at the start of the third trimester and continued until 26 September.

The most concentrated coverage was in July when observers monitored 77 (69%) of the research trips with participating fishermen during 1,209 net days. There were 35 trips in September for 31% of the observer coverage and 640 net days for a season effort total of 1,849 net days (Figure 3.4; Appendix 9).

Mean soak time for the season was 29 hrs (SD=12 hrs; range 12-78 hrs). These nets soaked at a mean depth of 98 m (SD=11; range 64-163 m). Mean distance from shore for net setting was 2.8 km (SD=0.9; range 1-6 km).

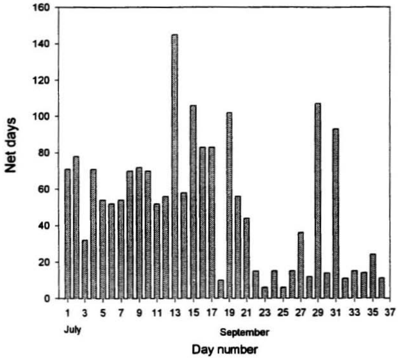


Figure 3.4: Daily effort for 36 days of fishing in waters adjacent to Grand Manan Island/Bay of Fundy, during 1995. Days 1-17 occurred in July and days 18-36 represent fishing effort in September. No fishing effort took place in August.

The landed target species fish harvest was counted per individual fish according to species for the 36 days of observed effort. The total harvest for cod was 8,503 fish or 50% of the total catch, with a mean catch of 236.1 fish per day (SD=186.8; range 14-702). Atlantic herring harvest was 6,745 fish or 39% of the total harvest with a mean of 187.3 fish per day (SD=254.6; range 1-1,232). Total pollock harvest was 1,940 fish or 11% of the landed harvest, the mean was 53.8 fish per day (SD=70.2; range 1-3,090). The combined total harvest for these target fish species was 17,188 individual fish.

3.2 ENVIRONMENTAL CONDITIONS

3.2.1 St. Brides, Newfoundland, 1993

A total of 132 vertical water column measurements for temperature and salinity at depth were collected. Mean daily water column temperature was 3.2°C (SD=0.13; range 2.9-3.4°C) the mean salinity was 31.6 ppt; (SD=0.40; range 31-32.7% ppt). The mean clarity of the water when nets were set was 15 m; (SD=5.5; range 9.5-30 m depth). The mean wind speed was 7 kn (SD=5.4; range 0-20 kn) with a mean Beaufort scale (measured as the limits of wind speed in knots) reading of 2.5 kn (SD=1.5; range 0-7 kn). Mean cloud cover was 70%; (SD=32; range 0-100% cloud cover).

3.2.2 Gulf of Maine/Jeffreys Ledge, 1993

The mean wind speed was 11 kn (SD=6.0; range 1-30 kn) with a mean daily Beaufort Scale reading of 4 kn. Mean cloud cover for days of fishing effort was 55% (SD=38; range 0-100%). One hundred and thirty-six vertical water column profiles for temperature and salinity measurements were procured during the research season. Mean water column temperature was 7.8°C (SD=1.3; range 6.2-11.3°C), and mean water salinity was 32.1% ppt; (SD=.54; range 30.1-32.7 ppt.). Water clarity readings were not collected.

3.2.3 Grand Manan Island/Bay of Fundy, 1994

The mean wind speed was 2 kn (SD=1.3; range 0-7) with a mean Beaufort Scale reading of 1. The mean water clarity was 8 m (SD=1.2; range 6-10). The mean percent of cloud cover for all fishing days was 50%; (SD=40; range 0-100%). Eighty-eight vertical water column profiles were collected during the research season. Mean water column temperature was 10.1°C; (SD=1; range 8.4-11.8). Mean water salinity was 32.7 ppt (SD=0.4; range 32-33.8).

3.2.4 Grand Manan Island/Bay of Fundy, 1995

Water column temperatures were obtained for 34 days of fishing effort. The mean daily water column temperature was 9.3°C (SD=1.9; range 5.4-11.8). The mean wind speed was 2.0 kn (SD=1.3; range 0-5) with a mean Beaufort Scale reading of 1 kn. The mean water clarity at set was 7.5 m (SD=1; range 5.5-9.5). The mean percent of cloud cover for all fishing days was 45 (SD=40; range 0-100%). Water column salinity data was not collected during this season and therefore, is not reported here.

3.3 HARBOUR PORPOISE BYCATCH

3.3.1 St. Bride's, Newfoundland, 1993

A total of 19 harbour porpoise were caught in gillnets; four dropped out of the net and were classified as not retrieved (n/r). Of the remaining porpoise, fourteen were necropsied and aged. The spatial distribution of this incidental capture of harbour porpoise is depicted in Figure 3.5. The mean bycatch for 27 fishing days was 0.7 harbour porpoise per day; (SD=0.10; range=1-4). For bycatch days only the mean capture was 1.5 porpoise (SD=0.9; range 1-4) per day.

Of the 19 bycaught porpoise 12 (63%) were captured at a bridle site. Fifteen (79%) of the 19 harbour porpoise were captured in strings with 10 nets (CPUE=0.0049). Four porpoise (21%) were captured in strings with five nets (CPUE=0.0015 porpoise) and no animals were captured in strings with three nets (CPUE=0; Figure 3.6 a and b). This linear relationship can be noted in Figure 3.6b.

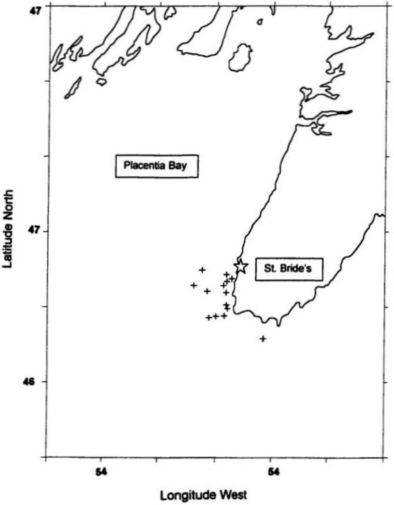


Figure 3.5: Spatial distribution of observed harbour porpoise incidental capture in fixed gillnets placed in waters adjacent to St. Bride's, Newfoundland during 1993.

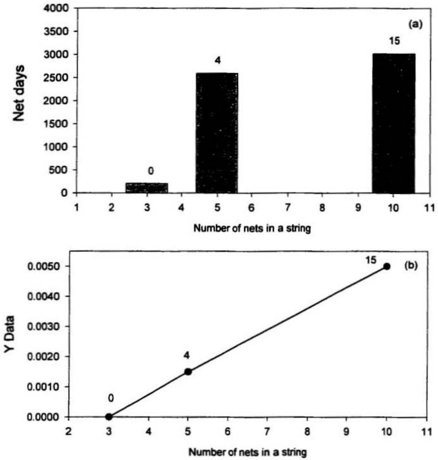


Figure 3.6: Frequency distribution for number of nets in a string and number of net days (a) and CPUE (b), for the number of nets per string, per net fished in St. Bride's, Nfld. during 1993. Numbers in graph refer to the number of harbour porpoise mortalities.

Net days and effort display bycatch peaks occurring at the 24-47 hr soak time (n=8; CPUE 0.0041) and the 48-71 hr soak time (n=9; CPUE=0.0028) respectively. Two animals were captured in nets with a 72 hr soak time (CPUE=0.003; Figure 3.7 a and b). The mean depth for nets which caught harbour porpoise was 40.8 m (SD=13.9 m; range 23-68 m). The greatest bycatch and effort was at 31-50 m depth with the highest CPUE occurring at < 30 m depth (Figure 3.8 a and b). No depth data are available for three bycaught porpoise.

Figure 3.9 (a and b) shows the distance offshore that incidental captures were made. Capture rates were highest with 86% of the porpoise captured at distances of 1-3 km from shore with a sharp drop in effort and bycatch rates evident at distances greater than 3 km from shore. No captures occurred in nets set less than 1 km from shore. Daily operational and catch per unit of effort data are reported in Appendix 10, weekly (six day interval) values are presented in Appendix 11.

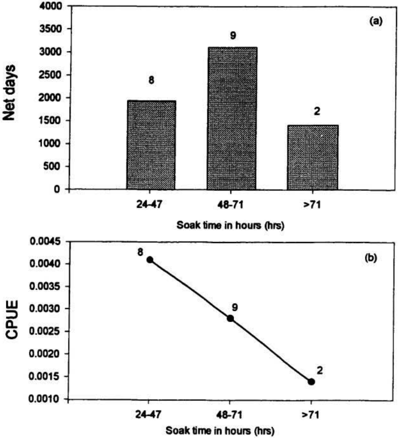
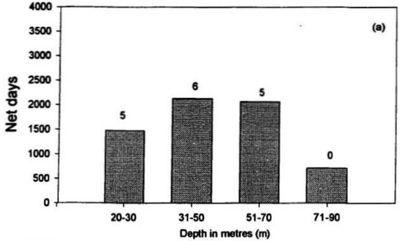


Figure 3.7: Frequency distribution for soak time per net, net days (a) and bycatch of harbour porpoise per unit of effort (CPUE) (b), during 1993 in waters adjacent to St. Bride's, Nfld. Numbers in graph refer to harbour porpoise mortalities.



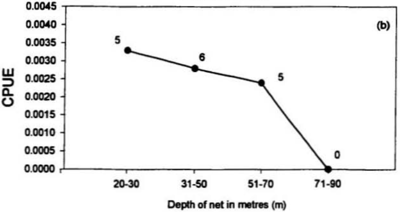


Figure 3.8: Frequency distribution for depth of net placement, net days at depth (a) and the catch per unit fishing effort (CPUE) (b), of harbour porpoise captured in waters adjacent to St. Bride's, Nfld. during 1993. Numbers in graph refer to harbour porpoise mortalities.

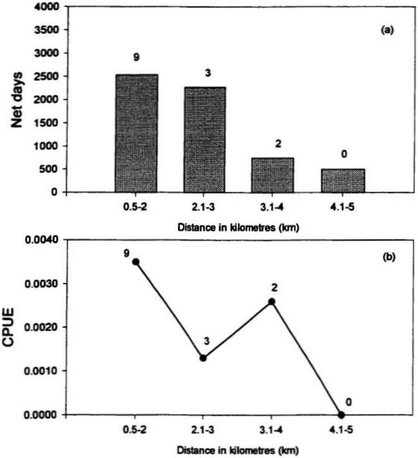


Figure 3.9: Frequency distribution for net days (a), and catch per unit effort (CPUE) (b), for distance from shore per net set for the 1993 gillnet fishery in St. Bride's, Nfld. Numbers in graph refer to harbour porpoise mortalities.

The greatest number of harbour porpoise (n=12) were captured in nets set for cod with a mesh size of 12.1 cm (Figure 3.10 a and b). Cod nets fished for 3,288 net days with a harvest CPUE of 49.7 kg of cod. The CPUE for harbour porpoise in cod nets was 0.0036. Flounder nets fished for a total of 1,402 net days with a mesh size of 17.6 cm. Flounder nets caught 5,051 kg of fish with a CPUE of 3.6 kg and had a CPUE for harbour porpoise of 0.0021. Four harbour porpoise were captured in lumpfish gillnets with a mesh size of 23.1 cm. These nets fished a total of 1,377 net days with a CPUE of 5.27 kg of lumpfish roe. The CPUE for harbour porpoise in these nets was 0.0029. Effort and CPUE data are reported in Appendix 12 and Table 3.1.

No statistically significant relationships were found between the bycatch of harbour porpoise, the depth of net set, the number of nets in capture string or the landed kilograms of flounder or lumpfish roe. These variables were not analysed further (Table 3.2).

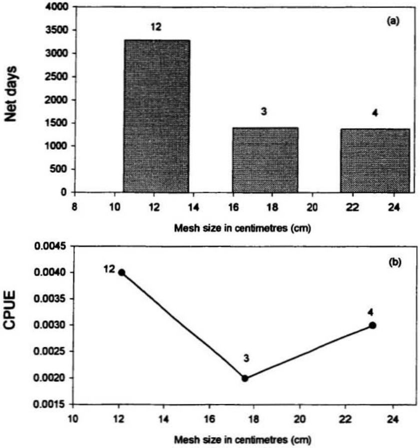


Figure 3.10: Frequency distribution of mesh size of gillnets, net days (a) and catch per unit effort (CPUE) (b) for mesh size per net set for the gillnet fishery in St. Bride's, Nfld. during 1993. Numbers in graph refer to harbour porpoise mortalities.

Table 3.1: Effort and CPUE for harbour porpoise data from the St. Bride's gillnet fishery during 1993. Bycatch numbers are mortalities of harbour porpoise. Effort units are based on one net day (ND) which is equivalent to one net set for a 24 hour period.

Category	Number of net days	Percent net days	Number of bycatch	Percent bycatch	Bycatch CPUE
Soak time (hr)					
≥ 24 (24-47)	1,940	30.1	8	42.2	0.0041
≥ 48 (48-71)	3,108	48.1	9	47.3	0.0028
≥ 72 (72)	1,413	21.8	2	10.5	0.0014
*Depth (m)					
≤ 30 (20-30)	1,476	23.1	5	26.3	0.0033
≤ 50 (31-50)	2,130	33.3	6	31.5	0.0028
≤ 70 (51-70)	2,064	32.3	5	26.3	0.0024
≤ 90 (71-90)	713	11.1	0	0	0
*Distance (km)					
0.5-2	2,535	41.9	9	47.3	0.0035
2.1-3	2,270	37.5	3	15.7	0.0013
3.1-4	750	12.3	2	10.5	0.0026
4.1-5	500	8.3	0	0	0
Mesh size (cm)					
12.1	3,288	54.2	12	63.1	0.0036
17.6	1,402	23.1	3	15.7	0.0021
23.1	1,377	22.7	4	21.0	0.0029
No.of nets in string					
3	209	3.5	0	0	0
5	2,595	44.5	4	21.0	0.0015
10	3,018	51.8	15	78.9	0.0050

* No depth data are available for three bycaught harbour porpoise (15.7% of bycatch; ND=78 or 15.8%) or distance for five porpoise (26.5% of bycatch; ND=406 or 6.2%). Mesh size is minus data for 394 net days and the variable number of nets in string is minus data for 639 net days all of which occurred on no bycatch days.

Harbour porpoise captures showed a positive correlation to the soak time of individual nets (P=0.03), distance of net placement from shore (P=0.01) and the number of net days per day of fishing effort (P=0.0002). The number of harbour porpoise captures had a positive correlation with the daily harvest of codfish (P=0.01; Table 3.2). Fourteen captures occurred on days with >9,000 kg of codfish harvested. No similar trend was noted for flounder or lumpfish roe harvest (Appendix 12; Figure 3.11). Results for daily values are presented in Table 3.2. Weekly (six day interval) fish harvest and the bycatch of harbour porpoise data are presented in Appendix 13.

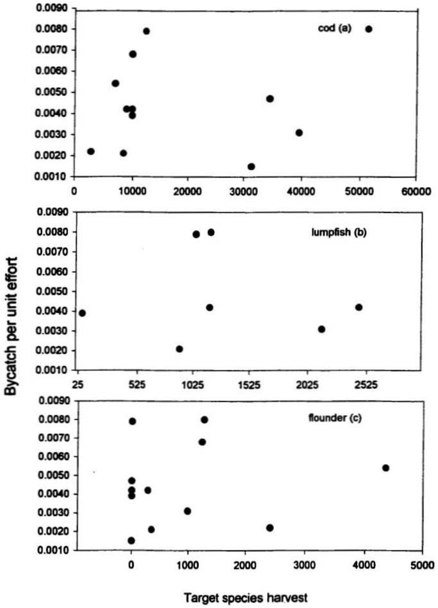
3.3.2 Gulf of Maine/Jeffreys Ledge, 1993

A total of 33 harbour porpoise were incidentally captured in gillnets. The spatial distribution of these catches is shown in Figure 3.12. Mean bycatch per day for 46 days of fishing effort was 0.7 (SD=0.24; range 1-4) harbour porpoise. For bycatch days only the mean capture was 1.6 porpoise per day (SD=0.93). Nine harbour porpoise (27.2%) dropped out of the net and were classified as not retrieved (n/r). An additional five porpoise were retrieved but not retained thus, not available for necropsy: one of these was retrieved and sampled at sea. A total of nineteen animals were necropsied and aged.

Table 3.2: St. Bride's, 1993 results of Logistic Regression analysis examining the daily incidental capture of harbour porpoise, the daily operational variables and the daily target species harvest. Variables reported are the depth of net at set (m), distance of net from shore (km), kilograms (kg) of cod, flounder and lumpfish harvested, mesh size (cm) the number of net days, the number of nets in the string of capture and the soak time of nets (hr). Values reported are the Wald Statistic depicted as the Z test for correlation coefficients and reported as the P value. P values determined to be statistically significant are presented in bold.

Variable	Z value	P value	Number of net days sampled
Depth of net set	1.69	0.09	6,383
Distance of net from shore	2.344	**0.01**	6,055
Kilograms of cod	2.448	**0.01**	3,288
Kilograms of flounder	-1.446	0.14	1,402
Kilograms of lumpfish	0.501	0.61	1,377
Mesh size	1.706	0.08	6,461
Number of net days	3.699	**0.0002**	6,461
Number of nets in capture string	1.751	0.07	5,822
Soak time of nets	2.063	**0.03**	6,461

Figure 3.11: Comparison of target species harvest in kilograms (kg) and the bycatch of harbour porpoise per unit of fishing effort per each species (cod P=0.01; lumpfish P=0.3; flounder P=0.6).


cod (a)
lumpfish (b)
flounder (c)
Bycatch per unit effort
0.0090
0.0080
0.0070
0.0060
0.0050
0.0040
0.0030
0.0020
0.0010
0
10000
20000
30000
40000
50000
60000
25
525
1025
1525
2025
2525
0
1000
2000
3000
4000
5000
Target species harvest

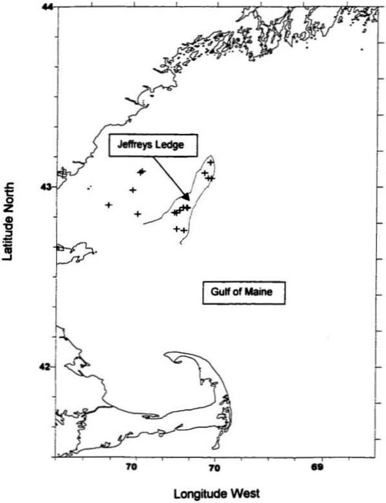


Figure 3.12: Spatial distribution of observed harbour porpoise incidental capture in fixed gillnets placed in waters adjacent to Jeffreys Ledge in the Gulf of Maine during 1993.

Strings consisted of 5-25 nets (450-2,250 m) tied together. Capture rates and nets fished per string show a distribution with two peaks evident at 10-15 nets (900-1,350 m) (CPUE=0.0044) and 21-25 nets (1,890-2,250 m; CPUE=0.0039) (Figure 3.13 a and b). Bycatch rates were lower in strings with <10 nets (< 900 m; CPUE=0.0018) and those with 16-20 nets (1,440-1,800 m; CPUE=0.0006) (Table 3.3; Appendix 14). Eleven (33%) of the 33 porpoise were captured at a bridle site.

Soak time displayed a peak in bycatch (n=19; CPUE=0.0034) at the ≤24 hr duration though no animals were captured in nets that soaked for <19 hours. Generally, there was a decrease in the number of porpoise caught per unit of effort with increased soak interval with the largest decline occurring after the initial 24 hour period (Figure 3.14 a and b; Table 3.3). However, six animals were captured in nets that soaked for >72 hours (CPUE=0.0038) including two that were retrieved from nets that had soaked for 213 hrs when inclement weather prevented the hauling of nets for seven days. Mean soak time of nets for bycatch days only was 40 hrs; (SD=37.2 hrs) (Appendix 14).

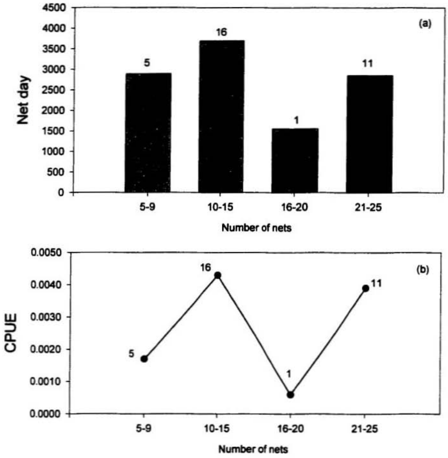


Figure 3.13: Frequency distribution for number of nets in a string (a), and CPUE (b), for the number of nets per string per net fished in the Gulf of Maine/Jeffreys Ledge fishery during 1993. Numbers in graph refer to harbour porpoise mortalities.

Table 3.3: Effort and (CPUE) for harbour porpoise data from the Gulf of Maine/ Jeffreys Ledge gillnet fishery during the fall of 1993. Effort units are based on one net day (ND) which is equivalent to one net set for a 24 hour period. Bycatch numbers are mortalities of harbour porpoise.

Category	No. of net days	Percent net days	No. of bycatch	Percent bycatch	Bycatch CPUE
Soak time (hr)					
≤ 24 (7-24)	5439	50	19	57.5	0.0034
≤ 48 (25-48)	2007	18	5	15.2	0.0024
≤ 72 (49-72)	1971	18	3	9.1	0.0015
> 72 (73-216)	1578	14	6	18.2	0.0038
Depth of set (m)					
≤ 70 (50-70)	4467	41	14	42.4	0.0031
≤ 90 (71-90)	1539	14	10	30.4	0.0064
≤ 110 (91-110)	3695	34	9	27.2	0.0024
> 110 (111-131)	1294	11	0	0	0
Mesh size (cm)					
14	5078	46.3	12	36.3	0.0023
15.2	2221	20.2	14	42.4	0.0063
16.5	3205	29.1	3	9.1	0.0009
20	104	0.9	0	0	0
No. of nets in string					
37168	2891	26.3	5	15.2	0.0017
37209	3694	33.6	16	48.5	0.0043
16-20	1555	14.1	1	3	0.0006
21-25	2855	26	11	33.3	0.0039

* Four harbour porpoise did not have data recorded for mesh size (=387 or 3.5% net days;12.2% bycatch; mesh size=10,608 net days).

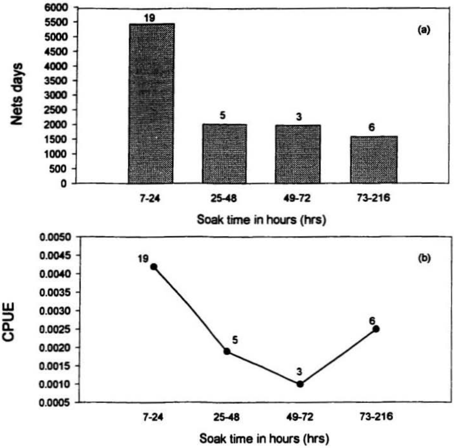


Figure 3.14: Frequency distribution and bycatch of harbour porpoise per net day (a), and catch per unit effort (CPUE) (b), for soak time of nets per net set for the Gulf of Maine/Jeffreys Ledge 1993 gillnet fishery. Numbers in the graph refer to number of harbour porpoise mortalities.

Twenty-six of the 33 harbour porpoise were captured in nets with a mesh size of less than 16 cm. These nets had a combined total of 7,299 net days and a CPUE of 0.0035. Three animals were captured in nets with a mesh size of 16.5 cm (CPUE=0.0009) with smaller sized meshes tending to have higher catch per unit of effort (Figure 3.15 a and b). No animals were captured in 20 cm mesh nets (Table 3.3; Appendix 14). The greatest catch per unit of effort occurred at the 50-70 (CPUE=0.0031) and 71-90 m (CPUE=0.0064) depth (Figure 3.16 a and b). No captures occurred in nets set at 50 m or >105 m. The mean depth for nets which caught harbour porpoise was 75 m (SD=18; range 51-105 m) (Table 3.3). All daily effort and bycatch data are reported in Appendix 14. Weekly effort and bycatch data are presented in Appendix 15.

Of the operational variables examined four had a correlation with the capture of harbour porpoise. The mesh size of the nets (P=0.02), the number of net days (P=0.01), the number of individual nets in a string (P=0.03) and the soak time of nets (P=0.0001), each had a statistically significant correlation with bycatch of harbour porpoise. No statistically significant relationships were found between distance of net placement from shore or depth of net set (Table 3.4).

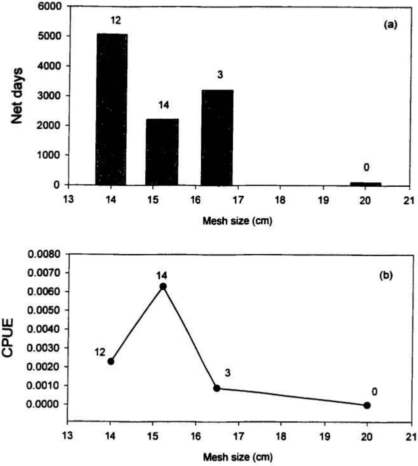
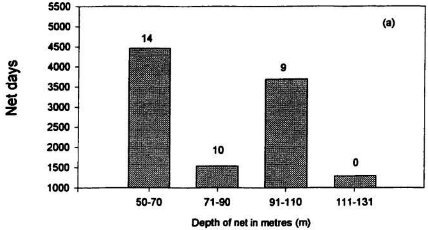


Figure 3.15: Frequency distribution for mesh size and net days (a), and catch per unit effort (CPUE) (b), for mesh size per net set for the gillnet fishery in the Gulf of Maine/Jeffreys Ledge during 1993. Numbers in graph refer to harbour porpoise mortalities.



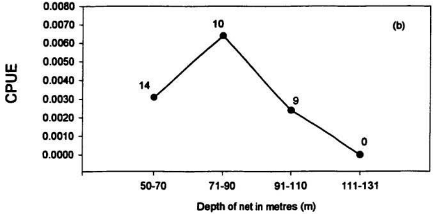


Figure 3.16: Frequency distribution for depth of net in metres (m) by net days (a), and catch per unit effort (CPUE) (b), for harbour porpoise captured in the Gulf of Maine/Jeffreys Ledge 1993 gillnet fishery. Numbers in graph refer to the number of harbour porpoise mortalities.

Table 3.4: Gulf of Maine/Jeffreys Ledge, 1993 results of Logistic Regression analysis examining the daily incidental capture of harbour porpoise, the daily operational variables and the daily target species harvest. Variables reported are the depth of net at set (m), distance of net from shore (km), kilograms (kg) of cod and pollock harvested, mesh size, the number of net days, the number of nets in the capture string and the soak time of nets (hr). Values reported are the Wald Statistic depicted as the Z test for correlation coefficients and reported as the P value. P values determined to be statistically significant are presented in bold.

Variable	Z value	P value	Number of net days sampled
Depth of net set	1.385	0.1	10,995
Distance of net from shore	1.178	0.2	10,995
Kilograms of cod	0.663	0.5	10,995
Kilograms of pollock	1.185	0.2	10,995
Mesh size	2.251	**0.02**	10,608
Number of net days	2.344	**0.01**	10,995
Number of nets in capture string	2.063	**0.03**	10,995
Soak time of nets	3.987	**0.0001**	10,995

* Four harbour porpoise did not have data recorded for mesh size (10,608 ND).

The kilograms of individual target species or fish catch totals harvested per day did not correlate significantly with the bycatch of harbour porpoise (Table 3.4; Appendix 16). The season CPUE for cod was 4.2 kg with a CPUE of harbour porpoise bycatch equal to 0.0030. For pollock the season harvest CPUE was 3.0 kg and the CPUE of porpoise was 0.0030. It is worth noting that 25 of the 33 bycaught porpoise were captured during six day intervals with >5,000 kg of fish harvested. Of this number 16 were bycaught during intervals with >8, 000 kg of fish harvested Appendix 17. The CPUE was 0.0030 harbour porpoise for the entire season of effort.

3.3.3 Grand Manan Island/Bay of Fundy, 1994

A total of 43 harbour porpoise were incidentally captured in gillnets, nine harbour porpoise dropped out of the net and subsequently not available for data collection. These porpoise were classified as not retrieved (n/r). Thus, data are available for 34 porpoise. The spatial distribution for these captures is depicted in Figure 3.17. Mean bycatch per day for 49 days of fishing effort was 0.8 (SD=0.28; range 1-3) animals. For bycatch days only the mean capture rate was 1.1 (SD=0.4; range 1-9) harbour porpoise.

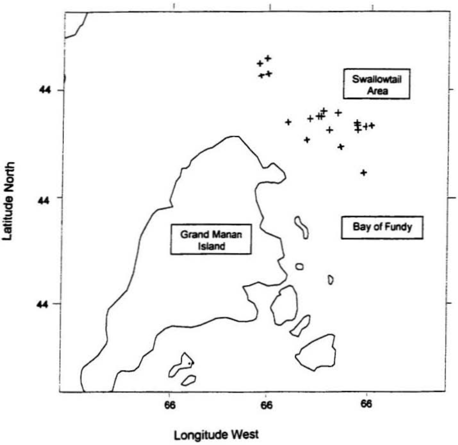


Figure 3.17: Spatial distribution of observed harbour porpoise incidental capture in fixed gillnets placed in waters adjacent to Grand Manan Island in the Bay of Fundy during 1994.

There was little variation in the number of nets per string. Ninety-eight percent of the strings consisted of three nets (mean 3.07; SD=0.259). The number of nets per string were not correlated with bycatch of harbour porpoise (P=0.10). Twenty-three (53%) of the 43 porpoise were captured at a bridle site. Daily effort data are summarized in Table 3.5; Appendix 18 and weekly effort in Appendix 19.

No harbour porpoise were captured in nets that soaked for less than 16 hrs or more than 96 hrs (Figure 3.18 a and b). The mean soak time for nets in which porpoise were caught was 41.8 hrs (SD=23.6; range 16-96 hrs). Soak time displayed the greatest bycatch number and fishing effort at the 25-48 hr soak time (CPUE=0.0145) and 10-24 soak hrs (CPUE=0.0137). However, the greatest CPUE (0.0224) occurred at the 49-72 hr soak time (Figure 3.18).

No harbour porpoise were captured in gillnets set at depths less than 76 m or greater than 112 m (Appendix 18). The mean depth for nets that captured harbour porpoise was 94 m (SD=10.7; range 76-112). Bycatch rates per unit of effort at depth show the greatest CPUE occurring between depths of 71-90 m (CPUE=0.2991) and the greatest fishing effort at 91-110 m (CPUE 0.0160; Figure 3.19 a and b; Table 3.5).

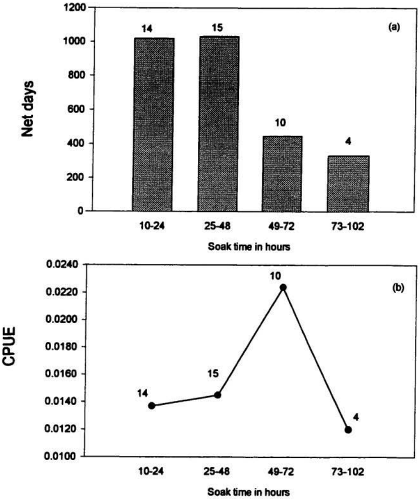


Figure 3.18 Frequency distribution for soak time per net, net days (a) and bycatch of harbour porpoise per unit of effort (CPUE) (b), for the Grand Manan Island/Bay of Fundy 1994 gillnet fishery. Numbers in graph refer to harbour porpoise mortalities .

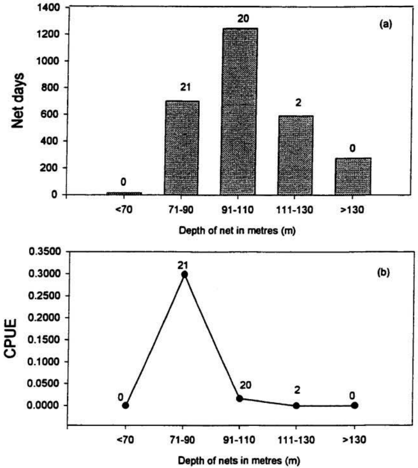


Figure 3.19: Frequency distribution for depth of net placement, net days at depth (a), and the catch per unit fishing effort (CPUE) (b), for the 1994 Grand Manan Island/Bay of Fundy gillnet fishery. Numbers in graph refer to harbour porpoise mortalities.

Table 3.5: Effort and CPUE for harbour porpoise data from the Grand Manan Island/Bay of Fundy 1994 gillnet fishery. Bycatch numbers are mortalities of harbour porpoise. Effort units are based on one net day (ND) which is equivalent to one net set for a 24 hour period.

Category	No.of net days	Percent net days	No.of bycatch	Percent bycatch	Bycatch CPUE
Soak time (hr)					
≤ 24 (10-24)	1,020	36	14	33	0.0137
≤ 48 (25-48)	1,031	36	15	35	0.0145
≤ 72 (49-72)	446	16	10	23	0.0224
> 72 (73-102)	331	12	4	9	0.0121
Depth at set (m)					
< 70	14	0.5	0	0	0
≤ 90 (71-90)	702	24.5	21	48.8	0.2991
≤ 110 (91-110)	1,248	44.1	20	46.5	0.0163
≤ 111 (111-130)	591	20.8	2	4.7	0.0033
> 131	273	10.1	0	0	0
Distance (km)					
1-2	1,264	45.6	26	60	0.0205
2.1-3	757	27.3	14	33	0.0184
3.1-4	349	12.6	3	7	0.0085
4.1-5	217	8	0	0	0
5.1-6	46	1.6	0	0	0
> 6.1	136	4.9	0	0	0

*Distance of net placement from shore is minus 59 net days of data (2,769 ND), all of which occurred on days with no bycatch.

Capture rates were highest (CPUE=0.0205) at the 1-2 km range with a sharp drop in effort and bycatch rates evident at distances greater than 3 km from shore. No animals were retrieved from nets set at greater than 4.1 km from shore (Figure 3.20 a and b; Table 3.5). The mean distance from shore for net placement with bycatch was 2 km (SD=0.6; range 1-3.5 km).

Statistically significant relationships were found between the bycatch of harbour porpoise and depth of net set (P=0.002), distance of net placement from shore (P=0.003), the daily harvest of Atlantic herring (0.0001), cod (P=<0.0001) and hake, (P=0.002) the number of net days (P=0.02), the harvest of pollock (P=< 0.0001 and the soak time of nets(P=0.01) (Table 3.6).

There was no variation in fishing procedure for all fishing effort. All species of fish were captured in common nets. The CPUE for Atlantic herring harvest was 6.3 fish per net day with a CPUE of harbour porpoise bycatch of 0.0020. The CPUE for cod harvest was 2.5 and a CPUE for harbour porpoise bycatch of 0.0060. The CPUE for pollock was 1.8 pollock per net day with a CPUE of harbour porpoise bycatch of 0.0081. Hake had a CPUE of 1.0 fish per net day with a CPUE for harbour porpoise bycatch of 0.0150.

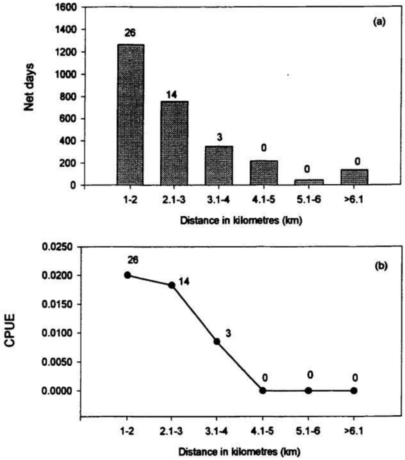


Figure 3.20: Frequency distribution for distance of net from shore and net days (a), and catch per unit effort (CPUE) (b), distance from shore per net set for the Grand Manan Island/ Bay of Fundy gillnet fishery during 1994. Numbers in graphs refer to harbour porpoise mortalities.

Table 3.6: Grand Manan Island/Bay of Fundy, 1994 results of Logistic Regression analysis examining the daily incidental capture of harbour porpoise, the daily operational variables and the daily target species harvest. Variables reported are the depth of net at set (m), distance of net from shore (km), number of individual Atlantic herring, cod, hake, harvested, the number of net days, number of nets in the capture string, the number of pollock harvested and the soak time of nets (hr). Values reported are the Wald Statistic depicted as the Z test for correlation coefficients and reported as the P value. P values determined to be statistically significant are presented in bold.

Variable	Z value	P value	Number of net days sampled
Depth of net set	-2.998	**0.002**	2,828
*Distance from shore	-2.905	**0.003**	2,769
Number of Atlantic herring	3.844	**0.0001**	2,828
Number of cod	3.943	**< 0.0001**	2,828
Number of hake	3.014	**0.002**	2,828
Number of net days	2.215	**0.02**	2,828
Number of nets in capture string	-1.6	0.1	2,828
Number of pollock	5.373	**< 0.0001**	2,828
Soak time of nets	2.531	**0.01**	2,828

*Distance of net placement from shore is minus 59 net days of data (2,769 ND).

The total amount of fish (all species inclusive) harvested on bycatch days was 17,959 fish (53.7% of total harvest; mean 4,490; SD=3304; range 1,783-9,248). The highest number of bycatch occurred on 1 August with nine harbour porpoise captured for a CPUE of 0.0775. The largest amount of herring, cod, pollock and the third largest amount of hake were also harvested on this day (Appendix 20). The only day with a greater CPUE was 17 July with five net days and one bycatch for a CPUE of 0.2000.

When calculated on a six day interval, the largest numbers of bycatch occurred during intervals with the greatest amount of fish harvested. Thirty-nine of the 43 harbour porpoise were caught during intervals with > 2,000 fish harvested. Of this number, 12 were captured during interval five with 6,618 fish harvested (Appendix 21). Atlantic herring harvest was significantly correlated with harbour porpoise bycatch (P=0.03) as was pollock harvest (P=0.02) when examined on a six day interval scale. In contrast, bycatch in relation to the harvest of codfish was not significant (P=0.4) nor was it related to hake (P=0.2) (Figure 3.21; Table 3.7).

Figure 3.21: Capture of harbour porpoise (in numbers above column) and capture of Atlantic herring (P=0.03) and pollock (P=0.02) (in number of individual fish) during six day intervals for the 1994 Grand Manan/Bay of Fundy gillnet fishery.

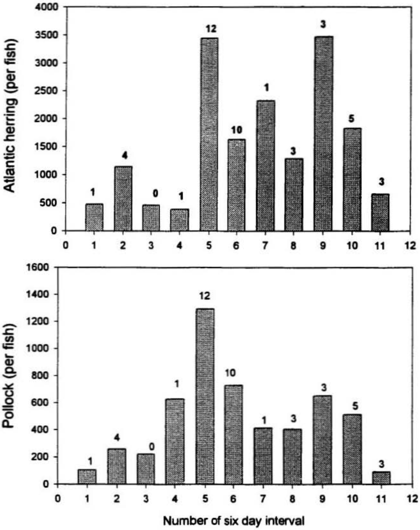

Atlantic herring (per fish)
4000
3500
3000
2500
2000
1500
1000
500
0
1
4
0
1
12
10
1
3
3
5
3
0 1 2 3 4 5 6 7 8 9 10 11 12
Pollock (per fish)
1600
1400
1200
1000
800
600
400
200
0
1
4
0
1
12
10
1
3
3
5
3
0 1 2 3 4 5 6 7 8 9 10 11 12
Number of six day interval

Table 3.7: Results of Logistic Regression analysis examining the incidental capture of harbour porpoise and the harvest of target species fish during six day intervals (n=11) from waters adjacent to Grand Manan Island, 1994. Values reported are the Wald Statistic depicted as the Z test for correlation coefficients and reported as the P value and number of data points used in the computation. P values determined to be statistically significant are reported in bold.

Variable	Z score value	P value	Number of intervals
Atlantic herring	2.129	**0.03**	11
Cod	0.827	0.4	11
Hake	1.131	0.2	11
Pollock	2.27	**0.02**	11

3.3.4 Grand Manan Island/Bay of Fundy, 1995

A total of 29 harbour porpoise were entrapped in gillnets, 11 of which were not retrieved. The remaining eighteen porpoise were sampled at sea. Data are not available for two of the captured harbour porpoise. The spatial distribution of bycatch is shown in Figure 3.22.

The greatest number of bycatch occurred on 6 July with four retrieved porpoise (Appendix 22). For bycatch days only the mean capture rate was 1.8 harbour porpoise per day (SD=0.83; range 1-4; net days=1,209). The mean soak time during these days was 33 hrs (SD=14.3; range 20-71 hrs). Mean depth for bycatch nets was 94 m (SD=10.6; range 73-110 m). The mean distance from shore for nets with bycatch was 2.5 km (SD=0.8; range 1-4.5 km). Seventy-nine (n=23) percent of the harbour porpoise (n=29) were captured in strings of three nets (300 m), and 14% (n=4) in strings with four nets, (400 m). Twelve of the 29 (41%) porpoise were captured at a bridle site. Daily effort data are presented in Appendix 22. Six day interval effort data are presented in Appendix 23.

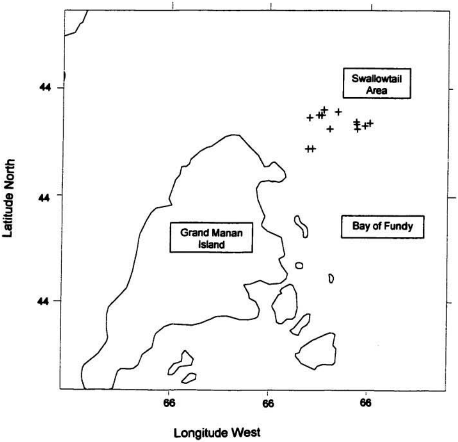


Figure 3.22: Spatial distribution of observed harbour porpoise incidental capture in fixed gillnets placed in waters adjacent to Grand Manan Island in the Bay of Fundy during 1995.

The mean soak time for nets in which porpoise were caught was 33 hrs (SD=14.3; range 20-71 hrs). Soak time displayed the greatest bycatch numbers and fishing effort at the less than 24 hr (CPUE=0.0144) soak times and at the 25-48 soak times (CPUE=0.0178) with 24 (82.7% of the total bycatch) occurring within these time periods. No porpoise were captured in nets which soaked for greater than 71 hrs (Figure 3.23; Appendix 22).

One hundred percent of the cases for which depths are known occurred in nets set at depths between 71 and 110 m (Figure 3.24 a and b). The greatest CPUE (0.0658) occurred at the 91-110 m depth with 16 captured porpoise. The mean depth for nets that captured harbour porpoise was 94 m (SD=10.6; range 73-110 m). Additionally, 21 (78% of the total known; CPUE=0.0183) porpoise were captured in nets placed less than or equal to 3 km from shore (Figure 3.25; Appendix 22). Bycatch and effort data are summarized in Table 3.8.

Operational variables found to have a significant relationships with the bycatch of harbour porpoise were, depth of net set (P=0.01), the daily harvest of Atlantic herring (P=0.006) and cod (P=<0.0001), the number of net days (P=<0.0001) and the harvest of pollock (P=0.04). No significance was found with the capture of harbour porpoise and the distance of net placement from shore, soak time of nets or the number of nets in the string of capture (Table 3.9).

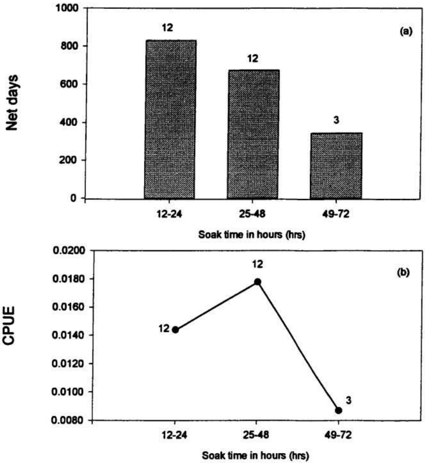


Figure 3.23: Frequency distribution for soak time per net, net days (a), and bycatch of harbour porpoise per unit of effort (CPUE) (b), during 1995 in the Grand Manan Island/Bay of Fundy gillnet fishery. Numbers in graphs refer to harbour porpoise mortalities.

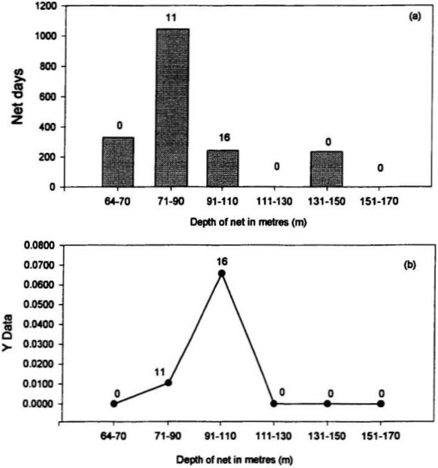


Figure 3.24: Frequency distribution for depth of net in metres (m) by net days (a), an catch per unit effort (CPUE) (b), for harbour porpoise captured in the Grand Manan Island/Bay of Fundy 1995 gillnet fishery. Numbers in graph refer to harbour porpoise mortalities.

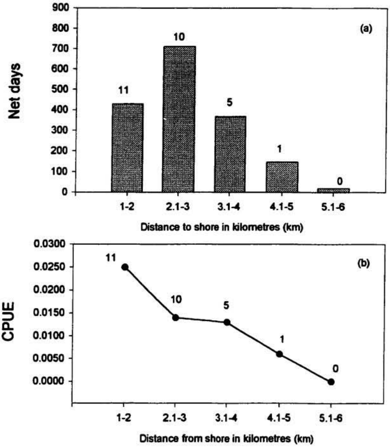


Figure 3.25: Frequency distribution for distance of net from shore and net days (a), and catch per unit of effort (CPUE) (b), for distance from shore per net set for the Grand Manan/ Bay of Fundy gillnet fishery during 1995. Numbers in graph refer to harbour porpoise mortalities.

Table 3.8: Effort and CPUE of harbour porpoise data for the Grand Manan Island gillnet fishery during 1995. Bycatch numbers are mortalities of harbour porpoise. Effort units are based on one net day (ND) which is equivalent to one net set for a 24 hour period.

Category	No. of net days	Percent net days	No. of bycatch	Percent bycatch	Bycatch CPUE
Soak time (hrs)					
≤ 24 (12-24)	831	45	12	41.3	0.0144
≤ 48 (25-48)	674	36.4	12	41.3	0.0178
≤ 72 (49-72)	344	18.6	3	10.4	0.0087
Depth at net set (m)					
≤ 70 (64-70)	328	18	0	0	0
≤ 90 (71-90)	1,044	56.4	11	38	0.0105
≤ 110 (91-110)	243	13	16	55	0.0658
≤ 130 (111-130)	0	0	0	0	0
≤ 150 (131-150)	234	12.6	0	0	0
≤ 170 (151-170)	0	0	0	0	0
Distance (km)					
0.5-2.0	430	23.2	11	38	0.0255
2.1-3	712	38.5	10	34.4	0.0141
3.1-4	369	20	5	17.2	0.0135
4.1-5	147	8	1	3.4	0.0068
5.1-6	191	10.3	0	0	0

* Data are not available for two harbour porpoise (7% of bycatch total), therefore, 27 animals are listed under bycatch/number porpoise caught.

Table 3.9: Grand Manan Island/Bay of Fundy, 1995 season results of Logistic Regression analysis examining daily operational variables and daily target species harvest. Variables reported are the depth of net set (m), distance from shore for net placement (km), the number of Atlantic herring and cod harvested (per number of fish), number of net days, the number of nets in capture string, the number of pollock harvested (per number of fish) and the soak time of nets (hrs). Values reported are the Wald Statistic depicted as the Z test for correlation coefficients and reported as the P value, and the number of data points used in the computation. P values determined to be statistically significant are presented in bold.

Variable	Z score value	P value	Number of net days sampled
Depth of net set	-2.377	**0.01**	1,849
Distance from shore	-1.849	0.06	1,849
Number of Atlantic herring	2.713	**0.006**	1,849
Number of cod	3.5	**< 0.0001**	1,849
Number of net days	4.3	**< 0.0001**	1,849
Number of nets in capture string	1.568	0.11	1,849
Number of pollock	2.054	**0.04**	1,849
Soak time of nets	1.311	0.18	1,849

The CPUE for cod was 4.6 fish per net day with a CPUE of harbour porpoise bycatch of 0.219 per net day. The CPUE for Atlantic herring was 3.6 fish per net day and the CPUE of harbour porpoise bycatch was 0.0042 per net day. The CPUE for pollock was 1.0 fish per net day with a CPUE of harbour porpoise bycatch of 0.0149 per net day. The association between harbour porpoise capture and the daily total harvest of individual fish is presented in Appendix 24 and in Appendix 25 for weekly data.

Atlantic herring (P=0.08) and pollock (P=0.40) were not significantly correlated with harbour porpoise bycatch when data are grouped by six day periods. However, it is worth noting that ten porpoise were captured during intervals with the highest catches of pollock (Appendix 25). A positive correlation was found between the bycatch of harbour porpoise and the six day interval harvest of cod (P=0.01; Figure 3.26; Table 3.10).

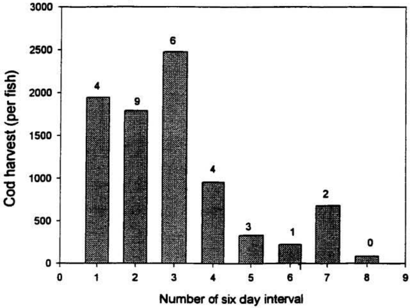


Figure 3.26: Comparison of the occurrence of harbour porpoise bycatch and the number of cod harvested during eight six day intervals for the summer of 1995 in waters adjacent to Grand Manan Island/Bay of Fundy (R=0.7; P=0.01). Numbers above column refer to the number of bycatch during specific interval.

Table 3.10: Grand Manan/Bay of Fundy, 1995 results of Logistic Regression analysis examining the incidental capture of harbour porpoise, the number of net days and target species harvest (cod, herring and pollock) during six day intervals (n=8). Values reported are the Wald Statistic depicted as the Z score for correlation coefficients and reported as the P value and the number of data points used in the computation. P values determined to be statistically significant are presented in bold.

Variable	Z score value	P value	Number of data points
Atlantic herring	1.713	0.08	8
Cod	2.349	**0.01**	8
Pollock	0.711	0.4	8

3.4 BIOLOGICAL DATA

3.4.1 St. Bride's, Newfoundland, 1993

For harbour porpoise in Eastern Newfoundland waters, Richardson (1992) determined that males are sexually mature at a mean length of 135.1 cm (SE=0.02) and a mean weight of 49 kg (SE=1.3). Females mature at a mean length of 146.4 cm (SE=0.03) and mean weight of 61.6 kg (SE=3.6). Equations for fit of harbour porpoise for Age-Mass and Age-Length from Richardson (1992) are reported in Table 2.3 of Chapter 2.

For this sample, age and sexual maturity were not determined but were estimated from Richardson's (1992) growth curves and estimates of length at sexual maturity by Lockyer (1999). Of the 15 retrieved animals, nine were male and six female. No significant difference ($P > 0.05$) was noted between the number of male and female harbour porpoise captured. A large proportion of both genders were mature animals. There were ten mature (five males and five females), four immature (three males, one female) one of the immature males which did not have any erupted teeth and was deemed to be a calf. Two females were lactating (animals # 16 and 19). Animal number 16 (143 cm in length; 51 kg) was smaller than the mean length and weight at maturity measurements reported by Richardson (1992) but was lactating and therefore classified as sexually mature. Life history data for individual porpoise are presented in

Appendix 26.

Mean length and weight for both genders all inclusive was 139 cm and 46.4 kg. Analyses of the length and mass distributions showed that females were longer and heavier than males but the difference was not significant (length, t=-1.157; df=12; P=0.27; weight, t=-1.811; df=12; P=0.09). Male maximum length was 150 cm, minimum 87.5 cm with a mean length of 133.8 cm, SD=20.9. Male maximum weight was 54 kg, minimum 11 kg with a mean of 39.3 kg, SD=15.4 kg, whilst female length values were maximum 157 cm, minimum 120 with a mean of 145.2 cm, SD=13.3 cm. Maximum female weight was 70 kg, minimum 31, with a mean of 53.5, SD=12.9 kg.

Stomach content analysis

Three of the 15 stomachs contained no identifiable prey remains. These stomachs were excluded from further analysis. In the remaining 12 stomachs a total of 1,041 prey items of four species were found. In total these weighed 36,962 g. Overall, three teleost fish species made up almost 100% of the total weight of prey. Results of stomach content analysis are summarised and presented in Appendix 27 and Table 3.11.

Table 3.11: Relative food importance measured by number of otoliths and prey remains present in harbour porpoise stomach contents. Mean weight of prey, proportion of numerical abundance (number of individuals of a prey species removed from all stomachs in %), and frequency of occurrence (% of stomachs specific species found in) for stomachs from 12 harbour porpoise captured in the gillnet fishery of St. Bride's, Nfld. during 1993.

Prey species	Number of prey remains	Weight of prey remains (g)	Proportion of numerical abundance in stomachs (%)	Percent contribution by mass	Percent occurrence in stomachs
Mallotus villosus (capelin)	1,017	25,787	97.6	70	n = 12 (100%)
Clupeidae harengus (Atlantic herring)	2	1,133	0.2	3	n = 2 (17%)
Ammodytidae (sand lance)	22	31	2.1	0.08	n = 7 (58%)
Hyperiidae spp.	n/a	73	n/a	0.1	n = 5 (42%)

* Note: Unidentifable items account for 26.8% contribution by mass of stomach contents.

Capelin was the most important species in the diet by frequency of occurrence (100%), numerical abundance (97.6%) in all stomachs and by mass (70%). Twenty-two sand lance were found, constituting 2.1% of the total prey items. Sand lance, occurred in seven (58%) of the stomachs. Total weight for sand lance was not known but was not expected to add much to the total. Two herring were found in two stomachs for a 0.2% proportion of occurrence and a 17% frequency of occurrence, with a total weight of 1,133 grams or 3.0% contribution by mass of total known prey weight (Table 3.11). Five stomachs contained specimens of *Hyperiidae* (amphipods) which are consumed by various teleost fish and may be a secondary contributor to the stomach contents of harbour porpoise. These specimens were counted but not analysed (Appendix 27).

Stomach contents by six day intervals reveals that stomachs from harbour porpoise captured during intervals two and three had the greatest number of capelin present and the greatest capelin weight (Appendix 28). Interval two also had the highest bycatch count and the greatest CPUE (0.0042). Target species stomachs were not collected during this season.

3.4.2 Gulf of Maine/Jeffreys Ledge, 1993

Twenty harbour porpoise captured and retained during commercial fishing operations in the Gulf of Maine were measured and examined for gender. Nineteen animals were necropsied and teeth were extracted to determine age.

Of the retrieved animals 15 were male and 5 were female. Large portions of both genders were immature animals. There were five mature and nine immature males, one of which was a calf. Morphometric and age data are not available for one male. Analyses of the length and weight distributions did not show significance differences between genders (length, t=-1.858; df=17; P=0.08; weight, t=-1.970; df=17; P=0.06). All the females (n=5) were immature; four were classed as calves. The males ranged in length from 110-160 cm with an average length of 129 cm (SD=13 cm). Male weight ranged from 29-67 kg with an average weight of 41 kg (SD=10 kg). The females ranged in length from 100-127 cm with an average length of 117 cm (SD=11 cm). The weight of the females ranged from 20-39 kg, with an average weight of 32 kg (SD=7 kg). The average length for the 18 measured harbour porpoise all inclusive was 126 cm (SD=14 cm) with an average weight of 39 kg (SD=10 kg). Equations for determining body mass from length in harbour porpoise were derived from Read and Tolley (1997; Table 2.5 of Chapter 2). The sex, total length, total weight, estimated age, and reproductive status of each animal examined are presented in Appendix 29.

Stomach content analysis

Results of harbour porpoise stomach content analysis for the nineteen available stomachs are presented in Appendix 30 and summarised in Table 3.12. The total fore-stomach content mass was 5,112 g with a mean of 284 (SD=330.4; range 6–913 g). One stomach did not contain any prey remains and was classified as empty. This stomach was excluded from further analysis. A total of 5,656 identifiable prey remains and sagittal otoliths belonging to seven species of teleost fishes were recovered from the remaining 18 stomachs. Euphausiids (*Meganyctiphanes norvegica*) were found in six porpoise stomachs. Four of these porpoise were calves, another was immature and the last one was mature. Euphausiids were noted as either present or absent but were not counted or weighed or analysed further (Appendix 30).

Atlantic herring, pearlsides (*Maurolicus weitzmani*), and silver hake (*Merluccius bilinearis*), occurred most frequently in the 17 stomachs based on frequency of occurrence and percent numerical abundance. Herring occurred in 10 stomachs with a total of 115 otoliths (58%) present. Pearlsides occurred in 13 stomachs (76%; n=4,253) and silver hake otoliths were recorded in 13 stomachs (76%; n=1,079) (Table 3.12). Two stomachs contained > 399 silver hake otoliths. (Appendix 30).

Table 3.12: Relative food importance, measured by number of otoliths and prey items present, mean length of prey, proportion of numerical abundance (%), and frequency of occurrence (%) of prey species found in the stomachs of 17 harbour porpoise captured in Gulf of Maine/Jeffreys Ledge waters during 1993. The number of prey remains equals otoliths and prey remains combined.

Prey species	Number of prey remains	Mean length ± SD (mm) of prey species	% Proportion of numerical abundance in stomachs	No. stomachs containing prey (% occurrence)
Clupea harengus (Atlantic herring)	115	175.5 ± 51.7	2	10 (58%)
Maurolicus weitzmani (Weitzman's pearlsides)	4,253	41.9 ± 1.4	75	13 (76%)
Meganyctiphanes norvegica (Euphausiids)	Present	Present	Present	Present 6 (35%)
Merluccius bilinearis (silver hake)	1,079	63.1 ± 54.7	19	13 (76%)
Urophysis spp. (red and white hake)	55	154 ± 138.2	0.9	6 (35%)
Pollachius virens (pollock)	128	186 ± 97.3	2.2	2 (12%)
Sebastes sp. (redfish)	25	33.4 ± 3	0.4	2 (12%)
Scomber scombrus (mackerel)	1	320	0.01	1 (5.8%)

* Note: *Meganyctiphanes norvegica* (Euphausiids) are reported as present (P) or absent (0).

Two stomachs contained pollock otoliths (12%; n=128). One hundred - twenty one pollock otoliths were recovered from a single stomach. Two stomachs contained a total of 25 (12%) otoliths from *Sebastes spp.*. One mackerel (*Scomber scombrus*) otolith (6%) was recovered. Fifty-five otoliths (35%) belonging to red or white hake (*Urophysis spp.)* were recovered from six stomachs (35%) (Appendix 30). These species (red and white hake, pollock, redfish and mackerel) each constituted less than 2.5% to the numerical proportion of otoliths recovered and were subsequently eliminated from further analysis (Table 3.12).

Length-frequency distributions for the three most prominent prey species, Atlantic herring, pearlsides and silver hake, are given in Figure 3.27. Atlantic herring were the longest prey consumed, the mean length was 175.5 mm (SD=51.7; range 110-332 mm; n=115). Atlantic herring length-frequency shows peaks between 139-146 mm and from 160-166 mm. The mean length for pearlsides was 41.9 mm (SD=1.7; range 40.5-44.5 mm; n=4,253) with a frequency peak at 42.5 mm. The mean fork length for silver hake was 63.1 mm (SD=54.7; range from 37.2 to 193.9 mm; n=1,079) with the strongest peaks at 30-50 mm (Figure 3.27). Calculations for these prominent species as well as those which constituted less than 2.5% numerical abundance are based on equations presented in Table 3.13.

Figure 3.27: Frequency distribution of estimated length of prey items from harbour porpoise stomachs obtained at the Gulf of Maine/Jeffreys Ledge in 1993. Figures show fork length frequencies (in mm) for Atlantic herring, pearlsides and silver hake. When possible otoliths were paired before number of fish were calculated.

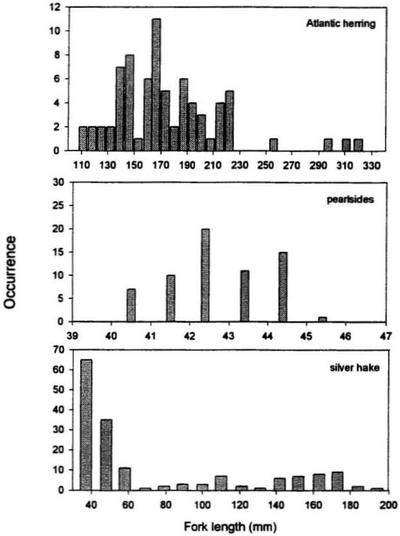

Atlantic herring
pearlsides
silver hake
Occurrence
Fork length (mm)
12
10
8
6
4
2
0
110 130 150 170 190 210 230 250 270 290 310 330
30
25
20
15
10
5
0
39 40 41 42 43 44 45 46 47
70
60
50
40
30
20
10
0
40 60 80 100 120 140 160 180 200

Table 3.13: Equations used to estimate the length of harbour porpoise prey.

FL = fork length; OL=otolith length.

Prey species	Equations	Source
Clupea harengus (Atlantic herring)	FL=69.23 OL - 27.48	Recchia and Read (1989)
Maurolicus weitzmani (Weitzman's pearlsides)	FL=9.82 + 28.75 OL	Harkonen (1986)
Merluccius bilinearis (silver hake)	FL=20.9 OL - 0.41	Recchia and Read (1989)
Pollachius virens (pollock)	ln(FL/10)=3.251 + 1.6251 OL	Harkonen (1986)
Scomber scombrus (mackerel)	FL/10=7.33 OL + 0.37	Recchia and Read (1989)
Sebastes sp. (Rockfish)	$FL/=16.165\ OL^{1.224}$	Harkonen (1986)
Urophysis spp. (Red and white hake)	$FL/10=1.525\ OL^{1.1456}$	Clay and Clay (1991)

Stomach content analysis for six day intervals reveal that mean weight of full stomachs and content amount of stomachs were greatest during weeks of highest bycatch. Twenty of the 33 bycaught harbour porpoise were captured during week intervals with a mean weight for full stomachs > 1,000 g and mean content weight > 600 g (Appendix 31).

Fish stomach content analysis

Four hundred and thirty target fish species stomachs were collected at the rate of ten per day during 43 of the 46 days of fishing effort (Appendix 32). The total fish stomach content weight was 3,215 g, the mean was 74.7 g (SD=32.2; range 11-155 g). In all, 2,923 prey items were identified. The three major prey removed from fish stomachs were euphausiids (n=1,555; mean 36 per stomach; SD=91.1; range 0- 550), Atlantic herring (n=371; mean 8.6 per stomach; SD=5.2; range 0-29), and shrimp (n=997; mean 23.1 per stomach; SD=24.8; range 0-127). One thousand and twenty-three prey items consisted of broken unidentifiable pieces of organisms and were discarded.

Nineteen (57.5%) of the 33 porpoise were captured on days with ≥ 60 g fish stomach content weight (Appendix 32). However, no statistically significant relationships were found between harbour porpoise capture and the amount of euphausiids (P=0.1), herring (P=0.6), shrimp (P=0.7), or content weight (P=0.2)

(Appendix 32). The relationship between harbour porpoise bycatch and target species stomach content analysis when calculated on a six day interval scale was not significant (number of prey; P=0.23; content weight; P=0.34). Six day interval data are presented in Appendix 33.

3.4.3 Grand Manan Island/Bay of Fundy, 1994

For harbour porpoise in Bay of Fundy waters, Lockyer (1995) and Read and Hohn (1995) determined that males are sexually mature at approximately three years of age and 130-132 cm in length at a weight of 41 kg. Probable age of sexual maturity in females is 3.4 years at a length of 140-145 cm and a weight of 34 kg.

Morphometric and gender data were collected from 34 retrieved animals. Animals were returned to ocean water after measurements and samples were collected. Of the retrieved animals, 18 were male and 16 were female. There was a significant difference between male and female porpoise length, but not weight (length, t=3.111; df=32; P=0.004; weight, t=-1.327; df=32; P=0.194). The males ranged in length from 109-156 cm with an average length of 133.6 cm (SD=15.1). Females ranged in length from 131-171 cm, the average length was 148.6 cm (SD= 12.7). Male maximum weight was 60 kg with a minimum of 27 kg (mean 43.6; SD= 9.6). Female weights ranged from 28-68 kg with a mean of

48.5 (SD=11.7). For both genders, the average length was 140.7 cm (SD=15.8), with a mean weight of 44.9 kg (SD=10.9).

Of the 18 male and 16 female harbour porpoise that were captured, the majority were sexually mature. Eleven males were mature, four immature and three were calves. Eleven of the females were mature and five were immature. Equations for determining body mass from length in harbour porpoise are from Read and Tolley (1997; Table 2.5 of Chapter 2). The gender, total length, girth, weight, estimated age and reproductive status of each animal examined are presented in Appendix 34. No teeth were obtained from any of the captured animals for age determination data.

Harbour Porpoise stomach content analysis

Results of harbour porpoise stomach content analysis are presented in Appendix 35 and summarized in Table 3.14. Twenty-nine harbour porpoise stomachs were analysed for prey contents. The total fore-stomach weight was 16,626 g; mean 615.7; SD=620.2; range 82.4-3,172). Fore-stomach content mass was 9,384 with a mean of 323.5 g; SD=587.9; range 1.2-2,966). Six stomachs did not contain any prey remains and were classified as empty. These stomachs were excluded from further analysis. Two stomachs were punctured implicating potential content loss, and were therefore discarded.

Table 3.14: Relative food importance, measured by proportion of total mass (%) and frequency of occurrence (%), of prey species in the stomachs of 21 harbour porpoise captured in waters adjacent to Grand Manan Island, 1994. Mean length is in millimetres (mm), n=total number of otoliths and specific prey found in all stomachs.

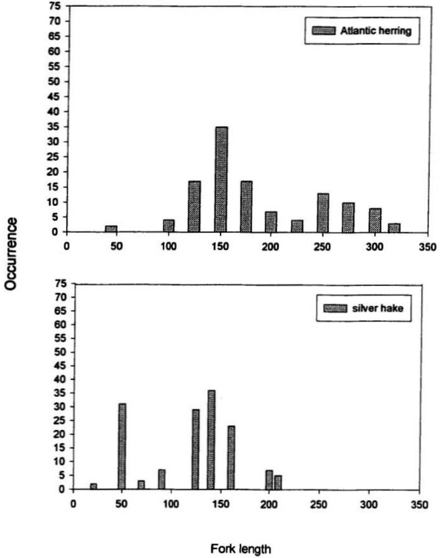
Prey species	Number	Mean length ± (mm) of prey species	Range (mm)	% Proportion of numerical abundance in stomachs	No. stomachs containing prey (% occurrence)
Merluccius bilinearis (silver hake)	524	103.2 ± 48.7	21.5-208.9	41	16 (76)
Clupea harengus (Atlantic herring)	514	159.2 ± 67.2	44.5-318	40	19 (90)
Urophysis spp.	4	n/a	n/a	0.31	4 (19)
Pollachius virens (pollock)	5	n/a	n/a	0.4	3 (14)
Gadus morhua (Atlantic cod)	82	n/a	n/a	6.3	12 (57)
Scomber scombrus (mackerel)	12	n/a	n/a	0.9	7 (33)
Squid beaks (spp.)	47	n/a	n/a	3.6	10 (47.6)
Meganyctiphanes norvegica (Euphausiids)	96	n/a	n/a	7.4	4 (19)

A total of 1,284 identifiable prey items and sagittal otoliths from six species of teleost fishes were recovered from the remaining 21 stomachs. Of these, herring and silver hake were the most prominent by frequency of occurrence, numerical abundance and percent occurrence of otoliths. Atlantic herring occurred in 19 stomachs (90%), silver hake in 16 (76%). Silver hake accounted for 41% and Atlantic herring for 40% by number of the prey items identified (Table 3.14).

Twelve stomachs contained cod, seven contained mackerel, and three had pollock remains. Remains belonging to *Urophysis spp.* were found in four stomachs. Forty-seven squid beaks (23.5 squid) were recovered from ten stomachs, and 4 stomachs contained euphausiids. These species each constituted less than 10% to the numerical proportion of remains recovered and were excluded from further analyses (Table 3.14).

Length-frequency distributions for the two prevalent prey species, Atlantic herring and silver hake are shown in Figure 3.28. Atlantic herring was the largest prey consumed by length, mean length was 159.2 mm (SD=67.2; range 44.5-318). The mean length for silver hake was 103.2 mm (SD=48.7; range 21.5-208.9). These fish lengths were estimated using equations previously given in Table 3.13.

Figure 3.28: Frequency distribution of estimated length of prey items from harbour porpoise stomachs obtained at Grand Manan Island/Bay of Fundy in 1994. Figures show fork length frequencies (in mm) for Atlantic herring and silver hake. When possible otoliths were paired before number of fish were calculated.


Atlantic herring
silver hake
Occurrence
Fork length

The mean weight of full stomachs and content amounts were greatest during weeks of highest bycatch numbers. Twenty-five of the 29 harbour porpoise were captured during six day intervals with >1,500 g fore-stomach weight and >1,000 g content weight. Twenty-two of these harbour porpoise were captured during intervals with >4,450 g fore-stomach weight and >1,900 g content weight (Appendix 36).

Fish stomach content analysis

A total of 640 stomachs from target fish species were collected during 32 of the 49 days of fishing effort. The total fish stomach content weight was 79,347 g (mean 104.5; SD=112.5; range 0-1,975). Collectively, a total of 23, 256 items were found in the fish stomachs. These included, euphausiids (n=21,025), shrimp (n=562) and herring (n=485) with a mean of 20.8 items (SD=146.7; range 1-3,532) (Appendix 37). The remaining 1,184 items consisted of broken parts that could not be identified and were therefore excluded from analysis.

Thirty-three of the 43 porpoise were captured on days with > 80 g (mean) of fish stomach content. Twelve of these animals were captured on days with a mean >100 g of stomach content (Appendix 37). Thirty animals were captured during week intervals with a mean > 100 g of fish stomach content (Appendix 38). There was a weak significance between the presence of euphausiids and the bycatch of harbour porpoise (P=0.05). There were no significant relationships between bycatch and herring (P=0.2), or shrimp (P=0.5).

3.4.4 Grand Manan Island/Bay of Fundy, 1995

Morphometric and gender data were collected from 18 retrieved porpoise from a total of 29 bycaught animals. Ten were male and eight were female. The males ranged in length from 97-155 cm with an average length of 133.3 cm; (SD=19.4). Females ranged in length from 144-161 cm. Their mean length was 152.8 (SD=5.8) cm. Male weights ranged from 22.3 to 61.6 kg with a mean of 41.2 kg (SD=13.4 kg). Females weighed 43.1 to 64.5 kg with a mean of 55.6 kg (SD=7.6). For combined gender the average length was 142 cm (SD=17.7; range 96.5-161). The average weight was 48 kg (SD=13.6; range 22- 67).

All eight females and seven of the ten males were mature. Of the three immature males, two were calves. One sexually mature female was found to be lactating (animal number 26). Equations for determining body mass from length in harbour porpoise were derived from Read and Tolley (1997; Table 2.5 of Chapter 2). The gender, total length, weight, estimated age and reproductive status of each animal are presented in Appendix 39.

Harbour porpoise stomach content analysis

Five stomachs did not contain any prey remains, these stomachs were excluded from further analysis. A total of 900 sagittal otoliths and identifiable remains were recovered from the remaining thirteen stomachs. Of these, species Atlantic herring and silver hake were the most prominent by frequency of occurrence, percent occurrence and numerical abundance of remains in the stomach. Atlantic herring occurred in 77% and silver hake in 46% of the stomachs with remains present. Herring accounted for 46%, silver hake 23%, cod 0.4% and pollock for 0.1 % of the numerical abundance (Table 3.15). Sixty-six squid beaks (33 squid) were recovered from four stomachs. One stomach excised from a calf contained euphausiids. Hagfish were removed from six (46%) stomachs. Hagfish and euphausiids were counted but not quantified for further analyses. Results of stomach content analysis are summarised and presented in Appendix 40.

Table 3.15: Relative food importance measured by number of otoliths and prey remains present in harbour porpoise stomach contents. Mean length of prey, proportion of numerical abundance to total contents and frequency of occurrence for stomachs from 13 harbour porpoise captured during 1995 in the Grand Manan /Bay of Fundy gillnet fishery.

Prey species	Number of prey remains	Mean length and SD of prey remains (mm)	% Proportion of numerical abundance in stomachs	% Occurrence in stomachs
Clupea harengus (Atlantic herring)	416	168 ± 50	46	10 (77)
Gadus morhua (Atlantic cod)	4	186 ± 31	0.4	2 (15)
Meganyctiphanes norvegica (Euphausiids)	116	Present	12.8	1 (8)
Merluccius bilinearis (silver hake)	208	62 ± 35	23	6 (46)
Myxine glutinosa (hagfish)	89	Present	9.8	6 (46)
Pollachius virens (pollock)	1	187	0.1	1 (8)
Squid beaks (spp.)	66	Present	7.3	4 (31)

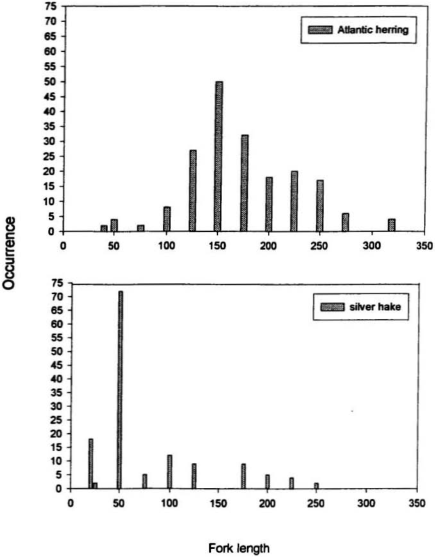
Atlantic herring was the longest prey consumed, with a mean length of 168 mm (SD=50; range 46-318 mm). The mean length for silver hake was 62 mm (SD=35; range 26-250). Length-frequency distributions for the two prevalent prey species, Atlantic herring and silver hake are reported in Figure 3.29.

No correlations were found between harbour porpoise bycatch and fore-stomach weight, content weight or remains removed from stomachs, (P> 0.05). However, it is worth noting that the mean weight of full fore-stomachs and content amount were greatest during six day intervals of highest bycatch numbers. Twenty-three of the 29 porpoise were captured during six day intervals with a >1,500 g total fore-stomach weight and a content weight >500 g. Fourteen of these porpoise were captured during intervals with fore-stomach weights >2,000 g and content weights >900 g (Appendix 41).

Fish stomach content analysis

Three hundred stomachs from target species fish were collected during 15 of the 36 days of fishing effort. The total fish stomach content weight was 37,550 g; the mean weight was 122 g (SD=111; range 10-925). In all, 13,120 prey items were identified. The three major prey removed from fish stomachs were euphausiids (n=12,871; mean 858 per stomach; SD=847; range 16-2,985). Atlantic herring (n=150; mean 10 per stomach; SD=11.1; range 1- 35) and shrimp (n=85; mean

Figure 3.29: Frequency distribution of estimated length of prey items from harbour porpoise stomachs obtained at Grand Manan Island/Bay of Fundy in 1995. Figures show fork length frequencies (in mm) for Atlantic herring and silver hake. When possible otoliths were paired before number of fish were calculated.


Atlantic herring
silver hake
Occurrence
Fork length
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
0
50
100
150
200
250
300
350

6.4 per stomach; SD=6; range 1-18). Six-hundred and sixty-one prey items consisted of broken pieces of organisms that could not be identified (Appendix 42).

Ten of the 29 harbour porpoise were captured on days when the greatest numbers of euphausiids and herring occurred coincidently in fish stomachs (Appendix 42). No statistically significant relationships were found between harbour porpoise capture and the amount of euphausiids (P=0.09), herring (P=0.1), shrimp (P=0.7) or content weight, (P=0.4). No statistical significance was found between harbour porpoise bycatch and target species stomach content analysis when calculated on a six day interval scale. Six day interval data are presented in Appendix 43.

3.5 ENVIRONMENTAL DATA

3.5.1 St. Bride's, Newfoundland, 1993

When analysed on a daily scale the rate of harbour porpoise bycatch did not vary significantly with respect to water column temperature, percent salinity or water clarity (P> 0.05). However, it is worth noting that seventeen of the 19 harbour porpoise were captured in waters with <16.5 m water column clarity and two in waters with >16.5 m clarity.

When analysed on a daily scale the rate of harbour porpoise bycatch did not vary significantly with respect to water clarity (P=0.1), water column temperature (P=0.6), wind speed at net set (P=0.1) or percent salinity (P=0.7). However, harbour porpoise captures had a positive correlation with daily cloud cover at the set of net (P=0.04; Table 3.16). When analysed at a six day interval scale the rate of harbour porpoise bycatch did not vary significantly with any environmental factors (P> 0.05). Results for daily environmental data analysis are reported in Table 3.16. Daily and six day interval environmental data are reported in Appendices 44 and 45.

3.5.2 Gulf of Maine/Jeffreys Ledge, 1993

Environmental data for daily measurements are reported in Appendix 46. The rate of harbour porpoise bycatch did not vary significantly with any of the environmental variables. All harbour porpoise were captured in waters with a temperature range of 6.5 to 11.3°C. This range was inclusive of all daily mean measurements, excluding one at 6.2°C.

The mean Beaufort Scale reading for net setting days in which a bycatch followed was four kn (SD=6; range 0-25 kn). The mean wind speed for these days was 11 kn. Thirty-two of the thirty-three animals were captured in nets set on days with a Beaufort Scale reading of three or greater. Of this number, 20

Table 3.16: St. Bride's, 1993 results of Logistic Regression analysis examining the daily mean environmental variables and the bycatch of harbour porpoise (n=19). Variables reported are the daily mean of cloud cover in percent, salinity in parts per thousand (ppt), water column clarity in metres (m), water column temperature in Celsius (°C), and wind speed in knots (kn). Values reported are the Wald Statistic depicted as the Z test score for correlation coefficients and reported as the P value, and the number of data points used in the computation. P values determined to be statistically significant are presented in bold.

Variable	Z score value	P value	Number of days data collected
Cloud cover	1.996	**0.04**	27
Salinity	0.351	0.7	27
Water column clarity	-1.415	0.1	27
Water column temperature	0.501	0.6	27
Wind speed	-1.415.	0.1	27

were captured in nets set on days with a Beaufort Scale rating of four or greater (Appendix 46).

For days with bycatch the mean cloud cover was 55% (SD=38.3; range 0-100%). Twenty-one animals were captured in nets set on days with a 50% or greater cloud cover (Appendix 46). Analysis for environmental factors are presented in Table 3.17. Water column clarity data were not collected during this season.

When analysed at a six day interval scale, the rate of harbour porpoise bycatch did not vary significantly with respect to cloud cover, wind speed, water column temperature, or percent salinity, all values were $P > 0.05$. Six day interval values are reported in Appendix 47.

Table 3.17: Gulf of Maine/Jeffreys Ledge, 1993 results of Logistic Regression analysis examining the daily mean environmental variables and the bycatch of harbour porpoise (n=33). Variables reported are the daily mean of cloud cover in percent, salinity in parts per thousand (ppt), water column temperature in Celsius (^{o}C), and wind speed in knots (kn). Values reported are the Wald Statistic depicted as the Z test score for correlation coefficients and reported as the P value, and the number of data points used in the computation. P values determined to be statistically significant are presented in bold.

Variable	Z score value	P value	Number of days data collected
Cloud cover	-0.621	0.5	45
Salinity	1.131	0.2	37
Water column temperature	0.64	0.9	37
Wind speed	-0.306	0.7	46

3.5.3 Grand Manan Island/Bay of Fundy, 1994

When analysed at a daily scale, the rate of bycatch did not vary significantly with respect to cloud cover, water column clarity, water column temperature, wind speed or percent salinity. Bycatch appeared to occur throughout most of the range of these variables. However, thirty-five porpoise of the forty-three total captures occurred in waters with temperatures of 10°C or greater (Appendix 48). Wind speed as calculated by the Beaufort Scale was found to be positively correlated to the bycatch of harbour porpoise (P=0.01). Thirty-five porpoise were captured in nets set on days with wind speeds of greater than three knots per hour and a Beaufort Scale reading of greater than one (Table 3.18). It is worth noting that 27 (63%; n=43) of the porpoise were captured in nets set on days with a clarity reading of eight m or less. All mean daily environmental data are reported in Appendix 48.

In contrast to analysis made at the one day scale, when analysed at six day intervals, porpoise bycatch was positively correlated with water column temperature (P=0.03;Table 3.19). There was little variability noted among the remaining factors. Mean six day interval environmental data are reported in Appendix 49.

Table 3.18: Grand Manan Island/Bay of Fundy, 1994 results of Logistic Regression analysis examining the daily mean environmental variables and the bycatch of harbour porpoise (n=43). Variables reported are the daily mean of cloud cover in percent, salinity in parts per thousand (ppt), water column clarity in metres (m), water column temperature in Celsius (^{0}C), and wind speed in knots (kn). Values reported are the Wald Statistic depicted as the Z test score for correlation coefficients and reported as the P value, and the number of data points used in the computation. P values determined to be statistically significant are presented in bold.

Variable	Z score value	P value	Number of days data collected
Cloud cover	-0.464	0.6	47
Salinity	1.71	0.08	37
Water column clarity	-0.145	0.8	47
Water column temperature	1.757	0.07	37
Wind speed	2.531	**0.01**	47

Table 3.19: Grand Manan Island/Bay of Fundy, 1994 results of Logistic Regression analysis examining the six day interval mean environmental variables and the bycatch of harbour porpoise (n=43. Variables reported are the daily mean of cloud cover in percent, salinity in parts per thousand (ppt), water column clarity in metres (m), water column temperature in Celsius (°C), and wind speed in knots (kn). Values reported are the Wald Statistic depicted as the Z test score for correlation coefficients and reported as the P value, and the number of data points used in the computation. P values determined to be statistically significant are presented in bold.

Variable	Z score value	P value	Number of intervals
Cloud cover	1.131	0.2	11
Salinity	0.185	0.8	11
Water column clarity	1.131	0.2	11
Water column temperature	2.129	**0.03**	11
Wind speed	1.881	0.5	11

3.5.4 Grand Manan Island/Bay of Fundy, 1995

When analysed at a daily scale, the rate of bycatch did not vary significantly with respect to cloud cover, water column temperature or water column clarity. Percent salinity data were not collected during this season thus, no data are reported. All 29 porpoise were captured in waters with temperatures ranging from 6-11.4°C. Twenty-five porpoise (86%) were captured in nets set in waters with a turbidity reading of eight m or less (Appendix 50). Captures had a weak but noteworthy correlation with wind speed (P=0.04) but were not correlated with mean water clarity or mean water column temperature (Table 3.20).

When analysed at a six day interval scale the rate of harbour porpoise bycatch did not vary significantly with respect to cloud cover, water clarity, water column temperature or wind speed (P=>0.05). Six day interval values are reported in Appendix 51.

Table 3.20: Grand Manan Island/Bay of Fundy, 1995 results of Logistic Regression analysis examining the incidental capture of harbour porpoise (n=29) and daily mean environmental variables. Variables are the daily mean wind speed in knots (kn), cloud cover in percent (%), water column clarity in metres (m) and mean water temperature in ^{0}Celsius (^{0}C). Values reported are the Wald Statistic depicted as the Z test score for correlation coefficients and reported as the P values and the number of data points used in the computation. P values determined to be statistically significant are presented in bold.

Variable	Z score value	P value	Number of days data collected
Cloud cover	-0.398	0.6	35
Water clarity	0.064	0.9	30
Water column temperature	-0.621	0.5	34
Winds speed	1.992	**0.04**	35

RESULTS: 3.6 ELAPSED TIME SINCE DEATH

3.6.1 ELAPSED TIME SINCE DEATH DATA

Elapsed time since data were collected from 24 harbour porpoise captured in nets placed in waters adjacent to Grand Manan Island during the summers of 1994-95 exclusively.

There was a significant difference ($P<0.001$) between normal antemortem serum concentrations and postmortem vitreous concentrations of potassium, magnesium, and glucose (Figure 3.30). The mean concentration of these variables were plotted against the covariables sodium, chloride, phosphorus, urea, calcium and the sodium/potassium ratio. Mean antemortem and postmortem values and ranges for the ocular fluid elements measured in 1994 and 1995 are given in Table 3.21.

A two-tailed paired t test; ($n=24$) was used to compare left and right ocular elements and determine if there were differences between the concentrations of elements in fluid extracted from individual eyes of a single harbour porpoise. Concentrations of each element in individual eyes of the same porpoise did not differ ($P>0.05$). Subsequently, for further statistical analysis, only the mean concentrations of chemicals in both eyes were used.

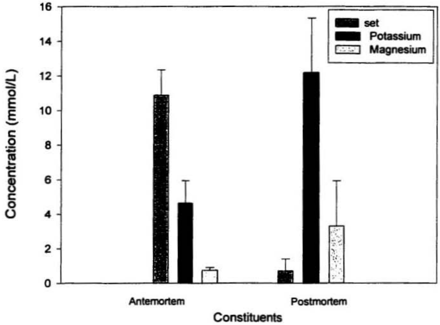


Figure 3.30: Comparison of mean concentrations of potassium, magnesium and glucose in serum of harbour porpoise incidentally captured and released from herring weirs and in vitreous humour of harbour porpoise captured in gillnets during the summers of 1994 and 1995 (mean soak time, 34 hours). Antemortem serum values are from Koopman *et al.* (1995).

Table 3.21: Comparison of antemortem (AM) blood chemistry values for harbour porpoise (*Phocoena phocoena*) released live from herring nets and postmortem (PM) vitreous humour chemical values for harbour porpoise incidentally caught in gillnets from the Bay of Fundy, Canada. Values presented are mean ± standard deviation, range, and sample size. All values are in mmol/L. Glucose and ancillary values are presented for 1994. Potassium, magnesium, glucose and ancillary constituents are presented for 1995. Live antemortem values are from Koopman *et al.* (1995).

Constituent 1994/1995	Mean AM value	Range	n	Mean PM value	Range	PM from AM mean	n
Glucose *	10.87 ± 1.46	8.2-13.8	27	0.71 ± 0.70	0-2.3	10.16	24
Sodium	156.6 ± 7.7	148-186	27	175.6 ± 33.18	144-245	19	24
Chloride	114.3 ± 3.8	110-127	27	153.6 ± 43.8	111-243	39.3	24
Phosphorus	1.76 ± 0.60	0.54-2.82	27	1.89 ± 1.82	0.40-5.62	0.13	24
Urea	21.14 ± 4.33	11.0-28.4	27	15.6 ± 4.94	3.0-22	5.5	24
Constituent 1995 only							
Potassium*	4.64 ± 1.30	3.1-8.3	27	12.18 ± 3.15	8.2-18.8	7.54	13
Magnesium*	0.75 + 0.16	0.51-1.28	27	3.30 ± 2.63	0.99-8.9	2.55	12
Calcium	2.41 ± 0.16	2.12-2.90	27	2.86 ± 1.74	1.72-8.2	0.45	13
Sodium/ Potassium ratio	36 ± 9	18-55	27	17 ± 5.04	8.5-31	19	13

* Indicates live antemortem serum value and postmortem value differ significantly (P<0.001).

3.6.2 Vitreous Humour Constituents

Postmortem glucose concentration in all samples of vitreous humour decreased to less than 25% of the AM serum concentrations values (SD=0.70; range of glucose decline was 8.57-10.87 mmol/L) with a postmortem mean value of 0.71 mmol/L (n=24) for the combined years (1994/1995) (Table 3.22).

There was a significant positive correlation between this concentration and core body temperature ($R=0.7$; $P< 0.0001$; $n=24$; Figure 3.31) and a negative correlation between glucose and vitreous concentration of K ($R=0.5$; $P<0.05$; Figure 3.32). There were no statistically significant correlations between the vitreous concentration of glucose, and the soak time of gillnets or with the vitreous concentrations of sodium (Na), magnesium (Mg), calcium (Ca), phosphorus (P), chloride (Cl), and urea ($P> 0.05$). Two porpoise (numbers 11 and 24) had no detectable glucose in their vitreous humour and a core temperature of < 13°C; the soak times of the gillnets in which these two porpoise had been caught were 95 and 69 hrs, respectively. Conversely, the two porpoise (numbers 5 and 23) with the highest vitreous concentration of glucose (>2 mmol/L) had among the highest core temperatures (>20°C), and the gillnets in which they had been caught had among the shortest soak times (23 and 21 hrs, respectively) (Table 3.22).

Table 3.22: Postmortem (PM) mean value for glucose (mmol/L) and temperature in °C. Temperature decrease and percent decline, from harbour porpoise caught in gillnets in the Bay of Fundy for combined years 1994/1995. Antemortem (AM) mean glucose value 10.87 (mmol/L) from Koopman *et al.* (1995). Antemortem temperature level 36.2 °C from Kastelein (1994).

Animal number	PM glucose	PM decline	Percent decline	PM temp.	Temp. loss	% temp. loss	Water temp.	Soak time
1	0.1	10.77	99	10	26.2	72	9.5	17
2	0.95	9.92	91	16	20.2	55	9.6	19
3	0.1	10.77	99	16	20.2	55	9.4	48
4	0.05	10.82	99	12	24.2	66	9.2	25
5	2.3	8.57	78	22	14.2	39	9.5	23
6	0.1	10.77	99	10.5	25.7	70	9.8	25
7	1.55	9.32	85	30	6.2	17	9.8	27
8	0.5	10.37	95	16	20.2	55	10.5	26
9	0.3	10.57	97	16	20.2	55	10.4	24
10	1.7	9.17	84	20	16.2	44	9.6	95
11	0	10.87	100	12	24.2	66	9.6	95
12	0.2	10.67	98	9.0	27.2	75	7.2	21
13	1.85	9.02	82	18	18.2	50	7.6	23
14	0.55	10.32	94	12	24.2	66	7.5	24
15	0.7	10.17	93	11	25.2	69	7.2	43
16	1.0	9.87	90	11	25.2	69	7.3	26
17	0.75	10.12	93	12	24.2	66	7.0	19
18	0.2	10.67	98	8.0	28.2	78	7.1	47
19	0.5	10.37	95	13	23.2	64	7.6	24
20	0.05	10.82	99	9.0	27.2	75	7.3	26
21	0.85	10.02	92	12	24.2	66	7.3	24
22	0.75	10.12	93	20	16.2	44	9.2	24
23	2.1	8.77	80	21	15.2	41	9.0	21
24	0	10.87	100	10	26.2	72	9.5	69

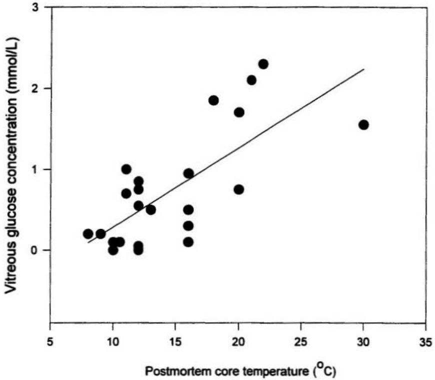


Figure 3.31: Comparison of postmortem temperature (^{0}C) and mean glucose values (mmol/L) (R=0.7: P=0.0001: N=24) for combined years 1994/1995.

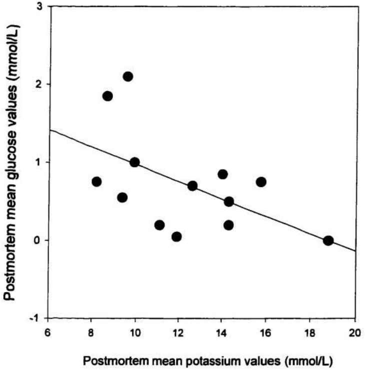


Figure 3.32: Comparison of postmortem mean potassium and glucose values (mmol/L) (R=-0.5; P=<0.05; N=13).

Eleven of 13 harbour porpoise with a >90% decrease in vitreous concentration of glucose as compared to normal serum concentrations had a >100% increase in vitreous concentration of potassium compared to normal serum values. Seven of 12 harbour porpoise examined for postmortem magnesium levels, with a >90% decrease in vitreous concentration of glucose had a >100% increase in vitreous concentration of magnesium (Tables 3.22 and 3.23).

The mean postmortem potassium level was 12.18 mmol/L (SD=3.15; range 8.20 -18.8; n=13) with a mean postmortem increase of 6.9 mmol/L (Table 3.21). Positive correlations were found between the vitreous concentrations of potassium and phosphorus (Figure 3.33) and between the vitreous concentration of potassium and the soak time of gillnets (Figure 3.34). The vitreous concentration of potassium was not statistically correlated with either the core temperature or the vitreous concentrations of magnesium, sodium, calcium, chloride, and urea (P > 0.05). However, when tested via Forward Stepwise Regression potassium could be predicted from a linear combination of sodium (R=0.5; P< 0.01; n=13) and the sodium/potassium ratio; (R=0.1; P< 0.0001; n=13; Figure 3.35).

Table 3.23: Postmortem (PM) mean values (mmol/L), amount decline and percent decline for potassium and magnesium, postmortem temperature, temperature loss and percent postmortem temperature loss from the live mean of 36.2°C Kastelein (1994), water column temperature and soak time of nets of harbour porpoise capture. Postmortem values are compared to live serum values reported by Koopman *et al.* (1995).

Sample number	PM K	PM increase	% increase	PM Mg	PM increase	% increase	PM temp.	temp. loss	% temp. loss	water temp.	soak time
12	14.3	9.66	> 100	8.9	8.16	> 100	9	27	75	7.2	21
13	8.65	4.01	86	1.5	0.71	94	18	18	50	7.6	23
14	9.35	4.71	>100	1.3	0.58	77	12	24	66	7.5	55
15	12.6	7.96	>100	4.9	4.17	>100	11	25	69	7.2	43
16	9.9	5.26	>100	1.5	0.7	93	11	25	69	7.3	26
17	8.2	3.56	76	1	0.24	32	12	24	66	7	20
18	11.1	6.46	>100	n/a	n/a	n/a	8	28	78	7.1	47
19	14.3	9.66	>100	7.5	6.7	>100	13	23	64	7.6	25
20	11.9	7.26	>100	3.4	2.63	>100	9	27	75	7.3	26
21	14	9.36	>100	4.5	3.77	>100	12	24	66	7.3	24
22	15.75	11.11	>100	2	1.27	>100	20	16	44	9.2	25
23	9.55	4.91	>100	1.4	0.67	89	21	15	41	9	21
24	18.8	14.16	>100	1.8	1.02	>100	10	26	72	9.5	69

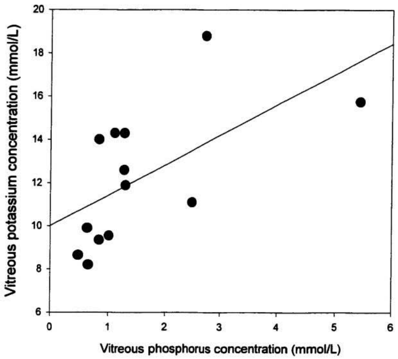


Figure 3.33: Comparison of postmortem mean potassium values with mean postmortem phosphorus (mmol/L) (R=0.6; P=<0.05: N=13).

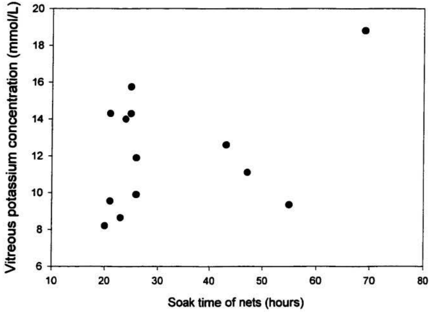


Figure 3.34: Comparison of soak time of nets in water (hours) and postmortem mean potassium values (mmol/L) (R=0.5; P=<0.05).

Figure 3.35: Comparison of postmortem mean potassium, sodium ($R=0.5$; $P<0.05$; $N=13$) and sodium/potassium ratio ($R=0.9$; $P<0.0001$; $N=13$) values via stepwise regression. All values are in mmol/L.

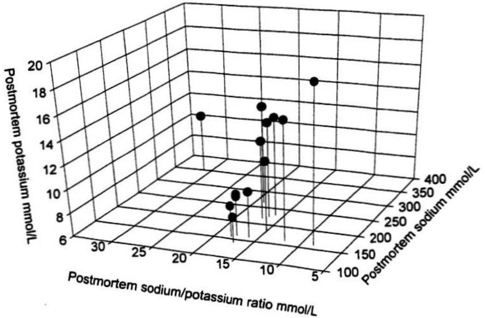
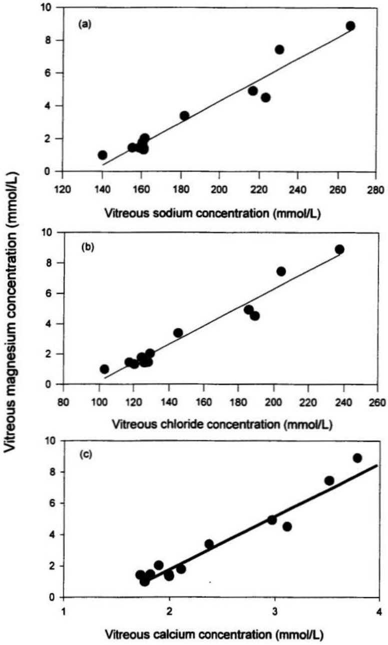


Figure 3.35: Comparison of postmortem mean sodium (R=0.05, P<0.05, N=13), sodium/potassium ratio (R=0.9, P=<0.0001, N=13 and potassium values via stepwise regression. All values are in mmol/L.

Animal number 24 had the highest vitreous concentration of potassium, its core temperature was 10°C. The concentration of magnesium in its vitreous humour was 1.77 mmol/L, with no detectable glucose. The gillnet in which it had been caught had a soak time of 69 hrs (Table 3.23). In contrast, of the 12 animals for which the vitreous concentrations of potassium and magnesium were determined, animal number 17 had the lowest concentrations of both electrolytes, and the gillnet in which it had been caught had one of the shortest soak time (19.30 hrs). Yet, the core temperature of this animal had already reached 12°C (Tables 3.23).

The mean postmortem magnesium value was 3.30 mmol/L (SD=2.63; range 0.99-8.9; n=12). Mean postmortem increase in magnesium was 2.55 mmol/L (Table 3.21). Strong positive correlations were found between the vitreous concentration of magnesium and those of sodium, (R=0.9; P<0.0001; n=12), chloride, (R=0.9; P<0.0001; n=12), and calcium, (R=0.9; P<0.0001; n=12; Figure 3.36 a,b and c). The vitreous concentration of magnesium was not correlated with either the soak time of the nets, the core temperature, or the vitreous concentrations of glucose, urea, phosphorus, and potassium (P>0.05).

Figure 3.36: Comparison of postmortem mean magnesium and sodium (a; R=0.9; P=<0.0001; N=12), chloride (b; R=0.9; P=<0.0001; N=12), and calcium (c; R=0.9; P=<0.001; N=12) values (mmol/L).



Vitreous magnesium concentration (mmol/L)
(a)
Vitreous sodium concentration (mmol/L)
(b)
Vitreous chloride concentration (mmol/L)
(c)
Vitreous calcium concentration (mmol/L)

Nine animals had a >90% rise in magnesium. Of these, eight had a >100% rise in potassium, a 90% or greater decrease in glucose and a greater than 50% postmortem temperature decline. Porpoise number 17 had the smallest rise in both magnesium (0.24 mmol/L or 32%) and potassium (3.56 mmol/L or 76%) Animal number 12 had the highest vitreous concentration of magnesium, its core temperature was 9°C, the ambient water temperature was 7.2°C, and the gillnet soak time was 21 hrs. This porpoise also had one of the highest vitreous concentrations of potassium, and one of the lowest vitreous concentrations of glucose (Tables 3.22 ad 3.23). Data analyzes are summarized in Table 3.24.

Table 3.24: Summary of vitreous humour, core temperature and girth correlations. Variables include glucose, potassium (K), magnesium (Mg), PM core temperature, and girth examined for correlation with ancillary elements.

Variables	Glucose	K	Mg	Core temp.	Water temp.	Girth
Calcium	n.s	n.s	****	n.s.	n.s.	n.s.
Chloride	n.s	*	****	n.s.	n.s.	n.s.
Glucose		*	n.s.	****		n.s.
Magnesium	n.s	n.s.		n.s.	n.s.	n.s.
Phosphorus	n.s.	*	n.s.	n.s.	n.s.	n.s.
Potassium	*		n.s.	n.s	n.s	n.s.
Sodium	n.s	n.s.	****	n.s.	n.s	n.s.
Sodium/Potassium ratio	n.s	****	n.s.	n.s.	n.s	n.s.
Urea	n.s	n.s.	n.s.	n.s.	n.s	n.s.
Core temperature	****	n.s.	n.s.		*	*
Girth	n.s	n.s.	n.s.	*	*	
Soak time	n.s.	*	n.s.	n.s.	n.s.	n.s.

Note: n.s.=P > 0.05,

* = P < 0.05,
** = P < 0.01,
*** = P < 0.001,
**** = P = < 0.00001

3.6.3 Deep core temperature

The mean soak time of gillnets from which the 24 harbour porpoise were retrieved was 34 hrs (SD=22 hours, range=17-95 hrs). The mean PM core temperature of the 24 animals was 14.6°C (SD=5.2 °C, range 8-30 °C). The range of temperature loss was 17-78%. Harbour porpoise were divided into two groups according to the degrees of PM temperature loss from the live mean of 36.2°C (Kastelein 1994): newly-dead (ND) =17-47% and long-dead (LD) =48-78% decrease in core temperature. Ambient water temperature ranged from 5.4-11.8°C. Nineteen porpoise had a greater than 48% temperature loss with five losing 70% or more body temperature from the live mean. Of this number 14 porpoise had a 24 hr, or longer soak time and a > 9.0 mmol/L decrease in glucose levels. Five porpoise had a < 47% temperature loss and were classified because of this, and the soak time of their nets of capture as newly-dead (Table 3.25).

Harbour porpoise number 18 had the greatest loss of temperature, with a reading of 8°C; this was a 28.2°C (78%) decrease from the live mean temperature. The corresponding postmortem glucose value was 0.20, a loss of 10.67 mmol/L (99%) from the live mean of 10.87 mmol/L (Koopman *et al.* 1995); a postmortem potassium value of 11.1 mmol/L (increase of 6.46 mmol/L >100%); no sample of magnesium was available. Soak time of the net was 47 hours (Table 3.25).

Table 3.25: Temperature of harbour porpoise for percent lost compared to the live mean of 36.2°C (Kastelein 1994). Animals are classified as newly-dead (ND=17-47) and long-dead (LD=48-78) according to percent temperature loss. Comparison of temperature loss to estimated time since death (Est. TOD; in hrs), for glucose (glu.) during 1994 and 1995, and for potassium, and magnesium postmortem (PM) changes, for 1995. Girth (cm), water temperature (°C) and soak time short (S=<24hrs) or long (L=>24 hrs) to the nearest hour are presented for 1994 and 1995.

Animal number	ND	LD	% temp. loss	Est. TOD	% Glu. decline	% K rise	% Mg rise	Girth	Soak time	Water temp.	S/L
1		x	72	10	99	n/a	n/a	87	17	9.5	S
2		x	55	8	91	n/a	n/a	93	19	9.6	S
3		x	55	8	99	n/a	n/a	82	48	9.4	L
4		x	66	10	99	n/a	n/a	81	25	9.2	L
5	x		39	6	78	n/a	n/a	91	23	9.5	S
6		x	70	10	99	n/a	n/a	79	25	9.8	L
7	x		17	2	85	n/a	n/a	101	27	9.8	L
8		x	55	8	95	n/a	n/a	87	26	10.5	L
9		x	55	8	97	n/a	n/a	97	24	10.4	L
10	x		44	6	84	n/a	n/a	93	95	9.6	L
11		x	66	10	100	n/a	n/a	79	95	9.6	L
12		x	75	11	98	> 100	> 100	81	21	7.2	S
13		x	50	7	82	86	94	81	23	7.6	S
14		x	66	10	94	>100	77	92	25	7.5	L
15		x	69	10	93	>100	>100	91	43	7.2	L
16		x	69	11	90	>100	93	96	26	7.3	L
17		x	66	10	93	76	32	70	20	7	S
18		x	78	11	98	>100	n/a	92	47	7.1	L
19		x	64	9	95	>100	<100	86	25	7.6	L
20		x	75	11	99	>100	>100	88	26	7.3	L
21		x	66	10	92	>100	>100	99	24	7.3	L
22	x		44	6	93	>100	>100	90	24	9.2	L
23	x		41	6	80	>100	89	99	21	9	S
24		x	72	11	100	>100	>100	74	69	9.5	L

Harbour porpoise with a core temperature of 12°C or less had the greatest postmortem glucose decline, and the highest postmortem increase in potassium values. Six of the seven porpoise with a >100% increase in magnesium also had a >60% decline in temperature (Table 3.25). However, of the ocular fluids, core temperature was significantly correlated with glucose postmortem levels only (Table 3.24).

Harbour porpoise with the highest postmortem glucose values (lowest decrease; range=8.2-13.8 mmol/L) also had the smallest temperature loss, none of which exceeded 50%. For example, porpoise number 5 had a 39% temperature loss and the highest postmortem glucose value (lowest decrease at 78%). Porpoise with the greatest decline in glucose value also had a > 43% decrease in temperature; 14 of these lost >60% body temperature from the live mean (Table 3.25). Eighteen porpoise had a temperature decline greater than 20°C, with a decrease in glucose greater than 8.5 mmol/L. Porpoise number 11 and 24 each had a 100% glucose decrease and a >65% temperature loss (Table 3.25). No porpoise core temperatures declined to ambient levels (n=24), though three were just 0.50, 0.70, and 0.90°C above ambient temperature. These porpoise had 99, 99, 97% glucose decline respectively. All three porpoise were classified as long - dead (Table 3.25).

Estimated time since death was calculated by assuming the 2.5°C loss in core temperature reported by McLellan *et al.* (1995). Twenty-three of the 24 porpoise examined for time since death were dead for at least six hours. Only porpoise number seven had a lower estimated time since death at two hours. Accordingly, this porpoise is assumed to be the only animal possibly captured during the hauling of the net. All other porpoise appear to have been captured either during setting of the net, or while the net was fishing.

Seven of the twenty-four porpoise were retrieved from nets with a soak time of less than twenty-four hours, (classified as a short soak interval). Seventeen porpoise were retrieved from nets with a soak time of 24 hrs or greater, termed long soak intervals. Thirteen of eighteen long-dead porpoise were caught in nets with a 24 hr or longer soak interval (long soak). Three of five porpoise classified as newly dead were retrieved from a net with a long soak interval (Table 3.25).

Weak but noteworthy correlations were found between PM core temperature and girth (cm) ($R=0.4$; $P=< 0.05$; $n=24$) and PM decline in core temperature and water temperature ($R=0.5$; $P=<0.05$; $n=24$).

3.6.4 Liver and intestine samples 1994

No bacteria were isolated from the 1994 liver samples. It appeared that the interval after death had not been sufficient in any of the animals tested to allow the bacterial flora from the digestive tract to invade the blood vessels and colonize the liver. Eleven of the samples of intestinal mucosa had a similar appearance consisting of autolysis of the superficial region of the mucosa but good preservation of the mucosal glands. Porpoise number 24 (Table 3.25) appeared more autolyzed than all the others; this was characterized by a greater abundance of sloughed surface epithelial cells coupled with a loss of differential staining affinity of these cells as well as some of the more superficial mucosa glands. This sample had the second longest soak time at 69 h, the greatest potassium increase and the lowest glucose decrease value at zero.

3.6.5 SINK TIME OF NET TO FISHING DEPTH

Two hundred and thirty-eight nets, all in the Grand Manan Island/Bay of Fundy fishery (mean=39.6; SD=4.17 per day) were monitored for time to reach fishing depth, measured as sink time. The mean sink time was 18.5 minutes (range 10-40 minutes; n=238). Nets were classified according to their sinking time. One porpoise was caught in a net which sank in 10-15 minutes (n=33); 5 in nets that took 16-20; (n=37) 8 in nets which sank in 21-25 (n=42); 6 in nets which took 26-30 (n=45);10

in nets which took 31-35 (n=40); and 11 in nets which sank to fishing depth in 36-40 minutes (n=41) (Figure 3.37).

Nine (37.5%) of the 24 animals examined for time since death were retrieved from nets placed in waters adjacent to Grand Manan Island during the summers of 1994-95 with time to depth probes attached. Six of the nine animals which were examined postmortem (animals number 3,4,12,14,16 and 19) were captured in nets which took 36-40 minutes to sink to depth. All six animals had among the lowest glucose levels and greatest declines in PM temperatures. Animals number 12, 14, 16 and 19 were among those with the greatest increases in both potassium and magnesium. All six porpoise were classified as long dead. The remaining three porpoise were captured in nets which sank in 16-20 minutes. One porpoise was classified as long dead (animal number 18), having a low level of glucose and high levels of potassium and magnesium, along with a 78% temperature loss. Two porpoise were classified as newly-dead (porpoise number 5 and 10), having among the highest glucose levels and postmortem temperatures. These porpoise were captured during the 1994 season therefore no potassium or magnesium values are available (Table 3.25).

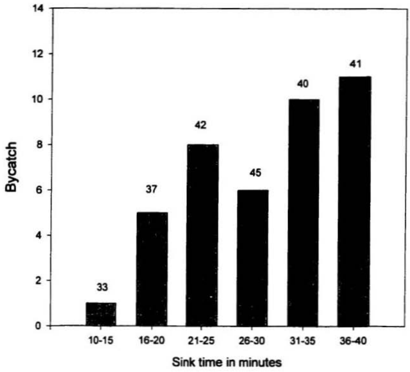


Figure 3.37: Comparison of the frequency of occurrence for harbour porpoise capture and time of net to sink to fishing depth during 1994 and 1995 in the Grand Manan/Bay of Fundy gillnet fishery. Time is measured in five minute intervals. The number above the column is the number of nets in each interval.

RESULTS: 3.7 SOCIOLOGICAL DATA

3.7.1 Fishermen's Traditional Knowledge

3.7.2 SURVEY RESULTS

Section A: Live sightings of harbour porpoise.

1. What month or months of year do you sight the most harbor porpoise? All fishermen (N=71) answered and gave multiple answers.

Month	NH	MA	ME	GM	Percent
January	0	6	0	0	4
February	0	9	0	0	6
March	0	3	0	0	2
April	0	0	1	0	1
May	1	0	3	0	3
June	0	0	7	23	19
July	0	0	19	8	17
August	0	0	17	22	25
September	0	0	6	2	5
October	8	0	2	0	6
November	15	0	1	0	10
December	3	0	0	0	2
Total	15	9	24	23	100

Fishermen from different areas of the Gulf of Maine/Bay of Fundy region gave varying times for harbour porpoise sightings. There were distinct times of the year that fishermen from each area reported harbour porpoise sightings. Fishermen from Grand Manan Island/Bay of Fundy waters stated they saw porpoise during late spring and summer months, while Gulf of Maine/Jeffreys Ledge fishermen sighted porpoise during October into December. Fishermen from Massachusetts were the only fishermen to observe porpoise during winter months. Fishermen from Maine had the longest sighting period, with porpoise seen from April until November. They reported the greatest amount of porpoise observed from June-August. These sightings are in line with those of Grand Manan Island/Bay of Fundy fishermen. These differences in sighting times are consistent with known spatial and temporal distribution pattern of the harbour porpoise in the Gulf of Maine and Bay of Fundy regions.

2. Do the number of sightings vary from year to year?

Location	N	Yes (%)	No (%)
NH	15	93	0.06
MA	9	46	13
ME	24	54	45
GM	23	47	52
Total	71	63	37

The majority of fishermen from New Hampshire, Massachusetts and Maine agreed that the number of porpoise sightings do vary from year to year though fishermen from Maine and Grand Manan Island were divided on the answer.

3. Do sightings occur in the same general areas from year to year?

Location	N	Yes (%)	No (%)
NH	15	100	0
MA	9	78	22
ME	24	79	21
GM	23	78	22
Total	71	83	17

The majority of fishermen from each region agreed that porpoise sightings occur in the same general areas from year to year. Almost 80% of respondents from Massachusetts, Grand Manan Island and Maine agreed. New Hampshire fishermen were the only group to agree unanimously.

4. Are the harbour porpoise you sight: alone; in pairs; in small groups (under ten); in large groups (ten or more). Respondents gave multiple answers.

Location	N	Alone (%)	Pairs (%)	Small groups (%)	Large groups (%)	DNR
NH	15	0	13	87	0	0
MA	9	0	22	78	0	0
ME	24	8	25	33	2	6
GM	23	9	26	65	0	0

The majority of fishermen sighted harbour porpoise in small groups of under ten animals or in pairs. Fishermen form Maine and Grand Manan Island also sighted harbour porpoise alone. Fishermen from Maine were the only respondents to sight porpoise in large groups.

5.What markers or behaviors helped you identify a marine mammal as a harbour porpoise? Fishermen gave multiple responses to this question.

Location	NH (%) (n=15)	MA (%) (n=9)	ME (%) (n=24)	GM (%) (n=23)
Shape of dorsal fin	80	100	33	61
Swimming pattern	8	0	38	22
Behaviour	13	0	38	13
Group size	7	0	38	0
Body size	0	0	46	22

Body Colour	0	0	33	0
Snout	0	0	8	0
Sound of porpoise	0	0	0	4
Experience sighting porpoise	0	0	8	0

Dorsal fin shape was by far the most widely used field marker by fishermen identifying porpoise. Sixty-four percent of the fishermen surveyed relied at least in part on dorsal fin shape to identify harbour porpoise. Fully 100 percent of answers for those fishing in Massachusetts used fin shape for recognition. Across regions, 31 percent of answers were for swimming pattern as an identifier. Animal size received 23 percent of the answers. Behaviour was answered for 14 percent and fourteen percent of the answers were for group size. Eleven percent of the answers were for the colour of the animal. Three percent of the fishermen said they used previous experience to recognize porpoise. One percent of the respondents relied on the animals' sound. Only fishermen from Maine said they used body colour to identify porpoise. Snout shape was used only by Grand Manan fishermen.

6. a. Do you often see harbour porpoise in the same area with dolphins?

Location	N	Yes (%)	No (%)	DNR (%)
NH	15	27	60	13
MA	9	0	100	0
ME	24	67	33	0
GM	23	13	87	0
Total	71	32	65	3

Fishermen from New Hampshire, Massachusetts and Grand Manan Island all saw harbour porpoise in the same area with dolphins. All Massachusetts fishermen surveyed said that they often saw both species together. However, most Maine fishermen did not.

6. b. If your response to question number 6a. is yes, state how you distinguish between each species.

The respondents that did observe dolphins and harbour porpoise swimming together agreed (100%) that their means of distinguishing the difference between the animals was the shape of the fin, swimming motion and group size.

Section B: Entanglement of Harbour porpoise

1. Why do you think harbor porpoise get caught in gillnets?

Fishermen gave multiple responses to this category of questions.

Reason	NH (%) n=15)	MA (%) (n=9)	ME (%) (n=24)	GM (%) (n=23)
Careless	13	0	0	0
Confusion	13	56	0	0
Curiosity	0	0	5	0
During net haul	0	0	0	44
During net set	0	0	5	57
Feeding	87	100	46	44
Greater # of animals present	0	0	0	5
Lack of attention	40	56	0	5
Lack of vision	0	0	25	13
No sonar	0	0	0	5
Sick	0	0	5	0
Swimming at night	0	0	5	0
Swimming fast	0	0	0	13
DNR	0	0	0	5

Of the 66 fishermen who responded, the majority gave feeding as the reason for harbour porpoise becoming caught in gillnets. Lack of attention and confusion were reasons supported by fishermen from New Hampshire and Massachusetts. Fishermen from Grand Manan identified the setting of the nets more often than the hauling as a time of bycatch. One fishermen from

Maine identified time of set as an issue. Lack of vision was noted by fishermen from Maine and Grand Manan Island. Only one fishermen from all the respondents felt the number of harbour porpoise present in the water was increasing.

2. Do you think entanglements occur in certain fishing areas more often than at others.

Response	NH (n=15)	MA (n=9)	ME (n=24)	GM (n=23)
Yes (%)	100	56	63	83
No (%)	0	44	21	4
Unknown (%)	0	0	0	13
DNR (%)	0	0	16	0

Fifty-four or 76% of the fishermen felt that entanglements occur in certain fishing areas more often than at others. Ten fishermen (14%) did not agree with this premise, three (4%) did not know and four (16%) did not answer.

3. Do you believe that certain gear or a specific area catch harbour porpoise on a regular basis?

Response	NH (n=15)	MA (n=9)	ME (n=24)	GM (n=23)
Yes (%)	80	100	50	65
No (%)	20	0	50	35

The majority (68%) of fishermen felt that certain gear, or a specific area, catch harbour porpoise on a regular basis. However, fishermen from Maine were evenly divided on the question. A total of 48 fishermen answered yes to the question while 23 answered no.

4. Have you ever entangled a large whale in your gear including end lines?

Response	NH (n=15)	MA (n=9)	ME (n=24)	GM (n=23)
Yes (%)	7	0	17	39
No (%)	93	100	83	52
DNR (%)	0	0	0	3

A total of 55 (77%) fishermen had not entangled a large whale in their gear or at their end lines (fourteen fishermen (20%) had). One hundred percent of the Massachusetts fishermen answered no. In all, two (3%) did not answer.

5. What number (percent) of your nets are torn at any one time?

Location	0-19%	20-39%	40-59%	>60%	Varies
NH (n=15)	13	53	27	7	0
MA (n=9)	33	67	0	0	0
ME (n=24)	67	25	8	0	0
GM (n=23)	35	30	0	0	35

The greater number of fishermen had less than 40% of their nets torn at any one time. The percentage of torn net varied for Grand Manan Island fishermen while fishermen from all other regions had a specific percent of nettage torn at a given time.

6. Do you catch harbor porpoise near or at a torn area?

Location	N	Yes (%)	No (%)	Seldom (%)	Unknown (%)	DNR (%)
NH	15	27	67	0	0	6
MA	9	100	0	0	0	0
ME	24	13	46	4	37	0
GM	23	13	74	0	0	13

In New Hampshire, Maine, and Grand Manan Island the majority of fishermen did not catch harbour porpoise near a torn area. All fishermen from Massachusetts however, said that they caught porpoise near a torn area. Of all respondents nine (13%) fishermen answered unknown, one (1%) seldom and four (6%) did not respond.

7. What percentage of your nets are torn before you consider replacements?

Location	N	0-19%	20-39%	40-59%	>60%	DNR (%)
NH	15	0	20	80	0	0
MA	9	0	22	78	0	0
ME	24	0	46	29	21	4
GM	23	0	26	61	13	0

No fishermen considered replacing his nets before at least 20% of the nets were torn. Fishermen from Maine had the highest percent of respondents that repaired their nets when less than 40% were torn. The majority of fishermen from the other three areas stated they repaired their nets when 40-59% were torn.

Section C: POSSIBLE RELATIONSHIPS/RATING FACTORS SURROUNDING ENTRAPMENT OF HARBOUR PORPOISE.

This section addresses the fishermens' beliefs about factors contributing to harbour porpoise bycatch. Fishermen rated the items listed below in terms of the strength of the relationship between these factors and harbour porpoise bycatch. Fishermen rated strength of relationship on the following scale: 1 **=no relationship (No)**; 2=**slight relationship (S)**; 3=**moderate relationship (M)**; 4=**strong relationship (St.)**; 5=**complete or total (C) relationship.** Numbers are the N of responses given for each relationship; not all fisherman mentioned several relationships.

1: **Responses from New Hampshire fishermen (N=15).**

Factor	No	S	M	St.	C	Mean	SD	Rank	DNR
Empty net	13	2	0	0	0	1.13	0.33	12	0
Full net	9	3	1	2	0	1.73	1.06	10	0
Bridle join	5	0	0	5	5	3.33	1.69	5	0
Bag area	8	2	1	0	3	2.14	1.59	8	1
Depth of net	0	0	1	4	10	4.6	0.61	1	0
Soak time	0	0	0	7	8	4.5	0.49	2	0
Setting of nets	1	2	1	11	0	3.4	0.95	4	0
Fish catch	5	0	6	4	0	2.6	1.2	7	0
Weather	6	0	2	7	0	2.6	1.39	6	0
Water temp.	2	0	1	12	0	3.5	1.02	3	0
Tide	7	1	3	3	0	2.14	1.24	8	1
Colour of net	12	3	0	0	0	1.2	0.4	11	0

The strongest perceived relationship (N=15;100%) was with the soak time of nets in the water. All 15 fishermen rated this variable as having either a strong or complete relationship to bycatch. The majority of fishermen (93%) from New Hampshire rated the depth at which the net was set as either a strong or complete relationship to the bycatch of harbour porpoise. A total of ten fishermen (67%) felt that the relationship between harbour porpoise bycatch and the bridle join of a string of nets was either strong or completely important. The highest ranked factors for a strong relationship were depth of net set, soak time, water temperature and the setting of nets with bycatch.

Six fishermen (40%) rated the tide as having either a moderate or strong relationship to porpoise bycatch. Three (20%) fishermen felt the bag area or bagging of the net while in the water was completely related to bycatch. All other variables were rated as having either a slight correlation or no relationship to bycatch.

2. Responses from Massachusetts fishermen (N=9).

Factor	No	S	M	St.	C	Mean	SD	Rank	DNR
Empty net	9	0	0	0	0	1	0	11	0
Full net	0	5	4	0	0	2.44	0.52	6	0
Bridle join	1	2	3	3	0	2.88	1.05	5	0
Bag area	6	3	0	0	0	1.33	0.5	9	0
Depth of net	0	0	5	4	0	3.44	0.52	3	0
Soak time	0	0	5	4	0	3.44	0.52	3	0
Setting of nets	0	0	0	9	0	4	0	1	0
Fish catch	0	0	0	9	0	4	0	1	0
Weather	7	2	0	0	0	1.22	0.44	10	0
Water temp.	0	7	2	0	0	2.22	0.44	7	0
Tide	6	2	1	0	0	1.44	0.72	8	0
Colour of net	9	0	0	0	0	1	0	11	0

Fishermen did not rate any variable as being completely related to bycatch. Fishermen ranked the setting of nets, fish catch, the depth of net set and the soak time of nets as the most significant factors involved in the bycatch of harbour porpoise. The setting of nets and fish catches each were rated as having a strong relationship to bycatch (N=9;100%). In line with fish catch, four fishermen, or 44% rated a full net as having a moderate correlation to bycatch. The depth of net set and the soak time of the net both were rated by all the fishermen (N=9; 100%) as either having a moderate or strong relationship with bycatch. The bridle join area was rated either moderate or strong by 6 (67%) of the respondents. Two fishermen (22%) rated water temperature as moderately related to bycatch. All other variables were rated as having either a slight correlation or none at all.

3. Responses from Maine fishermen (N=24).

Factor	No	S	M	St.	C	Mean	SD	Rank	DNR
Empty net	16	4	2	0	0	1.36	0.65	11	2
Full net	0	5	7	11	0	3.26	0.81	6	1
Bridle join	0	6	14	3	0	2.86	0.62	7	1
Bag area	7	12	4	0	0	1.86	0.69	9	1
Depth of net	0	3	8	12	0	3.39	0.72	5	1
Soak time	0	0	6	17	0	3.73	0.44	2	1
Setting of nets	0	0	2	21	0	3.91	0.28	1	1
Fish catch	0	0	7	17	0	3.70	0.46	3	0
Weather	7	5	12	0	0	2.20	0.88	8	0
Water temp.	0	0	10	12	0	3.54	0.50	4	2
Tide	16	5	0	0	0	1.23	0.43	12	3
Colour of net	11	6	6	0	0	1.78	0.85	10	1

Fishermen did not rate any one variable as having a complete correlation to the bycatch of harbour porpoise. They ranked the setting of nets, the soak time of nets in the water, fish catch and water temperature as the four most significant factors related to the bycatch of harbour porpoise. The setting of nets was rated as the most correlated to bycatch by 23 (96%) of the fishermen. Twenty-four (100%) of the fishermen rated fish catches as having either strong or moderate relationship with bycatch. Soak time was rated as having either a strong or moderate relationship to bycatch by 23 (96%) of the fishermen. Water temperature was regarded as having either a strong or moderate correlation to bycatch by 22 (92%) of the respondents. Twenty (83%) or the fishermen rated depth of net set as having either a strong or moderate relationship with bycatch. Both the bridle join area and a full net were rated as having a strong or moderate relationship to bycatch by 17 (71%) of the respondents. Weather was rated as having a moderate relationship with bycatch by 12 (50%) of the fishermen. Six (25%) fishermen rated the colour of the net as being moderately correlated to bycatch. All other variables were rated as having a slight relationship to bycatch or none at all.

4. Responses from Grand Manan fishermen (N=23).

Factor	No	S	M	St.	C	Mean	SD	Rank	DNR
Empty net	18	5	0	0	0	1.21	0.42	12	0
Full net	0	11	12	0	0	2.52	0.51	7	0
Bridle join	6	7	10	0	0	2.17	0.83	11	0
Bag area	5	7	11	0	0	2.26	0.81	8	0
Depth of net	0	3	9	11	0	3.34	0.71	4	0
Soak time	0	0	7	16	0	3.69	0.47	2	0
Setting of nets	0	0	5	18	0	3.78	0.42	1	0
Fish catch	8	2	13	0	0	2.21	0.95	10	0
Weather	0	7	11	5	0	2.91	0.73	6	0
Water temp.	0	2	9	12	0	3.43	0.66	3	0
Tide	0	3	11	9	0	3.26	0.68	5	0
Colour of net	2	13	8	0	0	2.26	0.61	8	0

Fishermen did not rate any one variable as having a complete correlation to the bycatch of harbour porpoise. They ranked the setting of nets, the soak time of nets in the water, water temperature and the depth of net set as the four most significant factors related to the bycatch of harbour porpoise. Fishermen unanimously rated both the setting of nets and the soak time of nets as having either a strong or moderate relationship to bycatch of porpoise with the setting of nets rated as strong by 18 (78%) of the fishermen and soak time by 16 (70%). Water temperature was regarded as having either a strong or moderate correlation to bycatch by 21 (91%) of the respondents. Depth of net set and tide were both rated as either having a strong or moderate relationship to bycatch by 20 (87%) of the fishermen. Sixteen (70%) fishermen rated the weather as having either a moderate or strong relationship to bycatch. A full net, the bag area, and the bridle join area were each rated as having a moderate correlation to bycatch by 12 (52%), 11 (48%), and 10 (43%) respectively by the respondents. The colour of nets was rated as moderately related to bycatch by eight (35%) of the fishermen. All other variables were rated as having a slight relationship to bycatch or none at all.

5. Cumulative totals by individual fishermen for the four locations (N=71).

Factor	N	No	S	M	St.	C	Mean	SD	Rank	DNR
Empty net	71	56	11	2	0	0	1.21	0.48	12	2
Full net	71	9	24	24	13	0	2.58	0.94	7	1
Bridle join	71	12	15	27	11	5	2.74	1.13	6	1
Bag area	71	26	24	16	0	0	1.98	1.00	10	1
Depth of net	71	0	6	22	31	10	3.64	0.83	3	2
Soak time	71	0	0	18	44	8	3.85	0.59	1	1
Setting of nets	71	1	2	1	59	0	3.78	0.56	2	1
Fish catch	71	13	2	25	30	9	3.02	1.09	5	0
Weather	71	20	12	25	13	0	2.40	1.07	8	0
Water temp.	71	2	14	22	37	0	3.33	0.81	4	2

Tide	71	31	11	15	12	0	2.14	1.17	9	1
Colour of net	71	34	22	14	0	0	1.71	0.78	11	1

Four variables were rated by fishermen as having a complete relationship with bycatch: the depth of net set by 10 (14%); fish catch by 9 (13%); soak time by 8 (11%); bridle join area by 5 (7%) of the fishermen. Soak time was rated as having either a strong or moderate correlation by 62 (87%) of the respondents. The setting of nets was rated as having a strong or moderate correlation to bycatch by 60 (85%) of the fishermen. Fifty-nine respondents (83%) rated water temperature as having a strong or moderate correlation to bycatch. Fish catch was rated by 55 (77%) of the fishermen as having a strong or moderate relationship to bycatch. Depth of net set was rated as having a strong or moderate relationship to bycatch by 53 (75%) of the fishermen. Weather conditions and the bridle join area were both rated as having a strong or moderate relationship with bycatch by 38 (54%) fishermen. A full net was rated to have a strong or moderate relationship to bycatch by slightly less with 37 (52%) fishermen. The tide with 27 (38%), bagging of the net with 16 (23%), and the colour of the net with 14 (20%) were all rated as having a moderate or strong relationship with bycatch of harbour porpoise. Fishermen ranked the soak time of nets, the set of nets, the depth of net set and the water temperature as the four most significant factors related to the bycatch of harbour porpoise.

Section D: Fishermen were asked to indicate "Agree" or "Disagree" in response to the following statements: Marine mammal bycatch in nets is both a local and global problem.

Location	Yes (%)	No (%)	DNR (%)
NH (n=15)	100	0	0
MA (n=9)	89	11	0
ME (n=24)	50	12	0
GM (n=23)	65	26	9

New Hampshire fishermen were the only group to agree 100% to the statement. The majority of fishermen in the other three regions did, however, agree that bycatch is a local and global problem. In total 50 (70%) of the fishermen agreed with the statement with 19 (27%) in disagreement and two (3%) that did not respond.

2. Harbour porpoise numbers may be declining in the Gulf of Maine, therefore, bycatch may have an impact on population growth.

Location	N	Yes (%)	No (%)	DNR (%)
NH	15	13	80	7
MA	9	11	89	0
ME	24	8	84	8
GM	23	57	39	4

The majority of fishermen from all areas except those from Grand Manan Island did not agree that bycatch might impact harbour porpoise population growth. In total 49 (69%) disagreed and 18 (25%) of the fishermen agreed with the statement with 4 (6%) not responding.

Section E: DISCUSSION SECTION:

Fishermen were asked to discuss in written statements the following: What do you think are the best solutions to the by-catch problem?

Responses of the 71 fishermen from four regions of the Northwest Atlantic for solutions to the harbour porpoise bycatch situation are tallied below. Responses are calculated both according to location and for all locations combined. Percent number is the proportion of all 71 respondents.

Response	NH	MA	ME	GM	N	Percent of total (n=71)
Use alarms	87	89	38	87	50	70
Time/area closures	67	89	25	48	35	49
Shallow sets	27	44	25	0	14	20
Do not set with porpoise	40	0	0	30	13	18
Extra weight for net	0	0	0	39	9	13
Research/gear	0	2	0	0	2	6
Research problem	0	0	17	17	8	6

No night sets	0	0	4	0	1	1
Listen to fishermen	0	0	4	0	1	1
Not a problem	0	0	17	0	4	6

A strong majority of the fishermen in each area (70% N=71) (excluding those from Maine), rated the use of alarms as the best solution to the bycatch problem. Massachusetts fishermen gave equal favour to the use of alarms and time/area closures. Sixty-seven percent of New Hampshire fishermen chose time/area closures. Twenty-five percent of those from Maine and 48% from Grand Manan Island chose time/area closures as well. Fourteen (20%) fishermen from all areas voted for shallow sets. Massachusetts fishermen were the most likely to make this choice. Fishermen from both New Hampshire and Grand Manan (13;18%) were willing not to set on porpoise traveling in the area. Nine fishermen (13%) from Grand Manan felt that placing extra weight on the net would sink the net faster, and thus decrease bycatch. Four fishermen (N=8;17%) from Maine and Grand Manan stated that bycatch is a research problem and should be treated by investing in research to find a solution. The same number of fishermen (N=4; 17%) from Maine did not feel bycatch was a problem either for them or the harbour porpoise.

2. If you sighted harbour porpoise in a high productive fishing area, would you change net location to an area of less fish per effort?

Response	NH	MA	ME	GM	N	Percent total of 71
Yes (%)	67	67	38	39	34	48
No (%)	33	33	54	57	35	49
DNR (%)	0	0	1	1	2	3

The response to this question was nearly evenly split with the majority of fishermen from New Hampshire (N=10; 67%) and Massachusetts (N=6; 67%) answering yes. Conversely 14 fishermen or 54% from Maine and 13 or 57% from Grand Manan would not change net location. Two fishermen did not respond.

RESULTS: 3.8 CROSS STUDY AREAS COMPARISONS

3.8.1 Operational/Fishing effort

The purpose of this summary is to present consistencies which were found in porpoise bycatch between areas and years. With all seasons considered, six of the seven operational/fishery variables were found to be correlated with the incidental capture of harbour porpoise during more than one research season. These include: soak time of nets in the water; depth at which the net was set; the distance of net placement from shore; target species harvest; net days and the number of nets in a string.

Total observer coverage for all seasons in all locations was 467 observer days during 158 days of fishing. A total of 22,352 net days during which 17,363 nets were hauled were observed. One hundred per cent of the observed nets were constructed of monofilament material with mesh size variations which included discrete sizes within the range of 12.1-23 cm. Soak time ranged from 7-216 hrs. The depth at which nets fished ranged from 20-177 m. Distance for the placement of nets ranged from 0.5-48 km from shore. A total of 124 harbour porpoise were incidentally captured. Thirty-six harbour porpoise dropped from the net during retrieval and were classified as not retrieved (n/r). Mesh size of gillnets was significantly correlated to bycatch during the fall 1993 research in the Gulf of Maine/Jeffreys Ledge only (Table 3.26).

Table 3.26: Cumulative operational/fishing effort and biological (target species stomachs) data from four seasons of research in Northwest Atlantic waters. Data are reported as either significant (x) or not significant (0) to the incidental capture of harbour porpoise. Target species are: c=cod, h=herring, ha=hake, p=pollock. New Hampshire = NH and Grand Manan is depicted by GM.

Area	Soak time	Depth	Distance	Mesh size	Number of nets in string	Net days	Target species harvest	Target species stomach contents
St. Bride's 1993	x	0	x	0	x	x	x (c)	n/a
NH 1993	x	0	0	x	x	x	0	0
GM 1994	x	x	x	0	0	x	x (c,ha,h,p)	0
GM 1995	0	x	x	0	0	x	x (c,h,p)	0
Total	3	2	3	1	2	4	3	0

The mean soak time of nets showed little variation between seasons and locations. The shortest mean season soak time (29 hrs; range 12-78) occurred in 1995 for the Grand Manan fishery and the second during the 1994 Grand Manan season at 32.8 (range 10-102) hrs. Mean soak times in the Gulf of Maine at Jeffreys Ledge was 34 (range 7-216) hrs and 34.4 (range 24-72) hrs for St. Bride's. For all seasons and all locations 53 of the 124 bycaught porpoise were captured in nets that soaked for ≤ 24 hrs (range 12-24 hrs; ND=9,238; CPUE=0.0057). Forty-one porpoise were caught in nets that soaked for >24 and <48 hrs (ND=7086; CPUE=0.0058), 18 in nets which soaked for >48 and ≤72 hrs (CPUE=0.0057). Nets that soaked for longer than 72 hrs were found in the Gulf of Maine/Jeffreys Ledge and during the 1994 Grand Manan/Bay of Fundy season only. Twelve porpoise were retrieved from these nets (range 73-216 hrs; ND=1,909; CPUE=0.0062).

The shallowest depths for net set were found in waters adjacent to St. Bride's in 1993 (range 20-90 m) and in the Gulf of Maine during 1993 (range 42-121 m). The deepest waters in which nets were set were off Grand Manan Island in 1994 at a range of 50-100 m and in 1995 at a range of 64-170 m. The shallowest bycatches occurred during 1993 at St. Bride's, Newfoundland with five porpoise caught at less than 30 m and no captures at >68 m. Bycatch in waters with the greatest depth occurred off Grand Manan Island during 1994 with two porpoise caught at 112 m. Collectively, 11 porpoise were captured at water depth of >20 and ≤50 m (ND=3,706; CPUE=0.0029), 30 at depths of >50 and ≤70 m, (ND=7,562; CPUE=0.0039), 43 at depths of >70 and ≤90 m (ND=4,644; CPUE=0.0092), 33 at depths of >90 and ≤110 m (ND=4,473; CPUE=0.0073), and two at depths of >110 and ≤130 m (ND=1,486; CPUE=0.0013).

Nets were set the greatest distance from shore in the Gulf of Maine/Jeffreys Ledge during 1993 with a range of 43.2-48 km from shore. Conversely, the shortest distance for nets occurred in St. Bride's during 1993 and Grand Manan Island during 1994 at 0.5 km from shore. Excluding the Gulf of Maine/Jeffrey Ledge 1993 season where the distance from shore was ≥40 km, the greatest CPUE occurred at distances <2 km from shore with 45 porpoise caught within this distance for a CPUE of 0.0106 (ND=4,229) and 31 between two and three km from shore (ND=3,739; CPUE=0.0082). Ten porpoise were captured in nets set between 3.1-4 km (ND=1,468; CPUE=0.0068) and one in nets set 4.1 to 5 km from shore (ND=864; CPUE=0.0011). During the 1994 Grand Manan Island/Bay of Fundy season nets were set from 0.5-17 miles from shore with the greatest effort at <three km from shore. Distance from shore did not vary to this degree in the St. Bride's or during 1995 Grand Manan Island fishery and they fell within the 0.5-6 km range. The greatest effort and CPUE during these seasons occurred within the distance range of 1-3 km from shore.

The number of nets in a string did not vary during either Grand Manan/Bay of Fundy season. In both years 98% of the strings consisted of 3 nets tied together. The longest strings were fished during the Gulf of Maine/Jeffreys Ledge 1993 season with a range of 5-25 nets per string. The greatest effort for nets in a string (excluding Grand Manan Island/Bay of Fundy where variation was not a factor) occurred at ≤10 nets per string (range3-10 nets; ND=5,595; bycatch=9; CPUE=0.0016). The only area to use more than 10 nets in a string was the Gulf of Maine/Jeffreys Ledge where the CPUE for 10-15 nets in a string was 0.0044 (bycatch=16; ND=3,594). One porpoise was captured in a string with 16-20 nets (ND=1,455; CPUE=0.0007), and 11 in strings with 21-25 nets (ND=2,805; CPUE=0.0039. Collectively, fifty-eight (47%) of the 124 bycaught harbour porpoise were captured at bridle areas (mean=14.5; SD=5.6). No statistically significant differences between groups caught and those not caught at a bridle site were found (t= -0.45; P=0.66). The mean for porpoise not caught at bridle sites was 16.5; SD=6.6.

The CPUE for harbour porpoise captured in St. Bride's was 0.0028, for the Gulf of Maine 0.0030, Grand Manan Island 1994, 0.0152 and 1995 0.0155. A summary of seasonal effort, target fish species harvest and harbour porpoise bycatch per unit of effort (CPUE) is presented in Table 3.27. The cumulative catch per unit of effort for all seasons is presented in Table 3.28.

Table 3.27: Summary of effort by year in net days, CPUE of target fish species per net day and CPUE of harbour porpoise and fish harvest per net day of effort.

Location	Target fish species	Net days	CPUE of fish harvest	CPUE of harbour porpoise
St. Bride's 1993	Cod	3,288	49.7 (kg)	0.0042
	Flounder	1,402	3.6 (kg)	0.0024
	Lumpfish	1,377	5.3 (kg)	0.0032
Gulf of Maine 1993	Cod	10,022	4.2 (kg)	0.0030
	Pollock	10,022	3.0 (kg)	0.0030
Grand Manan Island 1994	Atlantic herring	2,828	6.4 (no. fish)	0.0152
	Cod	2,828	2.5 (no. fish)	0.0152
	Pollock	2,828	1.9 (no. fish)	0.0152
Grand Manan Island 1995	Atlantic herring	1,864	3.6 (no. fish)	0.0155
	Cod	1,864	5.0 (no. fish)	0.0155
	Pollock	1,864	1.0 (no. fish)	0.0155

Table 3.28: Operational/fishing effort and the cumulative catch per unit of effort (CPUE) for four seasons of research in Northwest Atlantic gillnet fisheries. Operational variables are; soak time in hrs, depth in m, distance in km, mesh size in cm, and the number of nets in a string in total nets per string.

Soak time	CPUE	Depth (m)	CPUE	Distance (km)	CPUE	Mesh size (cm)	CPUE	No. nets in string (per net)	CPUE
≤ 24	0.0057	< 30	0.0033	≤ 2	0.0106	12.1	0.0036	<10	0.0078
25-48	0.0058	30-50	0.0026	2.1-3	0.0082	14.0	0.0023	10-15	0.0046
49-72	0.0057	51-70	0.0039	3.1-4	0.0068	15.2	0.0124	16-20	0.0006
> 72	0.0062	71-90	0.0092	4.1-5	0.0011	16.5	0.0009	21-25	0.0039
-	-	91-110	0.0073	-	-	17.6	0.0021	-	-
-	-	111-130	0.0013	-	-	20.0	0	-	-
-	-	-	-	-	-	23.1	0.0029	-	-

3.8.2 Biological parameters

Analyzes of the mean length and weight distributions of the 88 retrieved harbour porpoise demonstrates that females were significantly longer (t-test; P=0.001) and heavier than males (t-test; P=0.01). Females (n=35) had a mean length value of 144.3 cm; and a mean weight of 48.4 kg. Males (n=50) had a mean length of 132.4 cm; and a mean weight 42.0 kg. Males ranged in length from 87.5-160 cm. They weighed 11-67 kg. Females lengths ranged from 100-171 cm with a weight range of 20-70 kg. Estimated age from tooth samples for age determination (n=37 or 43%) or growth curve equations (n=48 or 57%) varied from 0 age (calf) to greater than seven years of age.

Greater than half (54 or 64%) of the bycaught animals were sexually mature. Twenty-three percent (n=20) were immature and 13% (n=11) were calves. There were 24 (69%) mature and 7 (20%) immature females; 4 (11%) were calves. There were 30 (60%) mature; 13 (26%) immature and 7 (14%) male calves (Table 3.29). The majority of porpoise captured in St. Bride's or Grand Manan Island during both seasons were mature. In contrast, of the five females captured in Gulf of Maine/Jeffreys Ledge waters during 1993 four were calves and one was immature (Table 3.29).

Table 3.29: Life history data from harbour porpoise incidentally captured during four seasons of research in Northwest Atlantic gillnet fisheries. St. Bri.=St. Bride's, Nfld., NH= the Gulf of Maine/Jeffreys Ledge, Gm 94=Grand Manan Island/Bay of Fundy during 1994 and GM 95=Grand Manan Island/Bay of Fundy during 1995. Mean length is in centimetres (cm) and mean estimated weight is in kilograms (kg).

Area	N	No. mature males	No. immature males	No. male calves	No. mature females	No. immature females	No. female calves	Mean length (cm)	Mean weight (kg)
St. Bri. 1993	14	5	2	1	5	1	0	139	46.4
NH 1993	19	7	6	1	0	1	4	126	39.0
GOM 1994	34	11	4	3	11	5	0	140.7	44.9
GOM 1995	18	7	1	2	8	0	0	142	48.0
Total	85	30	13	7	24	7	4	-	-

Of the eighty harbour porpoise stomachs collected during three research seasons, 17 were empty. Two were punctured, with potential content loss, and were discarded. The total of 8,394 prey remains belonging to ten species of teleost fishes, euphausiids and squid were found in the stomachs of the remaining 61 harbour porpoise. No significant differences were found in terms of percent occurrence or number of prey consumed between males (n=47) and females (n=32) (P=0.41).

The diet of harbour porpoise from the three areas differed in composition. The porpoise from St. Bride's, Newfoundland foraged primarily on capelin, sand lance and herring. Amphipods were found in five porpoise stomachs and are regarded as an indirect prey consumed from primary prey for adults. The diet of Gulf of Maine/Jeffreys Ledge porpoise consisted mainly of pearlsides and silver hake with contributions from pollock, Atlantic herring, red and white hake, redfish and mackerel. Diet composition did not vary between years for Grand Manan Island/Bay of Fundy porpoise. These porpoise preyed mainly on Atlantic herring, silver hake and cod, with pollock and mackerel represented as well. In addition, squid were found to be more common in the diet of porpoise from the Gulf of Maine/Jeffreys Ledge and Grand Manan Island/Bay of Fundy for both years. Euphausiids were represented in stomachs from porpoise caught in the Gulf of Maine and during both Grand Manan seasons. Euphausiids may represent indirect prey from primary prey for adult porpoise and a primary prey for juvenile porpoise. Hagfish were found in harbour porpoise stomachs during the 1995 season only. The dominant species for the three seasons (excluding St. Bride's) was Atlantic herring which occurred in 49 (80.3%) of the 61 stomachs examined for analysis. Atlantic herring was the longest prey consumed with a range of 44 - 332 mm.

A total of 1, 730 target fish species stomachs were weighed and examined during 91 days of fishing effort for three research seasons excluding the 1993 St. Bride's season where target species stomachs were not collected. No differentiation between seasons was noted with the dominant prey species found to be euphausiids which accounted for 96% of the prey from target fish species stomachs; shrimp (2%), and herring (2%).

3.8.3 Environmental

Environmental data were collected during 156 days of fishing effort all seasons inclusive. Harbour porpoise were captured throughout the range of water temperatures (2.9-11.8°C). Harbour porpoise bycatch was correlated to wind speed during both Grand Manan seasons. This was the only environmental variable found to have a relationship to bycatch of harbour porpoise for more than one season. Harbour porpoise bycatch was positively correlated to cloud cover during the summer 1993 St. Bride's season and to water temperature during the 1994 Grand Manan season.

The lowest water column temperatures occurred in waters adjacent to St. Bride's, Newfoundland during the summer of 1993 at a mean of 3.2°C (range 2.9 -3.4°C) and were warmest during 1994 at Grand Manan Island (mean 10.1°C; range 8.4-11.8°C). The greatest variance for salinity occurred in Gulf of Maine/Jeffreys Ledge waters with a mean of 32.1% ppt and with a range of 30.0-32.7. Salinity range in St. Bride's waters during 1993 was 31-33% ppt and for Grand Manan during 1994, 32-33.8% ppt.

Water column clarity varied from 4-30 m with the lowest of clarity occurring during the Grand Manan Island seasons. In 1994 the mean water column clarity was 7.5 m (range 5.5-9.5); during 1995 the mean was 8 m (range 4-11.5). The highest clarity was during the 1993 St. Bride's fishery with a mean of 15 m (range 9.5-30 m). No water column clarity collections were procured during 1993 from the Gulf of Maine/Jeffreys Ledge area.

Cloud cover range for all seasons and locations was 0-100% with a high mean of 70% cloud cover for St. Bride's during 1993. The range of wind speed for both St. Bride's and the Gulf of Maine/Jeffreys ledge was 0-30 kn. For Grand Manan Island the range for 1994 was 0-7 and 0-5 kn during 1995.

3.8.4 Elapsed time since death

In 1994 and 1995 core body temperatures and vitreous fluid were collected from 24 harbour porpoise. Core body temperature ranged from 8-30°C (mean 14.6°C). Glucose in vitreous humour decreased from antemortem serum values, and its level was positively correlated with core temperature. Potassium and magnesium in vitreous humour increased over antemortem serum values. These data suggest that all porpoise except one (number 7) had been dead for several hours. Number seven qualifies as being caught during the hauling process. The sink time to depth data collected during the 1994 and 1995 seasons displayed that the animals captured in nets which took the longest time to sink had the greatest changes in ocular fluid values and the greatest temperature declines.

3.8.5 Survey of Fishermen's Traditional Knowledge

Seventy-one fishermen were interviewed during three of the research seasons; surveys were not conducted during the 1993 St. Bride's season. The majority of fishermen, from all areas were in agreement on issues of harbour porpoise sightings and the markers for identifying harbour porpoise. Collectively the majority of responses for the causes of entanglement of harbour porpoise listed feeding at the time of bycatch as the primary reason for capture. Confusion and lack of attention on the part of the porpoise were reasons stated by fishermen from New Hampshire and Maine whereas the processes of setting and hauling the net were important to Grand Manan fishermen and lack of vision to fishermen from Maine.

When fishermen ranked 12 factors for their contribution to the bycatch of harbour porpoise the setting of gillnets received the most consideration while soak time, water temperature, depth of net set and fish catch all ranked as strong contributors. Fishermen from all areas were in agreement that harbour porpoise bycatch occurs in certain fishing areas more often than others. Fishermen did not agree where in the net porpoise were caught. New Hampshire and Massachusetts fishermen pointed to the bridle area, Maine to the middle one third of the net and Grand Manan fishermen to the ends. Maine fishermen were in dissent over the issue of whether specific gear captures harbour porpoise more often than others. Their vote was evenly divided while all other fishermen were in agreement that certain gear caught greater numbers of harbour porpoise.

A majority of fishermen perceive the capture of harbour porpoise as a local and global problem. However, when the issue is placed into a local context the responses are in reverse and only the fishermen from Grand Manan Island believed that porpoise numbers are declining in the Gulf of Maine and that bycatch may be having a negative impact on this porpoise population. The greater majority of fishermen from the other areas disagreed with this concept.

The greater number of fishermen regarded the use of acoustic devices as the main choice as a solution to the bycatch problem, with time area closures as a strong second choice. Fishermen were nearly evenly split on the question of changing net location to an area of less fish per effort if harbour porpoise were sighted in a more productive fishing area. The split occurred along geographic lines with fishermen from the southern Gulf of Maine in favour of re-location of nets to prevent the capture of harbour porpoise and those from the northern region of the gulf opposed.

CHAPTER 4: DISCUSSION

4.1 INTRODUCTION

This study investigated factors contributing to the incidental capture of harbour porpoise by examining operational, biological and sociological parameters associated with observed captures. The bycatch of porpoise is a complex problem and likely involves multiple causes. To date many potential causes of marine mammal bycatch in fishing nets have been identified but few have been verified by appropriate field studies. It has been noted that the frequency of harbour porpoise bycatch varies among regions, fisheries regimes, seasons and some oceanographic variables. I investigated the impact of net characteristics, target species harvest, the presence of prey species and environmental variables with the incidental capture of harbour porpoise in several fisheries and regions.

Six of the seven operational variables investigated were found to be significantly correlated with incidental capture during more than one research season. These included: soak time, depth at which the net was set, the distance of net placement from shore, length of the string, number of net days and catches of target species fish. The biological variable target species stomach contents was not found to be significant during any of the three seasons during which it was collected.

4.2 OPERATIONAL AND FISHING EFFORT

Depth

Depth was significantly related to bycatch during the Grand Manan/Bay of Fundy seasons. The fact that depth was not significantly correlated to bycatch in St. Bride's may reflect that nets targeted cod and lumpfish and were set in closer proximity to the shore at shallower depths (mean=43 m) than in the other regions. Similarly, gillnets for the Gulf of Maine/Jeffreys Ledge fishery were set at relatively shallow depths (mean of 79 m). In contrast, gillnets in waters adjacent to Grand Manan Island were set at greater depths (mean 102 m in 1994 and 98 m in 1995) and porpoise captured during these seasons were generally caught in the deeper sets (70-110 m), though nets were set at a wider range of depths. When the rate of bycatch was graphed at specific depths two peaks at 71-90 and 91-110 m were evident. These peaks reflect fishery effort.

The uneven distribution of harbour porpoise bycatch among varying depths suggests that harbour porpoise are not evenly distributed throughout the water column. Experiments with time depth recorders in the Bay of Fundy showed that porpoise dives to depths of 130 m were typical (Westgate *et al.* 1995). Differential catches at depth could reflect the relative frequency of porpoise occurrence at these depths or the differential frequency of activities that increase susceptibility to encounters with nets. Depth intervals of most bycatch may be due to preference of their primary prey which are found within these depth ranges along with the target species for fisheries. Porpoise prey species were typically strongly represented in the gillnet harvest. In the Bay of Fundy herring were the most captured fish in 1994, and the second highest in 1995. These nets were set for cod and pollock. Coincident with this affinity, prey contents in target species fish stomachs displayed a trend with bycatch, with the highest number of bycatch occurring on days and during intervals when the greatest mean content mass was found in target species stomachs.

Distance from shore

Distance of net placement from shore was significantly correlated with porpoise capture for all years, exclusive of the fall 1993 season in the Gulf of Maine when nets were set further offshore at distances of 43.2-48 km. Distance and depth are geographically linked and this may account for neither depth nor distance showing a significant relation to bycatch during this season in the Gulf of Maine. Generally the productivity which attracts fishery effort also attracts harbour porpoise. The inshore abundance of harbour porpoise has been shown using sighting data to coincide geographically, spatially and temporally with inshore commercial gillnets set for cod and pollock (Brodie 1995; Read and Hohn 1995).

Mesh size

In St. Bride's the greatest catch per unit effort of harbour porpoise occurred in nets with a small mesh size fishing for cod. In the Gulf of Maine this relationship was statistically significant. Although no statistical relationship was seen in the St. Bride's data (which may be attributed to small sample size), in the Gulf of Maine there was a significant negative correlation between mesh size and capture rate implying that capture decreased as mesh size increased in that region. No variability in mesh size was present for the two Grand Manan seasons. Where a variety of mesh sizes were employed (St. Bride's 1993 and Gulf of Maine 1993) a greater number of harbour porpoise were captured in nets with smaller mesh size.

These findings point to a degree of mesh size selectivity, with a peak in incidental captures per unit of effort occurring at mesh sizes of 12.1-15.2 cm. The ≤ 15.2 cm mesh gillnets, which were used in 71.4% of the observed fishing effort, were responsible for 82% of the animals captured. An explanation for these findings along with effort, is that larger mesh gillnets are not as efficient at capturing harbour porpoise. Mesh sizes within the peak catch range may fit the anatomical features of the porpoise, such as the fluke, pectoral fins or dorsal fin, while much smaller or larger mesh sizes may not. While all mesh sizes pose a potential risk to harbour porpoise it appears that certain mesh sizes (<23.0 cm) are a greater threat.

Net length

There was little variability in net length during the Bay of Fundy 1994 and 1995 seasons with 98% of the strings consisting of three nets. Where variability existed, (St. Bride's, and the Gulf of Maine) longer strings of nets was associated with a significant increase in CPUE. The capture rate for porpoise per net in the Gulf of Maine was greater in the 10-15 and 21-25 nets per string interval. Catch rate of porpoise per net was lower with 16-20 nets per string, but, fishing effort was lowest in this category and the results may have been affected by sample size. Incidental capture increased with string length in St. Bride's as well with 15 of the 19 porpoise captured in strings of 10 nets.

Longer strings could be perceived as a barrier where detour is difficult and penetration through it is a more probable solution. Close to half of the animals captured were retrieved from the bridle area of the string which is a gap between nets through which a porpoise might pass safely. In the Gulf of Maine where the greatest variety of net lengths occurred, 33% of the harbour porpoise were captured at the bridle site. When tested for statistical significance however no relationship between groups caught (mean 14.5; SD=5.6) and those not caught (mean 16.5; SD=6.6) at bridle sites were found (t=-0.45; P=0.66). Tests by Lien and Pittman (cited from Lien *et al.* 1995) conducted in flume tanks with gillnets showed that in a water current, bagging (net folding in on itself) occurs at the bridle areas. It is possible that the bagging process makes it more likely that fins or flukes could become entangled and contributes to the higher number of captures in this area of the string of nets.

Net days (CPUE)

The frequency of incidental captures of harbour porpoise covaried with the extent of fishing effort. A linear increase in capture rate per unit of effort with increasing net days was found during all seasons in all study areas. Declining bycatch rates occurred with decreases in net days fished throughout each season. During the summer 1994 Grand Manan season on 1 August nine harbour porpoise were incidentally captured in gillnets (CPUE 0.0775). Concurrently this was also the date of the greatest effort, (most net days) with the highest number of net days calculated for all seasons. For all seasons exclusive of Grand Manan 1995, bycatch numbers were highest during days of greatest effort. Intuitively, it is clear that the greater the effort the higher the risk of bycatch.

Soak time

Bycatch rates for harbour porpoise were highest when soak times were shorter with 78% being captured within a 48 hr set. The greatest declines in bycatch per hour occurred after 24 hrs of soak time in the Gulf of Maine and after the first 48 hrs in St. Bride's, 1993 and Grand Manan, 1995. The greatest amount of effort occurred during these soak times as well. There was little variation in the fishing effort and soak time from 16-48 hrs during Grand Manan 1994 which likely accounts for the fact that soak time was not significant for this season.

There may be a causal relationship between soak time and the rate of bycatch per hour. Porpoise may be captured during or soon after deployment of the net due to foraging behaviour, attraction to a clean net or other factors. In addition it may be that the presence of motionless dead fish, which presumably increases with soak time, makes the net more visible, thus decreasing the per hour catch rate.

Target species harvest

A positive association of target fish species harvest and harbour porpoise bycatch was consistent for all seasons, except in the Gulf of Maine during 1993, where little daily variability of catch existed during the monitoring period. The fact that the correlation with the target species harvest was significant for the 1995

Grand Manan season is of special interest, since no fishing effort took place from 21 July to 31 August, which is historically the time of greatest effort and harvest of target fish species. There were significant correlations between bycatch totals and the harvest of Atlantic herring, cod, hake, and pollock during the 1994 and 1995 seasons with the exception of hake in 1995. When analyzed for six day interval relationships cod and pollock were correlated with porpoise bycatch, These correlations may reflect common predation patterns by porpoise and targeted fish species.

Only cod harvest was significantly correlated with porpoise bycatch in St. Bride's during 1993. Lumpfish nets were set close to shore, generally less than one kilometre and in shallower water than cod nets. Lumpfish nets also had the largest mesh size employed in the study and had a low bycatch total. This bycatch number may reflect mesh size and net location as factors in harbour porpoise bycatch. In addition lumpfish nets were fished and removed from the water earlier than cod nets. Fishing effort for flounder was consistently lower than effort for cod and lumpfish in St. Bride's. As well, when properly set, flounder nets rest on the ocean bottom when fishing, with lead lines on the top and bottom of the nets to keep them in place. Flounder feed mainly on bottom dwellers such a various worms, crustaceans, mollusks and some small fishes. These factors may explain why the harvest of lumpfish and flounder was not correlated with the bycatch of harbour porpoise during this season.

The concurrence of harbour porpoise with cod and pollock gives credibility to the hypothesis by Brodie (1995) that species interactions within the system play an important role in the distribution of harbour porpoise. A coupling between harbour porpoise and these fishes may be motivated by their mutual preference for prey species; capelin, herring and sand lance in Newfoundland, and herring and silver hake the Gulf of Maine and Bay of Fundy.

The significant association of bycatch with catches of pollock noted for the Grand Manan seasons may be explained by the behaviour of pollock. Pollock feed on shrimp, euphausiids and small fishes, such as herring and hake species. They prefer water temperatures in the 7.2-8.6°C range, although they tolerate temperatures up to 15.5°C (Scott and Scott 1988). Cod, though primarily bottom feeders, also spend time within water temperatures from 3-8°C during the summer and autumn. Juvenile cod feed on shrimp, various crab species and euphausiids. Silver hake move from offshore into shallower warmer waters in the summer preferring temperatures of 6-8°C. Larger hake feed at night but smaller fish appear to feed during daylight. They are opportunistic feeders on several species including Atlantic herring, and crustaceans, especially euphausiids (Scott and Scott 1988). Harbour porpoise prefer the same temperature ranges

($7\text{-}15^0C$) and adults also feed on similar prey (especially Atlantic herring). Juvenile porpoise have been found to feed mostly on euphausiids and smaller fish as they mature (Gannon *et al.* 1998).

Pollock is uncommon in Newfoundland waters and was not a targeted species in St. Bride's, Newfoundland. In the Gulf of Maine/Jeffreys Ledge fishery of 1993 there was little variability in the catch rate between cod and pollock and, therefore, a relationship with bycatch cannot be examined.

4.3 Biological data

Sex and age ratio

Variations in the sex and age ratio distribution of the incidentally captured harbour porpoise were present for two of the research seasons. In St. Bride's during 1993, only male porpoise were captured from 5 July-10 July and six females and one male from 12 July-30 July. Results from the Gulf of Maine Jeffreys Ledge area show a predominance of captured males with only males being caught from 4 November-12 December. Gillnets in the Grand Manan Island/Bay of Fundy region did not appear to be selective for a particular gender or age group of harbour porpoise.

These findings may indicate a male-biased migration schedule in the two areas. DNA studies by Wang *et al.* (1996) to investigate stock structure of harbour porpoise in the Northwest Atlantic did not find different haplotype frequencies between Gulf of St. Lawrence and Newfoundland porpoise. This finding indicates a male- biased migration. The greater number of females captured during the initial effort in the Gulf of Maine/Jeffreys Ledge waters may be an indication of female philopatric behaviour at the time. Philopatric behaviour is believed to be more prevalent in female cetaceans than in males (Gaskin and Watson 1985; Wang *et al.* (1996). These authors report sighting recognized females which were seen annually during their migration into Gulf of Maine waters. Indications from the two areas are speculative as the study is restricted by small sample sizes.

In future studies, if human induced mortality is shown to be selective of gender or age and not a random event it could prove to have far reaching consequences for the population. For example, if instead of random captures, a higher number of females are captured in relationship to males, a population decline may result. A parallel situation would result if selective capture resulted in the mortality of a higher number of reproductive, or nearly reproductive, porpoise. The consequences for the removal of porpoise with the greatest reproductive potential would undoubtedly have a substantial impact on a population. A management regime implementing the PBR (Potential Biological Removal) mortality limit guidelines for porpoise undergoing selective mortality in gillnets must calculate the PBR according to an "age and sex-structured model" (Wade 1998).

Across all seasons, the capture rates of males and females were similar. In total 35 females and 50 males were captured. These findings agree with other findings (Read and Gaskin 1990; Richardson 1992; Read and Hohn 1995) in which there were no indications of geographic segregation of sexes in harbour porpoise (for Eastern Newfoundland, the Gulf of Maine or Bay of Fundy waters).

Previous studies by Kinze (1990), Lockyer (1999) and Lockyer and Kinze (1999) have documented a preponderance of immature and juvenile porpoise in bycatches. Results from only one season in my study corroborated this. During the Gulf of Maine 1993 season all five the females captured one was immature and four were classified as calves. Six of the 14 males captured during this season were immature as well, one was a calf and seven were mature.

One would expect calves to be present in greater numbers during the remaining seasons as sampling occurred during suspected post-calving (June to September) time and during periods of higher water temperatures which would result in less body heat loss for neonates who are reported by Lockyer (1999) to have a low blubber mass for thermal regulation. This expectation is consistent with findings from the Bay of Fundy (Read and Hohn 1995) and West Greenland (Lockyer 1999). However, these animals may not be able to dive to the depths at which gillnets are set. Another point is that harbour porpoise typically spend approximately eight-twelve months with their mothers before being weaned (Read and Hohn 1995). Very young calves may be protected by the fact that they stay in close proximity to their mother and while traveling in her care may benefit from her experience and knowledge of the environment including the presence of gillnets.

Little is know about the onset of echolocation in harbour porpoise. Older animals have a greater amount of experience with possible environmental dangers. This may mean they are more cautious and more frequently emit behaviours which detect and avoid nets. Older animals, though experienced with the use of their sonar abilities to navigate and detect an environmental danger may not employ their sonar at all times (Kastelein 1994). By emitting a signal the porpoise could call attention to their location, thus making it easier for potential predators such as sharks or killer whales (*Orcinus orca*) to locate them. It should be noted, however, that for most seasons and areas most of animals were mature, though porpoise of all ages were captured.

Two porpoise were captured together in the same net on three different occasions at different sites. In one instance a mature female and a juvenile male, possibly a mother and her calf, were retrieved. Only single captures occurred during the other three seasons. The predominance of single captures suggests that capture is related to individual behaviour not group activity.

Prey

Evidence for the importance of foraging behaviour to incidental capture is indicated by the fact that the majority of adult harbour porpoise stomachs were at least partially full of intact or partially digested prey suggesting they were either feeding or had recently been feeding at the time of capture. Behaviours consistent with feeding may make porpoise more likely to be caught if the porpoises' focus is concentrated on prey in or near the net, and not on the net itself. Porpoise found to have no prey contents in their stomach may have been captured at the beginning of a foraging attempt.

Harbour porpoise are opportunistic predators, feeding on a diverse variety of size specific prey. Some species of preferred prey are also species targeted by commercial fisheries. Stomach content analysis indicated regional differences in diet. It was found that capelin in 1993 (St. Brides); Atlantic herring, silver hake and pearlsides in 1993 (Gulf of Maine); Atlantic herring and silver hake in 1994 and 1995 (Grand Manan Island) were the dominant prey species for harbour porpoise. These findings are consistent with previous observations of harbour porpoise prey species seasonality in specific regions (Smith and Gaskin 1973; Recchia and Read 1989; Richardson 1992; Gannon *et al.* 1998). The abundance of primary prey species, such as Atlantic herring and silver hake, increases during the summer and fall months. The prevalence of redfish, red and white hake, and silver hake was greater in the autumn than in the summer harbour porpoise feeding patterns. Pearlsides, a schooling pelagic species found in depths of 10-400 metres were abundant during the autumn 1993 Gulf of Maine/Jeffreys Ledge season but not present during summer feeding in the Bay of Fundy.

Findings also suggest that the diet of the Gulf of Maine/Bay of Fundy population becomes more varied as the porpoise travel to southern waters of the Gulf of Maine from the Bay of Fundy. These results are consistent with those of Gannon *et al.* (1998) who found the relative importance of silver hake, red and white hake and pearlsides to be greater in the autumn Gulf of Maine/Jeffreys Ledge fishery. It is not clear if the greater diversity in the autumn diet is due to variation in prey availability or changes in environmental factors. Seasonal variations such as warmer waters may lead to a seasonal migration of harbour porpoise from the Bay of Fundy into the Gulf of Maine in order for them to maximize foraging efforts.

Inshore capture of harbour porpoise and abundance of prey species occur together (Gannon *et al.* 1998). Historically, capelin has been recognized as the predominant prey of harbour porpoise in the western North Atlantic with a geographic range that extends southward to Nova Scotia. However, capelin is not regularly seen in abundance south of Newfoundland (DFO 1996). Capelin was the dominant prey species collected from harbour porpoise stomachs in St. Bride's. However, studies to verify stomach content analysis in this population are insufficient to quantitatively evaluate a relationship between prey species abundance, distribution or size relationships and the bycatch of harbour porpoise. The primary prey of groundfish and harbour porpoise results in their co-occurrence spatially and temporally, thus predisposing the harbour porpoise to possible incidental capture.

The diversity of prey found in the stomachs of harbour porpoise retrieved during this study represents a pattern consistent with an opportunistic feeding strategy. Prey items are chosen according to local availability and abundance. However, it has been suggested by Recchia and Read (1989) and by Gannon *et al.* (1998) that harbour porpoise may feed selectively as well. The diversity of prey taxa found in harbour porpoise stomachs during this study suggests their diet may be linked to interannual prey variability or prey abundance. Throughout, herring remained the dominant prey item in the Gulf of Maine and Bay of Fundy during the fall of 1993 and summers of 1994 and 1995.

The results point toward a dominant role of capelin and herring in the summer and fall diet of harbour porpoise in the investigated areas. This seems consistent with previous observations made by Recchia and Read (1989); Gannon *et al.* (1998). Recchia and Read (1989) reported that though pregnant and or lactating females feed on similar prey as other harbour porpoise they were found to have a greater mass of contents in their stomachs than immature and non-pregnant or lactating animals. Few lactating females were found in the samples for this research (n=4) and none were found to have higher mass of stomach contents than nonlactating females. Previous studies have found quantifiable differences between the diet of lactating and nonlactating females of other cetacean species (Yasui and Gaskin 1986; Young and Cockcroft 1994).

With the exception of calves, there were few differences noted in the type of prey consumed between immature and mature animals. One difference was in St. Bride's where the immature animals fed exclusively on sand lance and the mature porpoise on capelin and herring. However, these findings may be the result of small sample size as only three of the eighteen porpoise with prey present were immature.

In the Gulf of Maine the one area where more calves than mature animals were captured, calves and immature harbour porpoise fed on a variety of prey including euphausiids, pearlsides and silver hake. Pearlsides were a more important prey for the calves than euphausiids when compared to older animals. Stomachs of immature porpoise from Grand Manan Island/Bay of Fundy did not show a great difference from those of adults though they contained greater numbers of euphausiids. In 1995 the only stomach to contain euphausiids belonged to a calf.

Autumn stomachs from calves were found to have more diverse contents than stomachs collected during the summer. These foods may be part of their transitional diet from nursing to consuming solid foods while they are learning to forage independent of their mother. The abundance of euphausiids in calf stomachs is similar to the findings of Smith and Read (1992) and Gannon *et al.* (1998), who propose that harbour porpoise calves are consuming euphausiids coincident to their mothers feeding on euphausiid predators such as herring and silver hake.

As was the case for calves, euphausiids were also the primary prey item recorded for immature harbour porpoise. Primary prey distribution depends on several biological factors predominant among which is the distribution of their prey. The distribution of harbour porpoise prey appears related to the structure and abundance of zooplankton communities and, specifically, to euphausiid communities. Euphausiids are planktonic and chiefly oceanic. They swarm in cold seas. Their distribution reflects spatial and temporal water characteristics such as temperature, depth, and salinity, and their associated plankton communities.

It is likely that the migration of capelin, herring and silver hake into waters co-occupied with harbour porpoise coincides with the presence of euphausiids. Hutchings *et al.* (1993) found that several areas in the Northwest Atlantic with a high abundance of euphausiids were also areas of spawning by cod. Carscadden *et al.* (1997) suggest that a match between capelin spawning and zooplankton abundance result in greater survival of capelin larvae. Capelin biology indicates their spawning, growth and maturation may be closely coupled to zooplankton production.

Harbour porpoise capture was not correlated with target species stomach content mass during any research season. During the weekly intervals in 1994 the greatest number of bycatch occurred concurrently with the highest amount of euphausiids being found in both harbour porpoise and target fish species stomachs. Additionally, the greatest mean weights for harbour porpoise stomach contents and the second greatest mean weight for a target fish species stomach occurred at this time. In 1995 interval number three had the highest mean porpoise stomach content weight, the greatest target fish species stomach content weight with the greatest number of euphausiids and the third largest number of herring present. Six of 29 bycatches occurred during this time. These data are in agreement with Brodie (1995) that harbour porpoise appear to be co-competitors with target species fish for prey items placing them in close association for location and time.

Because harbour porpoise are aggregation feeders, fish abundance is important. Locating the prey of choice requires energy costs. Since their prey of choice has seasonal variation in abundance and caloric content, the harbour porpoise likely move with the prey to maximize their foraging success both in number and quality of high lipid prey consumed.

The daily metabolic requirements for adult harbour porpoise are high: 2,471 kilocalories per day (Yasui and Gaskin 1986). Lactating females require 2,100 additional kilocalories per day. In order to meet increased energetic requirements, prey intake increases by up to 80% and foraging efforts are extended 4-5 hours per day (Yasui and Gaskin 1986). Such extensive foraging effort makes porpoise in fishery areas susceptible to bycatch for a large part of each day. It is unclear why more lactating females were not found in the current sampling of bycaught porpoise. It may be that prey were readily available and the females did not have to forage for extended periods of time, this would have aided in a possible decline of lactating female capture. In addition, lactating females are among those classified as mature and as such are presumed to be more experienced at swimming around fishing nets which may have resulted in them being caught less frequently. The mean age for lactating females caught in nets was 5.5 yrs and for mature nonlactating females the mean age was 5.1.

4.4 Environmental factors

The incidental capture of harbour porpoise was significantly correlated with isolated environmental parameters. The percent of cloud cover was correlated with bycatch in St. Bride's. Water column temperature was only associated with bycatch on a six day interval scale during the 1994 Grand Manan/Bay of Fundy season. No daily association for this variable or salinity was found for all seasons in all areas. Since there was little variability in water temperature and salinity a high degree of significance if any, would not be expected.

Several fishermen expressed the opinion that when nets were set during periods of higher wind speed they experienced a greater number of harbour porpoise bycatch. Fishermen felt that during higher winds, rough seas and increased water turbulence, harbour porpoise displayed increased activity at the water surface and were captured at greater rates. Environmental factors such as these could contribute to the bycatch of harbour porpoise through several processes:
(1) rain and wind effects increase ambient sound levels in the water column;
(2) storms cause a mixing of the water column temporarily resulting in dispersion of plankton communities and fish species.

Data from this study are consistent with beliefs of the fishermen. Wind speed was found to be correlated with harbour porpoise bycatch during both research seasons on Grand Manan Island. A stronger correlation was found during 1994 and this is attributable to a smaller number of samples in 1995. It seems reasonable to assume that harbour porpoise would exhibit a different foraging behaviour to compensate for the change in water column structure. This behaviour may involve the apparent increase in activity reported by the fishermen.

Water clarity was not found to be significantly correlated with bycatch during any of the three seasons this variable was collected. It is worth noting that in St. Bride's 17 (89%; n=19) porpoise were captured in nets set in waters with lower water clarity. During 1994 a total of 27 (63%; n=3 porpoise were captured in nets set in waters with a eight metre clarity or less and 25 (86%; n=29) in 1995. Collectively for the two Grand Manan Island seasons 52 (72%; n=72) porpoise were captured in nets set during periods of less than eight metres of water clarity. If nets are set in water with decreased clarity it may make the net more difficult to detect and thus avoid.

4.5 Elapsed time since death

4.5.1 Vitreous constituents

Many authors have utilized the concentration of various constituents of vitreous humour for estimating the postmortem interval in animals and humans (Coe 1989; DiMaio and DiMaio 1989; Sebag 1989; Henssge *et al.* 1995). The postmortem changes in vitreous concentrations of glucose, potassium and magnesium observed in this study show results similar to those found in studies of other mammals, including humans, whereby concentrations of glucose decrease, those of potassium increase after death, and concentrations of magnesium increase with immersion time in salt water.

According to Coe (1972), vitreous concentrations of glucose can show precipitous drops to very low levels in a matter of a few hours in some human cadavers. Similarly, Schoning and Strafuss (1980) observed that, regardless of ambient temperature, the vitreous concentration of glucose in dogs decreased to less than half of its antemortem value within 3 hrs. In the present study, the vitreous concentration of glucose in all porpoises examined decreased to less than 25% of the antemortem serum concentration as determined by Koopman *et al.* (1995). The range of serum glucose concentrations obtained from animals sampled by these authors (8.2-13.8 mmol/L) was higher than reported by Bossart and Dierauf (1990) (3.3-7.8 mmol/L).

Animals examined by Koopman *et al.* (1995) were considered stressed because they had been caught in fishing weirs and, therefore, may have experienced hyperglycemia due to elevated glucocorticoid activity. Similarly, entrapment in gillnets likely places the animal under maximum stress and presumably causes terminal hyperglycemia. However, it is doubtful that there would be enough time prior to death for the elevated serum glucose concentrations to equilibrate with those of the vitreous humour. Nonetheless, the mean decrease in vitreous concentration of glucose in captured porpoise was so dramatic that the difference with serum concentrations would have remained highly significant even with the use of lower serum values for comparison.

Since animals sampled for this study were from the same population as those of Koopman *et al.* (1995), and death by entrapment places the animal under maximum stress with disturbances to body fluids and chemicals incurred (Knight 1997) live values reported by Koopman *et al.* (1995) were considered more accurate for comparison to postmortem values. Magnesium levels are not known to deviate under stress conditions.

According to Adjutantis and Coutselinis (1972), the increase in vitreous concentration of potassium in human cadavers reaches a limit determined by the potassium supplies that can diffuse into the vitreous body from the surrounding tissues. They suggested that this limit is about 12-13 mmol/L, that the time required to obtain such a value is about 12 hrs from the time of death, and that the increase of potassium values is linear during the first 12 hrs after death. In contrast, according to Henry and Smith (1980), the postmortem vitreous concentration of potassium in human cadavers rises more rapidly in the first 6-12 hrs, but in a linear fashion after 24 hrs, reaching a maximum of 25-40 mmol/L at 100-120 hrs. In cattle, the mean vitreous concentration of potassium increased from 4.58 mmol/L at 0 hr to 7.35 mmol/L at 24 hrs (Hanna *et al*, 1990). The present findings are consistent with those documenting an increase of potassium after death. All potassium values increased over antemortem values with 10 of the 12 porpoise increasing over 100% and the remaining two over 75% of antemortem values reported Koopman *et al.* (1995). These results, including a maximum vitreous concentration of potassium of 18.8 mmol/L (animal number 24), seem to support previous studies.

Querido (1990) reported strong postmortem correlations between potassium, sodium and the sodium/potassium ratio in rats (N=40) concluding that these relationships offer a potentially valuable means for estimating the time since death in humans. The 1990 study found that sodium and potassium concentrations in postmortem rat plasma displayed a strong positive linear relationship. Sodium did not display a relationship with porpoise postmortem potassium, this may be due to sample size. With a larger sample size a relationship might be detected between potassium and sodium in harbour porpoise ocular fluid as well.

Vitreous concentrations of magnesium are fairly stable after death in humans (Henry and Smith 1980). However, following death in sea water, magnesium gradually diffuses from water into the eye. After death the wall of the ocular socket becomes a permeable membrane through which magnesium ions can diffuse rather steadily into the vitreous humour. In human drowning the rate of diffusion of magnesium ions is proportional to the time since death with an apparent concentration gradient which may be used to determine the interval of immersion in sea water. Thus, analyzing the vitreous humour for magnesium levels may provide an indication of the postmortem interval in harbour porpoise. The human intraocular magnesium content (normally 0.8-1.2 mmol/L) reaches equilibrium with the surrounding water (4.1-82.3 mmol/L) after approximately 24 hrs (Adjuntantis and Coutselinis 1974; Henry and Smith 1980). The maximum vitreous concentration of magnesium reached in my harbour porpoise was 8.9 mmol/L. Low water temperature may have slowed the rate of diffusion of this electrolyte from water into the porpoises' eyes. Perhaps more importantly, cetacean eyes have a very thick sclera which prevents its deformation under increased water pressure and may also act as an insulator to prevent excessive heat loss (Kastelein *et al.* 1990; Mobley and Helweg 1990). Therefore, diffusion of magnesium from water into cetacean eyes may require a longer postmortem interval than in terrestrial mammals before reaching equilibrium.

4.5.2 Body temperature

McLellan *et al.* (1995) observed that a harbour porpoise dead for less than 10 minutes had a colonic temperature of about 33°C in an ambient air temperature of 14-16°C. Following return to sea water of approximately 13°C, the core body temperature decreased gradually for 8.3 hrs at an average rate of 2.5°C per hour until it reached ambient water temperature. After 24 hrs, there was no evidence that the temperature of the carcass had increased as a result of putrefaction. Based on their results, McLellan *et al.* (1995) proposed that any similarly sized carcass with above ambient intramuscular temperatures would have died within the last 8-0 hrs. Similarly, a carcass at approximately 20°C would have died within the past 6 hrs; 30 degrees C within the past hour.

Based on the previous observations by McLellan *et al.* (1995), I presume the same body cooling sequence may be associated with porpoise from this study. Based on a 2.5°C core temperature loss, only one porpoise (number 7) could have been a recent death, perhaps at the hauling of the net. All other porpoise appear to have been incidentally caught either during the setting or fishing process. In addition, it is important to consider the mechanism of porpoise capture specifically the hauling time of the net. According to Tregenza *et al.* (1997) a gillnet is retrieved from the water for the most part in a vertical plane and any one area requires approximately six minutes to reach the water surface. If porpoise are captured during this process a certain number should be retrieved alive. No live porpoise were found during the present study. Similarly, no porpoise were observed around the fishing vessel during the setting of nets. These observations lend credence to porpoise capture occurring either during the set when the net is out of view or during the time the net is on the bottom fishing.

A slight correlation was found between core temperature and girth size. Such rates in harbour porpoise may be related not so much to weight, mass or girth per se as to insulative qualities of their blubber (Worthy and Edwards 1990). Worthy and Edwards (1990) found the harbour porpoise to have a "smaller surface area/volume ratios, higher lipid content in blubber, lower conductivity of heat through their blubber and, thicker blubber layers" for a given mass than the spotted dolphin *Stenella attenuata* which inhabits warmer waters. This suggests harbour porpoise have a decreased surface area/body mass ratio (Curren *et al.* 1994). In addition, harbour porpoise have the lowest conductivity values among cetacean species, indicating a high insulative quality for prevention of excessive heat loss for an animal that lives in a high heat-conductive environment such as ocean water (Worthy and Edwards 1990). Reduction of surface area/volume ratio in a marine mammal is thought to be an alternative to heat loss reduction measures which terrestrial animals are capable of employing such as curling their body or huddling to reduce surface area. These considerations suggest that, because of the high insulative value of harbour porpoise blubber, estimates of heat loss could be more closely related to blubber depth than to girth size. Findings from this study however, indicate girth is related to postmortem temperature, drop in temperature, and percent of temperature decline. Blubber depth and girth size as a measurement of blubber circumference or body state are factors which should be considered when using heat loss as an indicator of the time since death.

4.5.3 Liver and intestine samples 1994

The correlation between the 1994 liver or intestine samples and bycatch were not significant and the tests were not repeated in 1995. Results suggest that these particular tests do not provide a reliable way of assessing the lapsed time since death, though their usefulness may increase with longer postmortem intervals.

Whereas it seems difficult to accurately determine the postmortem interval in individual cases, some questions may be better answered by pooling data from several animals, thus circumventing the uncertainties of natural biological variation. The main objective of this study was to determine the time at which harbour porpoises get caught in a fishing net in the interval between its deployment and retrieval. Moreover, the spatial and temporal homogeneity of ambient water temperature leads to a much more uniform influence on autolytic processes than would be encountered in a terrestrial environment.

Results from most animals in this study point to a long postmortem interval, indicating that entanglement occurs most often as the net is deployed or fishing, rather than when it is hauled. Future work should aim at recording the gradual drop in body temperature and gradual change in concentrations of various constituents of vitreous humour at a set ambient temperature in harbour porpoises for which the exact time of death is known. This requires multiple temperature observations at hourly intervals and hence, determining the time constant which enable a body cooling rate and postmortem interval to be calculated.

Unfortunately, previous agreements with fishermen to return all retrieved porpoise to ocean water after samples and data were collected did not allow for the establishment of a postmortem interval. If an animal succumbs from natural causes while in captivity it would be useful to begin taking timed temperatures and extractions of ocular fluids in order to document an interval of values since at this time no data exists to ascertain the time since death.

Postmortem decrease in body temperature and changes in concentrations of some vitreous constituents tend to reach an equilibrium rapidly and, therefore, may be of limited use in estimation of the postmortem interval when the latter is more than two to four days. These factors are however helpful for this study since 21 of the 24 porpoise were captured in nets that had soaked for within these time limits.

4.6 SINK TIME OF NET TO FISHING DEPTH

An important question regarding harbour porpoise captures in gillnets is whether entrapment is more likely during net deployment, while the net is fishing, or during its retrieval. If captures occur as the net descends, then heavier anchors which sink the net more quickly may minimize catches of harbour porpoise. If captures occur as the net is being hauled out, then shorter strings requiring less hauling time may reduce catches. Captures which occur as the net fishes might be reduced by enhancing the acoustic signal of the net (Lien *et al.* 1995).

There were a greater number of harbour porpoise captured with an increase in the time it took a net to sink to fishing depth (range =10- 40 minutes). Forty of the 41 porpoise captured in nets with time depth recorders attached were caught in nets that took >15 minutes to sink to fishing depth. Of this number 21 (51%) were captured in nets which took >30 minutes to sink. These data, along with the time since death research suggest that incidental capture of harbour porpoise is associated with the sink time of fishing nets. Reducing the sink time by adding weight to the net is an area of future research into a practical solution to the problem. Expansion of these data may confirm the hypothesis of many fishermen that the animal is caught when the net is set.

4.7 SURVEY OF FISHERMEN'S TRADITIONAL KNOWLEDGE

Live sightings

The majority of fishermen reported sighting harbour porpoise during similar intervals in each region. Sightings varied from year to year according to fishermen from New Hampshire and Massachusetts. Those from Maine and Grand Manan were divided in their opinions. Some had noticed variation in the seasonality of sightings; others did not. The fishermen from northern Maine and Grand Manan Island fish in close proximity to each other (fishermen from Massachusetts and the Gulf of Maine/Jeffreys Ledge do not) and may sight harbour porpoise resident in their areas at similar times.

Ninety-two percent of all the fishermen stated harbour porpoise were sighted in either small groups or in pairs. Harbour porpoise are believed by scientists (Read and Hohn 1995) and fishermen to travel in small groups and seldom in large aggregations. Fishermen were familiar with the features used to distinguish harbour porpoise from dolphins. The three identification points employed most often were the dorsal fin, swimming patterns, and the size of the animal.

Entanglement of harbour porpoise

A majority of fishermen believe that harbour porpoise are captured while foraging for prey. Their second choice for a causal factor was lack of attention by the porpoise. Porpoise may focus on foraging and as a consequence be inattentive to other environmental features. A high percentage of fishermen from Grand Manan believe harbour porpoise are captured during the net setting process. These observations are consistent with the time since death data indicating porpoise were captured either during setting or fishing of nets. Fishermen from no other region counted this as an important factor in bycatch. Fishermen from Grand Manan also felt that harbour porpoise get caught during the net hauling process but time since death data did not support this hypothesis. Again, they were not joined in this opinion by fishermen from other regions. The tidal flux is greater in the Bay of Fundy than in the Gulf of Maine or Newfoundland and local fishermen expressed a two-fold concern that (1) during the setting or hauling process harbour porpoise are attracted to the net due to the movement and (2) because of the ambient noise the porpoise are not able to acoustically detect the nets. Fishermen in the Gulf of Maine seem to have similar concern, because more than half the fishermen stated that they felt the animal becomes confused in the presence of gillnets.

Fishermen collectively believe that entanglements of harbour porpoise occur in specific geographic fishing areas more often than at others. Operational and fishing effort data from this study are in agreement with this survey result. Where variability was present harbour porpoise bycatch was correlated with the depth of net set and the distance from shore for net placement.

Overall the majority of fishermen from Grand Manan Island felt that harbour porpoise are captured at random sites in the net. This belief may be influenced by the fact that they set only 3 or 4 nets in a string, therefore utilizing fewer bridle join sites. Conversely, fishermen from New Hampshire (67%) stated that captures occur most often at bridle join areas. The fishermen from Massachusetts were also in agreement with this concept though not as strongly (33%). Fishermen from both of these latter regions utilize strings with 5-28 nets tied together at bridle joins, thus creating a longer wall of gillnets for the porpoise to navigate around. Fishermen from Maine fish with strings consisting of 3-10 nets. Fishermen who believe bridle sites are related to the bycatch of harbour porpoise are consistent with my data which found that 63% of porpoise in St. Bride's, 33% from Jeffreys Ledge, 53% from Grand Manan Island during 1994 and 52% during 1995 were captured at a bridle join area. Collectively, 47% of all the porpoise bycatch was retrieved from bridle sites.

If the porpoise does become confused, as many fishermen noted, or simply does not perceive the wall as an obstacle and attempts to pass through a bridle area, it may become captured. With the number of bridle areas greater with longer nets, their chances of capture would be heightened. Grand Manan fishermen also responded (43%) that harbour porpoise were caught at the ends of their nets. Harbour porpoise that clear a string of nets may get caught if they do not negotiate a turn at the end of a string properly.

The majority of fishermen (79%) fished with up to 39% of their nets torn at any one time. They did not replace or repair torn nets until up to 59% of the net was torn. Most (66%) did not catch harbour porpoise near a torn area. However, Massachusetts fishermen unanimously responded (100%) that they caught harbour porpoise at torn areas in their nets. Concurrently, the majority of these fishermen do not repair or replace their torn nets until 40-59% are torn, indicating they do not equate porpoise captures with the condition of their nets. As well, they may not regard the problem to be sufficiently important to warrant removing the net for repair despite the fact that a torn net does not harvest as much fish as one intact.

Fishing with torn nets appears to be a contradiction for all fishermen since they lose fish catch by not replacing nets or repairing torn areas. It is a contradiction especially for the fishermen from Massachusetts who admit to catching porpoise at torn areas and those from New Hampshire who stated captures occur most often at bridle join areas. It appears reasonable to assume there is little distinction for a porpoise between a torn area in a net and the opening of the bridle join area, both may represent a place to exit thus predisposing the porpoise to capture if neither place is large enough to accommodate the body size and appendages of the animal. In addition Lien *et al.* (1995) found that bagging occurs at bridle joins in water current. Bagging will alter the tautness of the net by creating a slack area where a pocket can form. This alteration to the structure of the net may be responsible for the high number of bycatches at bridle join areas.

Factors surrounding entrapment of harbour porpoise

Regional fishing strategies were not evident when fishermen rated their responses for causes of harbour porpoise captures. Fishermen collectively rated the setting of nets, soak time, depth of net set, water temperature and fish catch as strong factors for the potential capture of harbour porpoise. Fishermen rated a full net, bridle join area, a bag area, the weather, the tide state and colour of nets as moderate influences on harbour porpoise bycatch. The rating from the respondents is in agreement with data from this present study. Depth of net, soak time and fish catch all had a correlation with harbour porpoise capture. In addition, studies of the time since death and sink time of nets point to an association between porpoise capture and the setting of nets.

The perception fishermen have of the harbour porpoise bycatch is of major importance as their efforts will reflect their concern for the problem. Seventy per cent of all the respondents agreed that marine mammal bycatch in gillnets is both a local and global problem. However, when this question was put into a local context, fishermen from New Hampshire, Massachusetts and Maine disagreed that harbour porpoise numbers may be declining and therefore, bycatch may be having a negative impact on their population growth in the Gulf of Maine.

Only the fishermen from Grand Manan Island responded positively to this question with 57% in agreement and 39% in disagreement. The political situation at the time the survey was conducted may account for this response. Fishermen from Grand Manan had only recently been approached by scientists and told that the capture of harbour porpoise was having a negative impact on their population in the Bay of Fundy. Scientists had been studying this population of porpoise since the early 1970's, often times paying the fishermen for harbour porpoise carcasses. In July of 1994 local fishermen were told by managers from the Department of Fisheries and Oceans that their fishery would be closed if the rate of bycatch did not decrease. It was in the best interest of the fishermen to recognize the problem and subsequently to attempt to work toward reducing or eliminating the capture of harbour porpoise in their waters.

Fishermen from New Hampshire and Maine had been aware of the possible effect of bycatch on harbour porpoise for several years and have fished under strong marine mammal protection guidelines since the implementation of the Marine Mammal Act of 1972. They are all presumably aware that a high take of harbour porpoise could cause a closure of any fishing grounds affected by this catch. Their responses however deny this awareness.

Although fishery management surveys have been conducted for many years relatively little research had been conducted on the attitudes of fishermen toward the problem of harbour porpoise incidental capture (Lien *et al.* 1994). Because of the increasing concern for sustainability of the species there is a need to increase awareness of the problem and to examine the current individual and group attitudes toward the problem.

Solutions

The use of active acoustic devices was a main choice as a solution to the bycatch problem for fishermen from all areas except Maine. Fishermen from Massachusetts divided their responses between alarms and time/area closures as solutions. Time/area closures were viewed as a viable solution by fishermen from the three other areas as well. Fishermen from Maine responded equally with time/area closures and shallow sets. While those from New Hampshire and Massachusetts did regard shallow sets as an alternative, they did not respond as strongly. Fishermen from Grand Manan did not view shallow sets as a solution. They did respond that extra weight on the net to help the net sink faster was a solution. This response is consistent with their concerns stated earlier in the survey that sink time of nets was a strong factor in porpoise capture.

Fishermen were split by geographic location regarding the extent of their commitment to preventing bycatch. Fishermen from the southern Gulf of Maine responded in favour of moving their fishing gear from a high productive fishing area to an area of less fish per effort to avoid setting nets when harbour porpoise were in the area. The majority of fishermen from Maine and Grand Manan would not relocate their nets to avoid catching a harbour porpoise. However, fishermen from New Hampshire and Massachusetts had stated previously that they did not believe harbour porpoise populations to be in decline. Maine fishermen did not believe porpoise were in decline either so their answer not to relocate is consistent with their perception of the local porpoise population. Grand Manan Island fishermen did believe harbour porpoise numbers may be declining in the Gulf of Maine but the majority would not relocate their fishing effort to avoid bycatch. One might predict that fishermen who believe that is a problem would consider displacing their nets as a viable management strategy, but this does not seem to be the case. Fishermen from the southern Gulf of Maine who were willing to move their nets to avoid catching porpoise, did not believe that the porpoise are in decline or threatened, while the fishermen from Grand Manan, who did believe that porpoise are in declined and threatened were not willing to move their nets. Maine fishermen were also not willing to move their nets but they did not believe the porpoise are in decline.

Some fishermen expressed concerns that harbour porpoise conservation efforts were unmerited. Their comments regarding this were centered on the fact that they personally had only caught a few animals. It was difficult for them to project such sporadic catches to numbers of conservation consequence. During periods of no bycatch fishermen stated they sighted many, even hundreds of harbour porpoise making it difficult for them to perceive the current capture of harbour porpoise situation as a problem.

There were specific issues and possible mitigation factors identified by the fishermen based on their responses to the survey. If there are modifications fishermen can make to avoid porpoise captures what factors regulate their behaviour (i.e. their value of harbour porpoise)? A fishermen's willingness to make seemingly costly modifications to his fishing methods is influenced by how much of a problem he perceives harbour porpoise bycatch to be. Fishermen quite specifically identified gear-related issues as problems associated with bycatch. These issues are controllable and, therefore, can be modified. Fishing with torn nets and the fact that harbour porpoise are captured at torn areas or in longer strings becomes a conservation issue. We need to ask what kind of incentives are necessary to enact effective change for the reduction or elimination of porpoise capture. It is vital therefore to educate fishermen to the benefits of eliminating porpoise bycatch. This should commence with knowledge of the natural history of the porpoise, their role in the local ecosystem, and feelings of the public who buy their fish about bycatches.

4.8 MITIGATION

A goal of this research was to identify possible modifications to fishing gear or changes in fishing practices that would reduce or ameliorate the incidental capture of harbour porpoise in gillnets. In summarizing the variables found to be significantly correlated with the bycatch of harbour porpoise it is evident that they occur in two categories: variables that can be controlled and variables that are stochastic. While environmental factors such as cloud cover, water column clarity, water column temperature, salinity and wind speed are not controllable, we can respond appropriately to environmental conditions. As well, analysis of such environmental parameters can contribute to our understanding of these conditions and help to identify mitigation factors associated with environmental variables.

Stochastic parameters may have an association with bycatch as shown with cloud cover in St. Bride's, water column temperature in Grand Manan during 1994 and wind speed during both Grand Manan seasons. However, the mechanisms by which stochastic factors affect harbour porpoise bycatch are not well understood. Environmental factors such as water column temperature, salinity, and conductivity relate to the community structure of the fish assemblages in the water. Specifically, water column temperature has been identified as the most important factor for fish survival (Carscadden *et al.* 1989). Environmental parameters may have intermediary links easily missed in analysis and clearly should be examined in greater detail in relationship to the bycatch of harbour porpoise.

In contrast, the operational/fishery effort variables examined in this study are controllable and offer the most promising areas for the reduction or elimination of harbour porpoise capture. Management techniques for facilitating the reduction of harbour porpoise bycatch which are the most effective at this time can be grouped under three categories, modification of fishing strategy, restrictions to fishing effort and modification to gillnets.

Modification of fishing strategy

Depth at fishing site has been identified as an important factor in porpoise bycatch (Frady *et al.* 1994; Kraus *et al.* 1997; Richter 1998). My research agrees with these previous findings. Placing depth restrictions on fishing gear may lessen the harbour porpoise capture rate. Depth restrictions are already in place in various regions including California and New Zealand in an effort to reduce the capture of marine mammals (Dawson 1994). A study of porpoise depth preferences at fishing areas in conjunction with current knowledge will give preliminary data of their behaviour. This study showed porpoise were foraging in waters of less than 110 m depth. Placing minimum depth of net set restrictions in areas where harbour porpoise are known to travel or forage and where historically high bycatchs have occurred may prove effective in reducing porpoise bycatch.

Distance of net placement from shore

Harbour porpoise are coastal inhabitants during their co - occurrence with prey and target fish. This affinity for certain fish species places them near fishing nets commonly set close to shore. Where porpoise are known to forage at certain distances from shore as shown in this study, then a minimum distance restriction for net placement of 5 km or greater from shore for gillnets would facilitate a decrease in porpoise capture. These approaches to depth and distance restrictions would require the displacement of nets and presumably a decrease in fish catch. Minimum depth and distance fishing restrictions as discussed previously are consistent with area and depth study findings from this study.

Mesh size

All mesh sizes are capable of capturing a porpoise, as harbour porpoise are larger than any of the mesh openings. However, larger mesh size (i.e. 23.1 cm or larger) may result in fewer porpoise bycatch. This is because porpoise may collide with the net but not become entrapped.

Gillnets are size selective, if not species selective. The portions of harbour porpoise anatomy most commonly caught are similar in size to the fish size for which the nets select. Fishermen employ a certain mesh size in order to maximize their target species catch and may find a size change difficult to accept. However, mesh size regulations are common in fisheries management regimes. Mesh selectivity results in a high degree of fish selectivity and may also be an effective strategy of fishing gear modification for the reduction of harbour porpoise capture. Mesh size restriction has been used in fisheries management to conserve fish stocks by decreasing the mortality of specific size class fish while maximizing the harvest of target species. Change in mesh size would result in a change in target species catch. Increasing mesh size for target species will select a different age cohort. Such a change could have important benefits for a fishery by presumably leaving those nearly reproductive or reproductive fish to spawn (FRCC 1997).

Mesh size change alone may not be a sufficient management measure and must be supplemented by ancillary restrictions on fishing gear. Incompatibilities between mesh size restrictions and other fishing regulations, such as length of string, location of the net in water and the amount of effort may not decrease harbour porpoise capture to negligible levels. The design of a mesh size must be acceptable to marine managers and fishermen alike and there will not be one optimum mesh size suitable for all fisheries due to multispecies harvesting. Mesh size modification needs to be designed for individual fisheries and their ability to capture harbour porpoise.

Although no statistically significant difference between groups of harbour porpoise caught and those not caught at a bridle site was found, this may be due to low sample size. With close to half (47%) of the animals captured at a bridle site it appears to be a trend worth further investigation.

Restrictions to fishing efforts

Time and area restrictions

In the Northwest Atlantic the majority of harbour porpoise are captured seasonally. The spatial distribution of fishing effort changes with the seasons as does the distribution of harbour porpoise. Additionally, the majority of harbour porpoise are captured incidentally in specific geographic locations. Trippel *et al.* (1996) credit the closure of the Grand Manan Island/Bay of Fundy gillnet fishery during August of 1995, typically a time of high fishing effort and presence of harbour porpoise, with the resultant decline in harbour porpoise captures from the 1994 capture numbers. Fishing effort during allotted times was similar during the two seasons. Temporal and spatial fishing restrictions that confine gillnet use to time and areas known to have few if any harbour porpoise captures could effectively decrease harbour porpoise mortalities (Dawson 1994). Fishermen would avoid fishing in areas at times of high porpoise population, thus preventing the joint capture of fish and harbour porpoise.

Closures during times when harbour porpoise are most abundant in a region may greatly reduce incidental capture. Unfortunately, such a management strategy would displace fishing effort at prime fishing time possibly reducing target species catch or increasing fishing effort to reach quotas. Time and area closures are currently in use in several areas including New Zealand to reduce the bycatch of Hector's dolphins (Dawson 1994), portions of the California coast to decrease marine mammal captures in gillnets and portions of the Gulf of Maine are restricted to gillnet fishing to reduce the incidental capture of harbour porpoise (Woodley 1995). While these programs have been in place, evaluation of their success or lack of has not been documented.

Fishing gear restrictions

One alternative put forth by Woodley (1995) to reduce the incidental capture of harbour porpoise is a change from gillnets to alternative fishing gear, for example, cod traps, long line, hand line and jigging. This measure requires transition for the fishermen from one mode of fishing to an alternative. Although it does not constitute a time or area closure, it does involve unknown cost and conversion of effort. Fishing gear restrictions would be in place for all fishermen equally and as such may be perceived as fair and hopefully more acceptable to the fishing industry.

Monofilament gillnets came into widespread use in the Northwest Atlantic during the middle to late 1970s. Considerations for them as fishing gear of choice focused on several attributes. Monofilament gillnets are more efficient at entangling fish since they are harder to detect both visually and acoustically than traditional cotton twine nets. Monofilament gillnets are also less expensive than traditional nets, they require less maintenance as they are more durable and they are species selective according to size, allowing the fishermen to retain fewer non-target fish species. Dawson (1994) and Jefferson and Curry (1994) argue against the continued use of gillnets and favour the use of more selective gear in regions where the incidental capture of marine mammals occurs. The issue remains one of serious contention between those who oppose the use of gillnets and those who find them an efficient way to earn their living.

Modification to gillnets

Efforts to reduce harbour porpoise bycatch by increasing the noise associated with the net have had promising results (Lien *et al.* 1994;1995; Kraus *et al.* 1995; Trippel *et al.* 1996; Richter 1998). Studies of captive harbour porpoise by Hatakeyama *et al.* (1990) and Kastelein *et al.* (1995) suggest that acoustic devices helped the harbour porpoise perceive the net as present, but entanglement could still occur.

The strategy for placing an active acoustic device on a gillnet is based on two presumptions. The first is that they enhance the detectability of a net and that this better enables the animal to detect, attend to or define it as a barrier. Although the sonar echo from a modern gillnet is weak, it is within the acoustic detection sensitivities of harbour porpoise (Au and Jones 1991; Hatakeyama *et al.* 1990). Hence, capture is not due simply to a failure to detect the gillnets, but may be a consequence of multiple behavioural and environmental factors and causes. In addition, if a porpoise is not using sonar pulses when in close proximity to the net, making the net intrinsically noisy may be important.

If harbour porpoise are capable of detecting the gillnets, capture is likely to occur due to other factors such as: (1) the porpoise is aware of the net but does not perceive it as a barrier; (2) the porpoise is not using echolocation at the time and thus is not aware of its presence; (3) even if the porpoise is capable of detecting the net, an array of behaviours may predispose it to capture, such as, exploration, curiosity, typical escape patterns, social responses or behaviours and feeding at the net site.

In compliance with the findings from this research, placing weight on strings to facilitate their sinking faster, soak time of less than a 24 hr duration, setting gillnets in waters deeper than 110 m at a distance greater than five km from shore will reduce the number of harbour porpoise incidentally caught in inshore fisheries. The use of larger than 23.1 cm mesh gillnets will aid in the reduction as well. A management regime may employ several varied management and conservation strategies, one of which may be the use of acoustic devices.

CHAPTER 5: RECOMMENDATIONS

5.1 OVERVIEW OF PRESENT STUDY

This study provides the first detailed investigation into multiple parameters affecting the bycatch of harbour porpoise in gillnets, while concurrently assessing the time elapsed since death.

The data presented in this study suggest that harbour porpoise incidental capture can be influenced by a number of factors relating to biological and ecological variables as well as fishing operations. In the following paragraphs, I identify these factors, which are important for several reasons as I explain below.

5.1.1 The Complexity of Biological and Ecological Variables

In areas where gillnet fisheries co-exist with the harbour porpoise, it is important to identify factors associated with bycatch, and solutions to the problem. Documenting harbour porpoise bycatch in relationship to variables allows for an evaluation of the importance of these variables in relationship to porpoise mortality. The factors related to harbour porpoise bycatch can be properly understood only when examined as a complex set of interactions within the context of the fishing effort and environmental variables. These results have practical implications, and should therefore be useful as a tool for management by stakeholders. As this study has demonstrated, diverse issues must be addressed with respect to harbour porpoise bycatch in gillnets. In the sections which follow, the general observations derived from this study are followed by specific recommendations.

5.2 BUILDING THE PROCESS OF WORKING TOWARDS SOLUTIONS

5.2.1 Pre-existing standing conditions

Strategies to mitigate harbour porpoise bycatch **must acknowledge several standing conditions** relevant to harbour porpoise incidental capture before measures to solve the problem can be undertaken. These are:

1. Maintenance of sustainable populations of harbour porpoise in perpetuity is not consistent with present and projected increases in gillnet fishery effort. At present it appears to be impossible to eliminate incidental capture entirely without incurring risk to the commercial fishery and to its stakeholders.

2. Our knowledge and understanding of the reasons why incidental captures occur is still insufficient to guarantee success in achieving and managing sustainable populations of the harbour porpoise. Bycatch can best be understood as a complex set of interactions within the context of porpoise behaviour and ecology as well as fishing operations.

3. For the most part, the biological significance and contribution of the harbour porpoise to the ocean ecosystem is not yet understood or valued by the fishing industry.

4. Components in solutions to the problem of harbour porpoise bycatch vary within fishery regions and local regimes. This means that each region is unique; what may work in one regional situation may not be the best solution in another. Harbour porpoise bycatch is a complex problem and must be assessed with respect to biological, environmental, ecological and operational factors. Appropriate solutions are needed for each region which will address and correct controllable factors causing harbour porpoise entrapment in gillnets.

Thus, a number of recommendations which have been determined as a result of this study can be made, based of course on region-based, principles, rather than a general industry-based regime.

5.3 SIX GUIDING PRINCIPLES FOR FISHERY STAKEHOLDERS

As I have already demonstrated, this study was predicated on the assumption that a better understanding of the circumstances that contribute to the incidental mortality of harbour porpoise could lead to constructive management actions. Consistent with this, the definitive goal for any bycatch management regime is to maintain viable harbour porpoise populations, while minimizing negative impacts on the commercial fishing industry.

Our ability to undertake constructive management actions and accomplish this goal needs to be framed within certain principles. I have identified five guiding principles which I believe, if implemented by management and stakeholders in the fishery, will address the voids in information and cooperative action which currently exist concerning harbour porpoise bycatch, while providing steps to alleviate the conditions which enable this problem to occur. These very basic general principles could be stated as follows:

1. The Precautionary Principle

Despite the lack of scientific certainty due to inadequate information currently available, agencies involved in management of the fishery, whether at the level of government or more direct stakeholders, should not use this lack of certainty as an excuse to postpone taking steps towards a practical solution while they wait for definitive answers to the porpoise bycatch problem. We already have adequate knowledge of the problem; it is knowledge of appropriate solutions which are limited. Nevertheless, some effective conservation measures can be identified. Those factors which are defined in this thesis include: bridle join area studies, depth of net set, distance from shore for placement of net, length of net, mesh size selection, soak time duration and wind speed at net set. Measures towards achieving a reduction in harbour porpoise bycatch can be implemented without the necessity of waiting for data which will add to our understanding of the scenarios that cause captures. Bycatch reductions can be achieved with conservation measures based on current knowledge.

2. Adaptive Management Principle

The principle of adaptive management allows for the accepting of identification of uncertainties and assumptions regarding the ecosystem of concern. Such a perspective incorporates the capacity to adapt to changing circumstances (i.e., environmental, economic, societal). This principle also allows plans and regulations to be designed with flexibility for a dynamic environment while maintaining management objectives. Dynamic management regimes are more representative of real systems than static ones. The adaptative management principle must take all factors into consideration and proceed to incorporate a sub-principle or a tailor principle by which conservation tools would be tailored to specific fisheries of a given area.

3. Integrated Management Principle

Integrated management employs policies that assess human impact on an environment. The principle then incorporates relevant biological, economic, environmental, and social considerations and values into decision-making and management plans. The interests of local stakeholder groups are incorporated into co-management processes and are considered an essential element to decision making.

4. The *Carpe Diem* Principle of Management

The measures based on the principles delineated in these recommendations should be pursued vigorously, as these measures provide guidance and may aid in preventing further degradation to habour porpoise populations. They challenge the notion that fishermen have an innate right to harvest the ocean wherever and whenever they choose, and provide avenues for decision making based on mutual respect between sectors.

These principles are designed to consider the present interests of the industry in balance with future generations of porpoise. As such, they provide routes for the mitigation of porpoise bycatch and consequently, assist in the goals set forth for maintaining viable harbour porpoise populations without negatively impacting a fishery. The assimilation of these principles with management programs in order to identify a solution for harbour porpoise capture in gillnets must not be delayed while studies of possible impacts on the harbour porpoise population are evaluated or until a solution is reached.

5. The Principle of Stakeholder Information Sharing

Data from the current research and recommendations should be disseminated to stakeholders and marine managers for inclusion into future management and conservation planning. Given the current paucity of information surrounding harbour porpoise populations and their natural history, coupled with the present rate of ocean exploitation, these data will be of substantial importance.

There are factors which may be viewed as steps towards an understanding of how the problem of harbour porpoise bycatch can be dealt with effectively. These steps are outlined below.

5.3.1 Step 1. Co-operation

Before steps can be taken to alleviate the problem of harbour porpoise bycatch, fishermen, managers and scientists must commit to working cooperatively and establishing guidelines toward a common goal. Communication between groups must be transparent, interactive, reciprocal and continuous, while acknowledging that solutions to the bycatch problem must take a diversity of viewpoints into account. The general operating principle can be summed up as follows:

Initially, all fishery stakeholders must:

a. find common ground and identify common goals

b. achieve a consensus

c. define management objectives that are suitable for everyone.

5.3.2 Step 2. Integration of Values

As stated in 1 (a) above, in order to alleviate the bycatch problem an agreement on the part of all stakeholders to co-operate is mandatory. Successful conservation programs must balance the needs of both the fishery and the harbour porpoise. We can evaluate the success of a conservation program by the measurable progress made towards the goal of achieving viable harbour porpoise populations without major negative impacts on the industry.

Integration of scientific knowledge and socio-economic values is necessary when working towards a common goal of protecting both the harbour porpoise and the fishery over the long term.

5.3.3 Step 3. Including the Variables

Fisheries management, including marine mammal management, should focus in the future on creating a system in which scientific knowledge is integrated with fishermen's knowledge to include operational, social, economic, ethical and political considerations.

Partnerships between scientists, managers and fishermen who are willing to look at the problems holistically are the sole avenue to making shared decisions, working towards a consensus in accomplishing mutual objectives and achieving compliance from the industry.

5.3.4 Step 4. Concurrent Implementation of Measurement Methods

According to Hall (1995) there are two units by which to measure bycatch for any fishing gear: (1) total bycatch, which is affected by total effort and (2) bycatch per unit of effort.

To reduce the number of incidences of harbour porpoise bycatch the options are: (a) to decrease the total fishing effort overall, or (b) attempt to reduce the catch per unit of effort. For the greatest success, both options should be implemented concurrently.

5.3.5 Step 5. The Importance of Education

Ideally, zero incidental captures of marine mammals is the goal for both fishermen and scientists. However, in reality, if gillnets are in the water they will capture porpoises. Thus, it is easy to recommend the removal of all gillnets. But we must ask "What are the consequences of this action?". Such a management scheme would certainly have an adverse economic impact on fishermen who rely on the ocean fishery for their livelihood.

Therefore, the management goals must be determined: questions should be discussed with all stakeholders, to answer such questions as "Is the goal *zero porpoise mortality*?" and "Is the goal *the maintenance of a sustainable population of the harbour porpoise*?". Obviously, it is imperative to define 'sustainable'. With so much uncertainty surrounding harbour porpoise populations, this has not yet been accomplished. Virtually no data exist for population(s) of the harbour porpoise in Newfoundland waters. With further research, education and evaluation, answers will become evident. It is apparent that more acute comprehension is needed of the importance of incidental capture and all involved components.

Such an understanding requires a change of perception essential to the understanding and appreciation of the biological importance of the harbour porpoise in its environment. The paradigm shift this change in perception necessitates would help alter the often reductionistic values of many stakeholders and lead to an understanding of the interrelatedness of ocean resources and ultimately to more ecologically-oriented fishing practices.

Education of fishery stakeholders should work towards a more holistic view of their relationship to the ocean and all aspects of its environment, including biological, physical, and chemical.

In the section which follows, specific measures are discussed.

5.4 SPECIFIC MITIGATION MEASURES AIMED AT REDUCING BYCATCH

5.4.1 Alternative fishing methods

This study showed that where variability was present, longer nets were more likely to entrap harbour porpoise than shorter ones. A maximum allowable length of nets would not affect quality of fish or target species catch. Shorter string lengths would only marginally increase work for fishermen. For areas such as Grand Manan Island/Bay of Fundy where net length does not vary, other net modifications (such as daytime sets, or measures to make the nets more visible) could be implemented.

In addition it is obvious that more study needs to focus on the bridle join area and a possible relationship with bycatch. Research on the effects of increasing and decreasing the bridle area may help our understanding of the gillnet as a barrier for harbour porpoise and their reaction to this barrier. Adjusting bridle join areas is a readily available solution at no cost to fishermen and may be part of an array of net modifications to decrease bycatch.

5.4.2 Regulating minimum allowable mesh size

This study showed that porpoise capture decreases as mesh size increases, pointing to a degree of mesh size selectivity, with a peak in incidental captures per unit of effort occurring at mesh sizes of 12.1-23.0 cm. Although all mesh sizes pose a potential risk to the harbour porpoise, imposing mesh size limits either greater than or less than these mesh sizes may result in reduced bycatches. This measure would be practical only for some fisheries because of its impact on age cohorts of target fish species.

5.4.3 Decrease soak time

Decrease soak time such that nets are set and hauled on the same day. Oversets should be discouraged and their prohibition enforced in a management regime. Flexibility for inclement weather conditions must, however, be allowed. This practice will also improve the quality of fish catch, thus increasing economic return and decreasing discards. This factor could be linked with shorter nets as well as if shorter nets are used they could be retrieved with less effort per string more often, perhaps within hours of setting.

5.4.4 Limit wind speeds for set and haul

Since wind speed was shown to be correlated to bycatch of porpoise, fishermen and management should design a protocol which dictates the maximum wind speed at which nets can be set. This protocol could be used to determine the maximum wind speed at which nets can be retrieved as well. Limiting fishing operations in some weather conditions may make fishing safer as well as decreasing bycatch.

5.4.5 Daylight set of nets only

Though not studied in this research some consideration should be given to restricting gillnet sets to daylight hours and to hauling on the same day. This tactic would allow the porpoise to better visually detect (or so it is presumed) the nets and thus avoid them. Fishermen would be able to determine if porpoise were in the vicinity and avoid setting near them. In daylight they could attempt to displace any porpoise seen near nets as well. As there is only traditional knowledge to support this recommendation tests to evaluate the effectiveness of this hypothesis should be conducted.

5.4.6 Setting limits on the number of porpoise bycatch allowed

By recognizing the PBR in the Gulf of Maine/Bay of Fundy or other regions where data are available for the harbour porpoise population(s), **a bycatch quota lower than the present mortality rate could be enforced.** All effort could be terminated once the predetermined number of allowable harbour porpoise bycatches is reached. This strategy would allow fishermen to accept responsibility for porpoise bycatch and use any initiatives to develop procedures and technological improvements to gear that would effectively reduce bycatch.

If stakeholders are not able to find short-term or long-term solutions, they could be obliged to reduce or terminate effort once the quota has been reached. Setting a quota limit provides a strong motivation to alleviate bycatch, but also may encourage fishermen to attempt to falsify bycatch reports. In order to enforce compliance with quotas, it is imperative to have as complete a fisheries observer coverage as possible.

5.4.7 Pre-quota data collection for Newfoundland and Labrador

Before a PBR and capture quota could be implemented for Newfoundland and Labrador fisheries, information on the spatial and temporal distribution and abundance of harbour porpoise population(s) in the region must be gathered. It is not clear if animals in Newfoundland and Labrador are captured from one or more populations. The implications of removing harbour porpoise from one population may in fact be more deleterious than if two populations are identified. Inadequate information on stock structure, abundance and distribution patterns prevents an assessment of past and current effects of estimated bycatch on potentially affected populations. Concerns about the effects of incidental captures by fishing gear on these populations highlight the critical need for estimates of abundance and incidental captures of harbour porpoise.

Future studies to provide integrated baseline data for understanding and monitoring harbour porpoise that frequent Newfoundland and Labrador waters are necessary. Such data should include: population structure, population biology parameters, feeding regimes, magnitude of incidental captures, and abundance on geographic, temporal and biological scales. Better understanding of harbour porpoise biology and ecology and the circumstances that contribute to their incidental mortality should lead to constructive conservation measures to minimize and preclude deleterious effects to harbour porpoise population(s).

5.4.8 Time and area closures

The spatial and temporal occurrence of the harbour porpoise is known in the Gulf of Maine/Bay of Fundy sub-population. **In fishing grounds in which fishermen are known to catch porpoise during certain seasons, management actions to close these grounds temporarily could be employed while the harbour**

porpoises are present.

Once areas of porpoise abundance are identified in Newfoundland and Labrador waters, steps can be taken to consider time/area closures during high attendance periods. Time/area closures restricting the set of nets within the depth or distance range most preferred by the harbour porpoise during its resident time in the region can serve as a short-term management solution. These temporal and spatial restrictions should coincide with the historic presence of harbour porpoise in the region. **Time and area closures are an alternative to the complete elimination of gillnets. If they are to be used as a harbour porpoise conservation tool, they must be large enough and appropriately timed to accommodate the life history and distribution patterns of the harbour porpoise.**

5.4.9 Educating Communities

There are several workable options to be considered for a management regime. Though depth, distance and soak time restrictions are likely candidates, as demonstrated by the present research, they will not eliminate harbour porpoise bycatch. They are potentially short-term means of reducing harbour porpoise capture, which may serve until long-term and more effective programs are identified and implemented.

Whatever working solution is employed, it must be designed and evaluated for a specific fishery in local conditions. **As the principle states, fishing communities should be part of an education program which will identify the reasons for the importance of a reduction in bycatches; and they should be involved in the process of evaluating possible solutions.** These measures would be equitable for all fishermen and as such have a greater chance of being perceived as fair.

5.4.10 Alternative fishing gear

Alternative gear that is more selective, such as handlines and longlines, would help to decrease the bycatch of porpoise and would mitigate the economic impact on the industry. To make an alternative gear or gear use acceptable to fishermen:

1. additional expense to the fishermen should be considered, and
2. alternative fishing practices should maximize fishing effort in areas where gillnets do not capture marine mammals or where few captures have been documented.

5.5 CONCLUSION

The challenges of harbour porpoise conservation for all sectors is immense, but its goal is of great importance. Scientists and fishermen need to come together, identify common ground, achieve unity on these issues, share their expertise and collectively become effective partners.

Indeed, for the harbour porpoise, a marine mammal which occupies a specific niche as yet not fully understood in terms of its importance to the ecology of Northwest Atlantic waters, the outcome of the challenge of reducing, and eventually eliminating, bycatch in gillnets as a result of fishing effort is of cardinal significance.

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Appendix 1: TERMS OF REFERENCE

- DEFINITIONS

- Antemortem: The time before death.

- Bagging: The process of a net folding in on itself creating bag like area.

- Beaufort Scale: A scale to relate wind to sea conditions devised by Rear - Admiral Sir Francis Beaufort in 1805.

- Bridle: The location where nets are tied together to form a string. Bridle join areas appear susceptible to bagging.

- Bycatch: The incidental capture of a species not targeted for harvest

- Catch per unit of effort: Calculated as the number of animals captured per net day fished.

- Deep core temperature: Body temperature procured by placing a thermometer near the core of the body.

- Distance from shore: The shortest measured distance in kilometres between the shoreline and the placement of a gillnet in the water.

- Drop out: During the hauling of the net the harbour porpoise drops from the net into the water before it can be retrieved.

- Gillnet: Fixed rectangular nets deployed in the form of a curtain or wall, suspended vertically in the water which entangle or ensnare fish in the net's meshes. Commonly constructed from multifilament twine, currently constructed from a single or mono fibre, often times nylon.

- Growth layer groups: A measurement of age using incremental lines as annuli criteria for yearly growth.

- Incidental capture: A synonym for bycatch and entanglement.

- Length of net: Total length of the net in metres

Appendix 1: (continued)

- Mesh size: The size in centimetres of stretched open spaces that comprise the network of the net.

- Monofilament: Constructed of a single fibre type.

- Net day: The time a net remained submerged in the water capable of fishing expressed in days of 24 hours or fractions thereof.

- Net depth: The depth at which the net fished after placement into the water. Depth was procured from electronic equipment on the vessels and by comparison with a nautical chart.

- Net haul: The process of removing the net from the water.

- Net set: The process of placing the net in the water.

- Postmortem: Subsequent to death.

- Soak time: The duration of time that the net remained in the water fishing, starting from the end of the net setting process and ending with the beginning of the hauling process. Soak times were calculated to the nearest hour.

- Standard length: A straight line measurement in centimetres taken from the tip of the rostrum to the fluke notch.

- String: Individual nets tied together at the bridle to form a wall of nets.
- Target species: Fish species harvested for their commercial value.

- Vitreous humour: An ocular fluid found in the vitreous body which fills the posterior compartment of the vertebrate eye

- Wind speed: The speed at which the wind is traveling measured in knots.

* Nomenclature note: All the fishermen involved in this study requested that they be referred to as fishermen and that the term fisher not be employed. To honour their request the term fishermen is used exclusively in this thesis.

Appendix 2: ABBREVIATIONS AND ACRONYMS

- cc: cubic centimetre(s)
- cm: centimetre(s)
- CTD: Conductivity, Temperature and Depth Probe
- FRCC: Fisheries Resources Conservation Council
- g: gram(s)
- GLG: growth layer groups
- hr: hour(s)
- IWC: International Whaling Commission
- kg: kilogram(s)
- kn: knot(s)
- m: metre(s)
- min: minute(s)
- NMFS : National Marine Fisheries Services of the United states
- PBR: Potential Biological Removal
- PMI: postmortem interval
- ppt: salinity measured in parts per thousand

Appendix 3: Resolution on North Atlantic Harbour Porpoise by the International Whaling Commission, May 1993 (IWC 1994).

RESOLUTION ON HARBOUR PORPOISE IN THE NORTH ATLANTIC AND THE BALTIC SEA

RECALLING that at the commission's 42nd, 43rd and 44th Annual Meetings, the Scientific Committee recommended as high priority that in the North Atlantic, bycatch mortality of harbour porpoise should be reduced, and further recommended that research be conducted to determine abundance, stock identity, bycatch levels, and pollutant levels;

RECOGNISING that considerable research has been initiated by member and non-member countries to address some of these needs, including in different regions, abundance, distribution, ecological requirements, vital rates, movements, stock identity, and by-catch mortality levels;

RECOGNISING that these studies need to be continued and additional research undertaken to provide a sound basis for understanding the status of the stocks of harbour porpoise throughout the North Atlantic and Baltic Sea in the face of continuing by-catch and other threats;

RECOGNISING the relevance of the Agreement of the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS) for the protection of harbour porpoises;

The Commission RECOMMENDS:

(1) That Range-States take action to meet the Scientific Committee's request for the collection and analysis of additional data on population distribution and abundance, stock identifies, pollutant levels, and by-catch mortality level'

(2) That range states give high priority to reducing by-catches of harbour porpoise;

(3) That Range States report to the 46th Annual Meeting of the Commission on their progress in implementing the above recommendations.

(4) That information about the harbour porpoise be exchanged with the Interim Secretariat of the Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas.

Appendix 4: Beaufort Scale of Wind Force (Adapted from Beer 1983).

Beaufort number	Mean wind speed in knots	Limits of wind speed in knots	Wind description	Wave height (m)	Appearance of the sea
0	0	1	Calm	0	Mirror - like
1	2	1 - 3	Light air		Wavelet - scales
2	5	4 - 6	Light breeze	0 - 0.1	Short waves, none break
3	9	7 - 10	Gentle breeze	0.1 - 0.5	Foam has glassy look, not yet white
4	13	11 - 16	Moderate breeze	0.5 - 1.25	Longer waves with white areas
5	19	17 - 21	Fresh breeze	1.25 - 2.5	Long pronounced waves/ white foam crests
6	24	22 - 27	Strong breeze	2.5 - 4.0	Large waves, white foam crests all over
7	30	28 - 33	Near gale	4.0 - 6.0	Wind blows foam in streaks
8	37	34 - 40	Gale		Higher waves
9	44	41 - 47	Strong gale	6.0 - 9.0	Dense foam streaks
10	52	48 - 55	Storm		High waves with long over - hanging crests
11	60	56 - 63	Violent storm	9.0 - 14.0	Ships in sight hidden in wave troughs
12	68	64 - 71	Hurricane	over 14	Air- sea boundary indistinguishable

Appendix 5: Survey questions for the assessment of fishermen's traditional knowledge.

Section A: LIVE SIGHTINGS

•What time of the year do you sight the most harbor porpoise?

•Do the number of sightings vary from year to year?

•Do sightings occur in the same general area?

•Are the harbor porpoise you sight;
  a) alone
  b) in pairs
  c) in small groups (under ten)
  d) in large groups (ten or more); does this vary with season?

•What markers or behaviours help you identify a marine mammal as a harbor porpoise?

•Do you often see harbor porpoise in the same area with dolphins, if so how do you distinguish them?

Section B: ENTANGLEMENT

•Why do you think harbor porpoise get caught in gillnets?

•Do you think entanglements occur in certain fishing areas more often than at others.

•Do you believe that certain gear or a specific area catch harbour porpoise on a regular basis?

•Have you ever entangled a large whale in your gear including end lines?

•What number (percent) of your nets are torn at any one time?

•Do you catch harbor porpoise near or at torn areas?

Appendix 5: (continued)

•What percentage of your nets are torn before you consider replacements?

Section C: POSSIBLE RELATIONSHIPS/RATING FACTORS SURROUNDING ENTRAPMENT OF HARBOUR PORPOISE

Please rate the items listed below according to factors you feel may contribute to harbor porpoise by-catch occurrences, on a scale of 1 to 5, according to the following definitions:

1. no relationship; 2. slight relationship; 3. moderate relationship; 4. strong relationship; 5. complete/total relationship
How do you rate the relationship between harbor porpoise by-catch and...

	Circle Your Choice				
__ a) an empty net	1	2	3	4	5
__ b) a full net	1	2	3	4	5
__ c) the bridle area	1	2	3	4	5
__ d) a bag area	1	2	3	4	5
__ e) depth of net set	1	2	3	4	5
__ f) length of soak	1	2	3	4	5
__ g) setting of nets	1	2	3	4	5
__ h) fish catch	1	2	3	4	5
__ i) weather conditions	1	2	3	4	5
__ j) water temperature	1	2	3	4	5
__ k) tide	1	2	3	4	5
__ l) colour of net	1	2	3	4	5

Rank the above in the order of importance to you, (use numbers 1 to 12 to fill in blanks, with 1 being the most important and 12 being the least).

Appendix 5: (continued)

Section D: AGREE OR DISAGREE QUESTIONS

Please answer (A) agree or (D) disagree to the following:

__ 1. Marine mammal by-catch in nets is both a local and global problem.
__ 2. Harbor porpoise numbers may be declining in the Gulf of Maine, therefore by-catch may have an impact on their population growth.

Section E: DISCUSSION (Searching for solutions)

1. What do you think are the best solutions to the by-catch problem?

2. If you sighted harbor porpoise in a high - productive fishing area would you change net location to an area of less fish per effort?

Appendix 6: Summary of observed fishing effort in waters adjacent to St. Bride's, Newfoundland during the summer of 1993.

Date	Number of observed trips	Number of nets	Number of net days
7/1	1	35	35
7/2	1	35	35
7/3	3	135	135
7/5	3	235	470
7/6	3	235	235
7/7	3	235	235
7/8	3	253	253
7/9	3	253	253
7/10	3	253	253
7/11	3	318	318
7/12	3	318	318
7/13	3	318	318
7/14	3	318	318
7/15	3	318	318
7/16	3	228	228
7/17	3	228	228
7/18	3	228	228
7/19	3	250	250
7/20	3	250	250
7/21	3	250	250

Appendix 6: (continued)			
7/23	3	185	370
7/24	2	145	145
7/26	3	219	438
7/27	2	145	145
7/28	2	145	145
7/29	2	145	145
7/30	2	145	145

Appendix 7: Summary of observed fishing effort for Gulf of Maine waters adjacent to Jeffreys Ledge during the fall of 1993.

Date	Number of observed trips	Number of nets	Number of net days
10/13	1	44	33
10/14	2	91	149
10/15	3	206	247
10/16	4	276	350
10/17	3	219	209
10/18	2	168	206
10/19	2	187	185
10/23	2	177	212
10/24	4	303	279
10/25	4	319	339
10/26	4	295	323
10/28	2	92	170
10/29	3	151	200
10/30	3	185	183
11/3	4	212	661
11/4	2	123	122
11/5	3	144	141
11/6	3	156	145
11/7	3	176	258
11/8	4	239	234
11/9	4	223	209
11/10	4	234	229
11/11	4	224	223
11/12	1	74	74

Appendix 7: (continued)			
11/13	3	154	252
11/14	1	48	48
11/15	4	238	323
11/16	4	205	203
11/17	4	233	249
11/19	4	238	470
11/22	2	104	311
11/23	4	227	580
11/24	3	138	126
11/26	2	128	252
11/27	2	120	140
11/30	2	134	402
12/1	2	134	132
12/2	3	191	191
12/3	3	190	180
12/4	3	192	183
12/6	1	35	105
12/7	3	183	318
12/8	3	131	124
12/9	3	190	181
12/10	3	118	108
12/18	3	85	736

Appendix 8: Summary of observed fishing effort for waters adjacent to Grand Manan Island during the summer of 1994.

Date	Number of observed trips	Number of nets	Number of net days
7/7	1	12	40
7/8	1	12	40
7/9	1	15	10
7/11	3	46	73
7/12	3	51	46
7/14	4	66	65
7/15	4	53	50
7/16	3	48	68
7/17	1	6	5
7/18	4	69	128
7/19	4	42	40
7/20	3	51	66
7/21	1	18	18
7/27	3	48	49
7/28	2	25	23
7/29	2	29	28
7/30	1	14	12
8/1	5	80	116
8/2	5	80	78
8/3	4	48	49
8/4	4	65	77
8/5	1	17	33
8/6	4	63	126
8/8	4	62	120

Appendix 8: (continued			
8/9	4	54	40
8/10	5	68	65
8/11	4	54	68
8/12	2	33	30
8/13	1	15	14
8/15	3	45	76
8/16	3	45	41
8/17	3	48	45
8/18	2	33	31
8/19	2	30	28
8/20	1	9	9
8/22	1	3	9
8/23	4	63	51
8/24	5	75	69
8/25	5	75	71
8/26	6	74	68
8/27	2	24	42
8/29	3	33	67
8/30	5	52	133
8/31	4	39	49
9/1	4	55	100
9/2	4	50	72
9/3	4	38	37
9/7	4	63	247
9/10	1	6	6

Appendix 9: Summary of observed fishing effort for waters adjacent to Grand Manan Island during the summer of 1995.

Date	Number of observed trips	Number of nets	Number net days
7/3	3	16	28
7/4	3	33	73
7/5	3	42	47
7/6	4	57	66
7/7	4	57	59
7/8	4	57	52
7/10	3	45	54
7/11	5	69	70
7/12	5	72	77
7/13	5	69	70
7/14	4	54	52
7/15	4	57	57
7/17	6	85	170
7/18	6	61	58
7/19	6	79	109
7/20	6	85	84
7/21	6	85	83
9/1	1	16	30
9/2	5	92	103
9/3	4	57	56
9/4	2	36	45

Appendix 9: (continued)			
9/5	1	15	15
9/6	1	6	6
9/7	1	9	15
9/8	1	6	6
9/11	1	15	15
9/12	4	54	36
9/14	2	6	12
9/15	3	36	108
9/16	1	15	14
9/19	3	45	94
9/20	1	12	12
9/21	1	15	15
9/22	1	15	14
9/25	1	15	30
9/26	1	15	14

Appendix 10: Daily operational measures and effort (CPUE) data for harbour porpoise captured in the St. Bride's Newfoundland gillnet fishery during July, 1993 (n=19). CPUE is measured as one net set for a 24 hour period. Total net days are inclusive of all nets fished per day. Data not attained =n/a.

Date of capture	Animal no.	Soak time (hr)	Depth of net (m)	Net distance to shore (km)	Mesh size (cm)	Number of nets in bycatch string	Total net days	Bycatch CPUE
7/5	1	48	29	1	12.1	10	470	0.002
7/6	2	24	68	1.5	12.1	10	235	0.004
7/7	3	48	37	n/a	23.1	10	235	0.004
7/9	4	24	37	1	12.1	10	506	0.008
7/9	5	48	n/a	n/a	23.1	10	506	0.008
7/9	6	48	n/a	n/a	23.1	10	506	0.008
7/9	7	24	42	3.5	12.1	10	506	0.008
7/10	8	24	40	3	12.1	10	253	0.004
7/12	9	48	36	n/a	23.1	10	636	0.002
7/14	10	24	29	2.5	12.1	10	636	0.005
7/14	11	24	53	1	12.1	10	636	0.005
7/14	12	24	22	1	12.1	5	636	0.005
7/15	13	24	55	1	12.1	5	318	0.003
7/19	14	48	36	4	12.1	10	250	0.004
7/19	15	48	59	2	12.1	5	250	0.004
7/23	16	72	24	1	17.6	10	185	0.005
7/23	17	48	27	1.5	12.1	5	185	0.005
7/26	18	48	n/a	n/a	17.6	10	438	0.002
7/30	19	72	60	3	17.6	10	145	0.003

* Note: Lumpfish nets were removed on 19 July, 1993.

Appendix 11: Operational measures and effort (CPUE) data for harbour porpoise captured in the St. Bride's, Newfoundland gillnet fishery during July, 1993 (n=19). Mean and standard deviations (± SD) are presented in six day intervals. Total net days are the unit of effort for the entire interval, and CPUE is the bycatch of harbour porpoise per unit of fishing effort.

Date	Mean (± SD) of soak time (hr)	Mean (± SD) of depth of net set (m)	Mean (± SD) of distance for net from shore (km)	Total net days	Total bycatch	Bycatch CPUE
7/1-7/6	29 ± 10.7	35.4 ± 16.1	2 ± 1.1	910	2	0.002
7-7/12	36 ± 14	39.4 ± 17.8	2.2 ± 0.5	1,630	7	0.0042
7/13-7/18	29 ± 10.7	43.2 ± 19.7	2.2 ± 1.4	1,638	4	0.0023
7/19-7/24	34 ± 13.1	37.1 ± 17.1	3.1 ± 1.3	1,265	4	0.0031
7/25-7/30	48 ± 27.7	43.1 ± 18.5	1.6 ± 0.8	1,237	2	0.0016

* Note: Lumpfish target species nets were removed from the water on 19 July, 1993.

Appendix 12: Number of target species harvested during days harbour porpoise were captured in the St. Bride's, Newfoundland gillnet fishery during July, 1993. CPUE is measured as one net set for a 24 hour period. Fish harvest is in kilograms (kg).

Date	Lumpfish roe (kg)	Cod (kg)	Flounder (kg)	Daily total net days	Bycatch total	Bycatch (CPUE)
7/5	909	8,361	352	470	1	0.0021
7/6	2,456	9,831	286	235	1	0.0042
7/7	1,170	8,834	n/a	235	1	0.0042
7/9	1,045	10,251	n/a	506	4	0.0079
7/10	59	9,828	n/a	253	1	0.0039
7/12	n/a	31,348	n/a	636	1	0.0015
7/14	n/a	34,366	n/a	636	3	0.0047
7/15	2,148	39,485	990	318	1	0.0031
7/19	1,175	51,313	1,267	250	2	0.0040
7/23	n/a	6,833	4,362	185	2	0.0054
7/26	n/a	2,861	2,412	438	1	0.0015
7/30	n/a	9,808	1,232	145	1	0.0026

* Note: Lumpfish nets were removed on 19 July, 1993.

Appendix 13: Gillnet fishery harvest and bycatch of harbour porpoise (at St. Bride's, Newfoundland, 1993). Values reported are total harvest, mean and standard deviation (± SD) in six day intervals. Fish species harvest is in kilograms (kg). Bycatch indicates mean, standard deviation (± SD) and CPUE for harbour porpoise captured during the time interval.

Date	Lumpfish			Cod			Flounder			Harbour porpoise bycatch		
Date	N	Mean	Range	N	Mean	Range	N	Mean	Range	N	Mean	CPUE
7/1-7/6	3,678	716.9 ± 641.3	0 - 1,607	9,880	1,663 ± 1,984.3	0 - 4,514	131	65.9 ± 9.6	59 - 73	2	0.3 ± 0.5	0.0022
7/7-7/12	1,969	331.4 ± 248	0 - 537	35,473	5,972 ± 4,137	4,057 - 14,393	81	13.6 ± 33.4	0 - 82	7	1.2 ± 1.5	0.0042
7/13-7/18	1,085	181 ± 397	0 - 986	64,186	10,805 ± 5,669	5,046 - 18,129	462	77.7 ± 122	205 - 262	4	0.7 ± 1.2	0.0023
7/19-7/24	534	534 ± 0	0 - 534	35,119	5,912 ± 8,890	549 - 23,560	1,233	206 ± 343	417 - 818	4	0.7 ± 1.0	0.0031
7/25-7/30	0	0	0	16,818	2,803 ± 1,504	2,801 - 4,938	3,155	525.8 ± 563	255 - 3,186	2	0.3 ± 0.5	0.0016

* Note: Lumpfish nets were removed on 19 July, 1993.

Appendix 14: Operational measures and effort (CPUE) data for harbour porpoise captured in the Gulf of Maine/Jeffreys Ledge gillnet fishery during the autumn of 1993 (n=33). CPUE is measured as one net set for a 24 hour period. Total net days are inclusive of all nets fished per day. Non-retrieved porpoise are designated as n/r.

Date of capture	Animal number	Soak time (hr)	Depth of net (m)	Mesh size (cm)	Number of nets in string	Total net days	CPUE
10/17	1	19	55	14	22	209	0.0047
10/19	2	24	90	15.2	17	185	0.0054
10/24	3	24	56	14	13	279	0.0143
10/24	4	24	54	14	15	279	0.0143
10/24	5	24	51	15.2	11	279	0.0143
10/24	6	24	52	15.2	12	279	0.0143
10/25	7	24	55	14	25	339	0.0029
10/28	8	46	54	14	13	170	0.0117
10/28	9	45	56	14	24	170	0.0117
10/29	10	23	57	14	23	200	0.0050
10/30	11	24	55	16.5	13	183	0.0054
11/ 3	12	95	101	15.2	9	661	0.0015
11/4	13	23	105	15.2	12	122	0.0163
11/4	14	24	82	14	23	122	0.0163
11/7	15	48	78	14	25	258	0.0077
11/7	16	48	78	14	25	258	0.0077
11/9	17	21	90	15.2	10	209	0.0143
11/9	18	23	91	15.2	10	209	0.0143
11/9	19	23	57	15.2	12	209	0.0143

Appendix 14: (continued)							
11/10	20	22	88	15.2	11	229	0.0043
11/15	21	24	74	n/a	10	323	0.0030
11/17	22	25	59	15.2	13	249	0.0040
11/22	23	69	62	14	12	311	0.0032
11/23	24	96	99	15.2	10	580	0.0034
11/23	25	23	87	15.2	12	580	0.0034
11/30	26	72	94	16.5	25	402	0.0024
12/1	27	72	88	n/r	10	132	0.0227
12/1	28	73	88	n/r	10	132	0.0227
12/1	29	24	57	n/r	12	132	0.0227
12/8	30	24	101	16.5	11	124	0.0080
12/18	31	194	101	15.2	12	736	0.0040
12/18	32	216	86	14	8	736	0.0040
12/18	33	216	77	15.2	10	736	0.0040

Appendix 15: Harbour porpoise bycatch (n=33) and operational data calculated for six day intervals at the Gulf of Maine/Jeffreys Ledge, 1993. Total net days are for the entire period. Net days are the unit of effort and CPUE is the bycatch of harbour porpoise per unit of fishing effort.

Date	Mean soak time (hr) (± SD)	Mean depth of net set (m) (± SD)	Total net days	Total bycatch	CPUE
10/13-10/18	29 ± 15.3	59 ± 8.7	1,193	1	0.0008
10/19-10/24	26 ± 14.8	63 ±18.8	676	5	0.0073
10/25-10/30	29 ± 14	61 ± 14.2	1,225	5	0.0041
10/31-11/5	47 ± 26.4	80 ± 20.2	923	3	0.0032
11/6-11/11	25 ± 7.8	84 ± 17.8	1,298	6	0.0050
11/12-11/17	28 ± 9.5	83 ± 22	1,148	2	0.0017
11/18-11/23	56 ± 25	82 ± 21	1,362	3	0.0022
11/24-11/29	33 ± 14.7	97 ± 10	518	0	0
11/30-12/5	31 ± 17.5	89 ±16.8	1,088	4	0.0036
12/6-12/11	33 ± 20.2	95 ± 13.3	830	1	0.0011
12/12-12/18	213 ± 7.6	94 ± 9.7	734	3	0.0040

Appendix 16: Number of target species harvested during days harbour porpoise were captured in the Gulf of Maine/Jeffreys Ledge gillnet fishery during 1993. CPUE is measured as one net set for a 24 hour period. Fish harvest is in kilograms (kg).

Date of capture	Cod (kg)	Pollock (kg)	Daily total number net days	Bycatch total	Bycatch CPUE
10/17	1,288	1,262	209	1	0.0050
10/19	690	403	185	1	0.0054
10/24	1,101	694	279	4	0.0143
10/25	1,622	972	339	1	0.0029
10/28	433	256	170	2	0.0117
10/29	563	886	200	1	0.0050
10/30	443	721	183	1	0.0054
11/3	1,484	1,224	661	1	0.0015
11/4	499	740	122	2	0.0163
11/7	1,110	629	258	2	0.0080
11/9	674	860	209	3	0.0143
11/10	1,025	837	229	1	0.0043
11/15	670	282	323	1	0.0030
11/17	921	725	249	1	0.0040
11/22	550	519	311	1	0.0032
11/23	1,655	842	580	2	0.0034
11/30	766	1,350	402	1	0.0024
12/1	740	733	132	3	0.0227
12/8	765	525	124	1	0.0080
12/18	25	140	736	3	0.0040

Appendix 17: Gillnet fishery harvest and bycatch of harbour porpoise at the Gulf of Maine/Jeffrey's Ledge, 1993. Values reported are total harvest, mean and standard deviation (± SD) in six day intervals. Fish harvest is in kilograms (kg). Bycatch indicates mean, standard deviation (± SD) and CPUE of harbour porpoise captured during the time interval.

Date	Fish harvest (kg)	Mean (± SD)	Range	Total bycatch	CPUE
10/13- 10/18	10,950	192.1 ± 11.9	352-2,056	1	0.0008
10/19-10/24	4,341	131.5 ± 85.8	1,093-1,795	5	0.0073
10/25-10/30	8,154	118.1 ± 89.6	689-2,594	5	0.0041
10/31-11/5	5,026	139.6 ± 94.6	1,080-2,707	3	0.0032
11/6-11/11	9,577	89.5 ± 56.3	1,325-1,862	6	0.0050
11/12-11/17	6,127	79.5 ± 73.7	302-1,646	2	0.0017
11/18-11/23	5,657	128.5 ± 100.6	1,069-2,507	3	0.0022
11/24-11/29	3,358	139.9 ±115.8	908-1,255	0	0
11/30-12/5	10,773	179.5 ± 109.1	1,473-2,540	4	0.0036
12/6-12/11	7,993	170.0 ± 116.3	506-2,540	1	0.0011
12/12-12/18	165	20.6 ± 8.9	165	3	0.0040

Appendix 18: Operational measures and effort (CPUE) data for harbour porpoise captured in the Grand Manan Island/Bay of Fundy gillnet fishery during the summer of 1994 (n=43). CPUE is measured as one net set for a 24 hour period. Total net days are inclusive of all nets fished per day. All strings of bycatch were mesh size 15.2 cm; total three nets and 300 metres in length.

Date of capture	Animal number	Soak time (hrs)	Depth of net (m)	Net distance to shore (km)	Total net days	CPUE
7/9	1	16	86	3	10	0.1001
7/14	2	48	88	2	65	0.0153
7/15	3	23	81	1	50	0.0200
7/16	4	19	81	2	68	0.0147
7/17	5	21	81	1	5	0.2000
7/28	6	21	82	1.5	23	0.0357
8/1	7	26	104	2	116	0.0775
8/1	8	29	110	2	116	0.0775
8/1	9	29	110	2	116	0.0775
8/1	10	29	110	2	116	0.0775
8/1	11	47	84	1.5	116	0.0775
8/1	12	51	81	1	116	0.0775
8/1	13	51	81	1.5	116	0.0775
8/1	14	21	102	1.5	116	0.0775
8/1	15	24	99	2	116	0.0775
8/2	16	24	84	2	78	0.0384
8/2	17	20	82	1.5	78	0.0384
8/2	18	20	82	1.5	78	0.0384
8/6	19	71	101	1.5	126	0.0317
8/6	20	72	86	3	126	0.0317
8/6	21	72	86	2	126	0.0317

Appendix 18: (continued)						
8/6	22	72	97	1.5	126	0.0317
8/8	23	50	101	2	120	0.0166
8/8	24	52	95	2	120	0.0166
8/10	25	20	92	2.5	65	0.0307
8/10	26	17	108	3	65	0.0307
8/11	27	48	101	1	68	0.0294
8/11	28	44	102	1	68	0.0294
8/15	29	27	104	2	76	0.0131
8/18	30	23	108	2	31	0.0322
8/23	31	25	88	2.5	51	0.0392
8/23	32	27	92	3	51	0.0392
8/24	33	23	88	3	69	0.0144
8/26	34	26	76	2	68	0.0147
8/29	35	47	81	2.5	67	0.0149
8/30	36	72	102	3.5	133	0.0150
8/30	37	72	102	3.5	133	0.0150
9/1	38	48	92	3.5	100	0.0100
9/2	39	74	106	2.5	72	0.0277
9/2	40	25	92	2.5	72	0.0277
9/7	41	96	112	2.5	247	0.0121
9/7	42	96	112	2.5	247	0.0121
9/7	43	92	95	1.5	247	0.0121

Appendix 19: Harbour porpoise bycatch (n=43) and operational data calculated by mean and standard deviation ($\pm$ SD) for six day intervals (n=11) in the groundfish gillnet fishery at Grand Manan Island in 1994. Total net days are for the entire interval. Net days are the unit of effort and CPUE is the bycatch of harbour porpoise per unit of fishing effort.

Date	Mean soak time (hr)	Mean depth of net (m)	Total bycatch	Total net days	CPUE
7/7-7/12	30.2 $\pm$ 13.7	91 $\pm$ 17.8	1	209	0.0047
7/13-7/18	33.3 $\pm$ 12	99 $\pm$ 13.9	4	316	0.0126
7/19-7/24	27.1 $\pm$ 7.3	98.3 $\pm$ 20	0	124	0
7/25-7/30	23.4 $\pm$ 3.5	96 $\pm$ 15.5	1	112	0.0089
7/31-8/5	28 $\pm$ 10.7	102 $\pm$ 17	12	353	0.0339
8/6-8/11	35.7 $\pm$ 14.5	107 $\pm$ 18.3	10	419	0.0238
8/12-8/17	27 $\pm$ 10	108 $\pm$ 14	1	206	0.0048
8/18-8/23	24 $\pm$ 2.4	97 $\pm$ 11	3	128	0.0234
8/24-8/29	27 $\pm$ 11.2	99 $\pm$19.8	3	317	0.0094
8/30-9/4	41.4 $\pm$ 21.5	108 $\pm$ 21	5	391	0.0127
9/5-9/10	88 $\pm$ 23	95 $\pm$ 16	3	253	0.0118

Appendix 20: Number of target species harvested during days harbour porpoise were captured in the Grand Manan Island/Bay of Fundy gillnet fishery during 1994. CPUE is measured as one net set for a 24 hour period. Target species fish harvest equals number of each fish species landed.

Date of capture	Herring	Cod	Pollock	Hake	Daily total net days	Bycatch total	Bycatch CPUE
7/9	101	225	19	6	10	1	0.1000
7/14	321	250	39	29	65	1	0.0153
7/15	363	117	15	11	50	1	0.0200
7/16	634	186	69	15	68	1	0.0147
7/17	52	13	13	1	5	1	0.2000
7/28	115	250	182	161	23	1	0.0357
8/1	2327	591	655	164	116	9	0.0775
8/2	34	414	302	86	78	3	0.0384
8/6	221	257	163	134	126	4	0.0317
8/8	553	109	127	58	120	2	0.0166
8/10	67	89	92	63	65	2	0.0307
8/11	462	142	259	72	68	2	0.0294
8/15	424	92	87	51	76	1	0.0131
8/18	295	89	138	22	31	1	0.0322
8/23	219	337	46	93	51	2	0.0392
8/24	667	266	88	91	69	1	0.0144
8/26	529	60	121	54	68	1	0.0147
8/29	351	83	72	75	67	1	0.0149
8/30	479	112	105	217	52	2	0.0150
9/1	106	185	137	254	100	1	0.0100
9/2	259	121	108	70	72	2	0.0277
9/7	669	60	43	56	247	3	0.0121

Appendix 21: Gillnet fishery harvest and the bycatch of harbour porpoise during the 1994 Grand Manan Island/Bay of Fundy, season. Values reported are total harvest, mean and standard deviation (± SD) in six day intervals. Fish species harvest is counted per fish. Bycatch indicates mean, standard deviation (± SD) and CPUE for harbour porpoise captured during the time interval.

Date	Herring			Cod			Pollock			Hake			Bycatch	
Date	N	Mean	Range	N	Mean	Range	N	Mean	Range	N	Mean	Range	Total	Mean
7/7-7/12	481	160 ± 124	77-303	710	237 ± 107	135-350	106	35 ± 31	16-71	62	21± 14	6-34	1	0.25 ± 0.5
7/13-7/18	1,145	229 ± 164	77-481	1,540	308 ± 244	108-710	259	52 ± 36	16-106	137	27 ± 22	6-62	4	0.5 ± 0.2
7/19-7/24	465	115 ± 122	14-226	208	69 ± 41	35-114	222	74 ± 62	13-136	77	26 ±17	15-45	0	0
7/25-7/30	392	65 ± 87	0-217	762	127 ± 105	15-250	630	105 ± 59	45-182	483	81 ± 64	7-161	1	1 ± 0
7/31-8/5	3,445	861 ± 1,065	2,327-34	1,450	363 ± 178	198-591	1,294	324 ± 238	92-655	429	107 ± 40	72-164	12	2 ±3.6
8/6-8/11	1,638	328 ± 187	67-533	742	148 ± 65	89-257	733	147 ± 69	92-259	359	72 ± 38	32-134	10	1.6 ± 1.5

Appendix 21: (continued)

8/12-8/17	2,,328	466 ± 245	109-793	504	101 ± 54	43-173	417	83 ± 35	30-124	183	37 ± 19	20-62	1	1 ± 0
8/18-8/23	1,292	323 ± 176	199-579	495	124 ± 144	32-337	407	102 ± 41	46-138	144	36 ± 38	9-93	3	0.5 ± 0.8
8/24-8/29	3,474	695 ±455	351-1,482	957	191 ± 183	60-482	654	131 ± 121	33-340	383	77 ± 39	30-133	3	0.5 ± 0.5
8/30-9/4	1,831	366 ± 187	106-582	528	106 ±54	51-185	514	103 ± 26	65-137	608	122 ±106	21-254	5	0.8 ± 0.9
9/5-9/10	669	335 ± 473	0-669	76	38 ±31	16-60	93	47 ± 5	43-50	62	31 ±35	6-56	3	1 ± 1.7

Appendix 22: Operational measures and effort (CPUE) data for harbour porpoise captured in the Grand Manan Island/Bay of Fundy gillnet fishery during 1995 (n=29). CPUE is measured as one net set for a 24 hour period. Total net days and CPUE are inclusive of all nets fished per day. All strings where bycatch occurred used a mesh size of 15.2 cm with three nets in the string. Porpoises number 24 and 25 were non-observed captures, data are listed as non - attained (n/a). Soak time in hours (hrs), depth in metres (m) and distance to shore in kilometres (km).

Date of capture	Animal number	Soak time (hrs)	Depth of net (m)	Distance to shore (km)	Number of nets	Total net days	CPUE
7/6	1	21	101	3.5	3	71	0.0563
7/6	2	22	108	3.5	3	71	0.0563
7/6	3	22	110	3.5	3	71	0.0563
7/6	4	23	92	2	3	71	0.0563
7/10	5	25	86	1.5	3	54	0.0370
7/10	6	43	101	3	3	54	0.0370
7/11	7	26	86	2	3	70	0.0142
7/12	8	20	86	2	3	77	0.0389
7/12	9	43	75	1	3	77	0.0389
7/12	10	25	88	3	4	77	0.0389
7/13	11	24	104	3	3	70	0.0285
7/13	12	25	110	3	3	70	0.0285
7/14	13	22	106	3	3	52	0.0192

Appendix 22: (continued)							
7/17	14	47	93	2.5	4	170	0.0117
7/17	15	51	99	3	4	170	0.0117
7/19	16	24	108	4	4	109	0.0183
7/19	17	26	97	2	3	109	0.0183
7/20	18	24	88	1.5	3	84	0.0238
7/20	19	22	88	2.5	3	84	0.0238
9/2	20	25	92	3	3	103	0.0194
9/2	21	29	86	2	3	103	0.0194
9/3	22	21	104	2	3	56	0.0178
9/4	23	30	73	1.5	3	45	0.0222
9/9	24	n/a	n/a	n/a	n/a	n/a	n/a
9/9	25	n/a	n/a	n/a	n/a	n/a	n/a
9/12	26	24	84	2.5	3	36	0.0277
9/15	27	69	79	2.5	3	108	0.0092
9/19	28	71	92	2	3	94	0.0212
9/19	29	48	101	4.5	3	94	0.0212

Appendix 23: Harbour porpoise bycatch (n=29) and operational data calculated for Grand Manan Island/Bay of Fundy waters during 1995 (n=29). Mean and standard deviations (± SD) are presented in six day intervals (n=11). Total net days are for the entire period. Net days are the unit of effort and the CPUE is the bycatch of harbour porpoise per unit of fishing effort.

Date	Mean ± SD soak time (hrs)	Mean ± SD depth (m)	Mean ± SD distance (km)	Bycatch	Total net days	CPUE
7/3-7/8	22 ± 0.8	103 ± 8	3 ± 0.7	4	330	0.0121
7/9-7/14	28 ± 8.6	93.5 ±11.9	2.3 ± 0.7	9	323	0.0278
7/15-7/21	32.3 ± 13	95.5 ± 7.6	2.5 ± 0.8	6	561	0.0106
9/1-9/6	26 ± 4.1	88.7 ± 12.8	2.1 ± 0.6	4	255	0.0156
9/7-9/12	24 ± 0	84	2.5 ± 0	3	72	0.0416
9/13-9/18	69 ± 0	79 ± 0	2.5 ± 0	1	134	0.0074
9/19-9/26	59.5 ± 16.2	96.5 ± 6.3	3.2 ± 1.7	2	179	0.01117

*Note: Interval number three equals seven days (six days of fishing) and the final interval equals eight days (six days of fishing).

Appendix 24: Number of target species harvested during days harbour porpoise were captured in the Grand Manan Island/Bay of Fundy gillnet fishery during 1995. CPUE is measured as one net set for a 24 hour period. Target species fish harvest equals number of each fish species landed.

Date of capture	Cod	Herring	Pollock	Daily total number of net days	Bycatch total	Bycatch CPUE
7/6	702	227	59	71	4	0.0563
7/10	460	175	21	54	2	0.0370
7/11	372	433	19	70	1	0.0142
7/12	356	438	36	77	3	0.0389
7/13	390	200	19	70	2	0.0285
7/14	215	22	10	52	1	0.0192
7/17	352	701	68	170	2	0.0117
7/19	666	1232	148	109	2	0.0183
7/20	378	359	102	84	2	0.0238
9/2	373	119	309	103	2	0.0194
9/3	166	203	85	56	1	0.0178
9/4	203	375	210	45	1	0.0222
9/12	169	75	23	36	1	0.0277
9/15	136	52	34	108	1	0.0092
9/19	382	116	142	94	2	0.0212

Apppendix 25: Gillnet fishery harvest and bycatch of harbour porpoise for Grand Manan Island/Bay of Fundy waters during 1995. Values reported are total harvest, mean, and standard deviation (± SD) in six day intervals. Fish species harvest is counted per fish. Bycatch indicates mean, standard deviation (± SD) and CPUE of porpoise captured during the interval.

		Cod			Herring			Pollock			Harbour porpoise catch		
Date	Net days	N	Mean	Range	N	Mean	Range	N	Mean	Range	N	Mean	CPUE
7/3-7/8	330	1,947	315.8 ± 240.3	74-702	481	93.2 ± 114.9	0-227	163	28.2 ± 19.9	8-59	4	0.6	0.0121
7/9-7/14	318	1,793	360.2± 80.2	215-460	1,268	214 ± 187.8	15-438	105	21.2 ± 8.42	10-36	9	1.8 ± 0.8	0.0278
7/15-7/21	561	2,478	413 ± 195.3	144-666	3,315	552.5 ± 408	73-1232	595	99.2 ± 79.5	9-228	6	1 ± 1.0	0.0106
9/1-9/6	255	956	145.7 ± 132.2	19-373	1,081	159.3 ± 129	1-375	664	109.7 ± 124	3-309	4	0.6 ± 0.8	0.0156
9/7-9/12	87	336	84 ± 63.2	16-169	164	41 ± 24.1	19-75	63	15.8 ± 10.9	1-25	3	0.25 ± 0.5	0.0416
9/13-9/18	134	224	74.7 ± 61.0	14-136	99	33 ± 27.1	2-52	46	15.3 ± 16.9	1-34	1	0.3 ± 0.6	0.0074
9/19-9/26	135	769	170.8 ± 141.0	91-382	314	78.5 ± 67.7	20-155	275	68.8 ± 49.8	31-142	2	0.5 ± 1	0.0111
9/25-9/26	44	86	43 ± 26.9	24-62	23	11.5 ± 10.6	4-19	29	14.5 ± 12.0	6-23	0	0	0

Note: Interval number three equals seven days (six days of fishing) and the final interval equals two days of fishing.

Appendix 26: Life History data from harbour porpoise captured in the St. Bride's, Newfoundland gillnet fishery during July, 1993. Nineteen animals were captured, four dropped from the net and were not retrieved (n/r). One porpoise was not examined. Predicted age and sexual maturity are estimated from Richardson (1992) Gompertz growth curve data. Sexual maturity categories: calf, immature and mature are given for 14 porpoise. A calf is designated as 0. Females found to be lactating are reported as (L).

Date	Animal number	Gender	Length (cm)	Estimated weight (kg)	Girth (cm)	Estimated age	Sexual maturity
July 5	1	m	150	48.5	93	6	mature
July 7	3	m	138	40	76	3	mature
July 9	4	m	147	54	95	5	mature
July 9	5	m	145	49	92	5	mature
July 9	6	m	130	40	80	2	immature
July 9	7	m	87.5	11	55	0	calf
July 10	8	m	149.5	47	88	5	mature
July 12	9	f	151	55	97	5	mature
July 14	10	f	146.5	61	95	4	mature
July 14	11	f	157	53	93	5	mature
July 19	14	m	124	34.8	86	2	immature
July 23	16	f	143	51	93.5	3	mature (L)
July 23	17	f	120	31	84	1	immature
July 26	18	m	n/a	n/a	n/a	n/a	n/a
July 30	19	f	154	70	106	>6	mature (L)

Appendix 27: Stomach content analysis by weight in grams (g) and the number of intact prey and otoliths from species of prey in stomachs of harbour porpoise captured in the St. Bride's, Newfoundland gillnet fishery during July, 1993 (n=19). Species identified are capelin, sand lance, Atlantic herring and amphipods spp. P indicates capelin was present but not counted or weighed.

Animal number	Fore-stomach content wgt. (g)	Capelin total (n)	Capelin wgt. (g)	Sand lance total (n)	Sand lance wgt. (g)	Atlantic herring total (n)	Atlantic herring wgt. (g)	Amphipod wgt. (g)
1	0	0	0	0	0	0	0	0
3	3,059	52	3,059	0	0	0	0	0
4	3,669	246	3,669	0	0	0	0	10
5	28	28	18	1	10	0	0	0
6	1,184	18	1,171	1	11	0	0	0
7	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0
9	6,240	197	6,210	0	0	0	0	30
10	11,035	215	9,902	0	0	1	1,133	0

Appendix 27: (continued)								
11	5,120	230	4,058	4	n/a	0	0	0
14	650	19	645	0	0	0	0	5
16	430	1	40	1	n/a	0	0	10
17	35	10	15	14	10	0	0	0
18	5,077	P	n/a	P	n/a	0	0	18
19	447	1	n/a	1	n/a	1	n/a	0

Appendix 28: Mean and standard deviation of stomach contents of harbour porpoise captured in the St. Bride's Newfoundland gillnet fishery during July, 1993. Fore-stomach and content weight are in grams (g) averaged over six day intervals.

Six day intervals	7/1-7/6 (n = 1)	7/7-7/12 (n = 7)	7/13-7/18 (n = 2)	7/19-7/24 (n = 3)	7/25-7/30 (n = 2)
Empty	1	2	0	0	0
Total stomach wgt. (g)	0	14,228	16,187	1,145	5,534
Mean and SD	1	2,032 ± 2,394	8,093 ± 4,174	382 ± 311	2,767 ± 3,266
Fore-stomach wgt. (g)	n/a	14,178	16,155	1,105	5,524
Mean and SD	n/a	2,025 ± 2,395	8,078 ± 4,182	368 ± 317	2,762 ± 3,273
Capelin total	n/a	524	445	30	1
Mean and SD	n/a	105 ± 109	223 ± 10.6	10 ± 9.0	1 ± 0
Capelin wgt (g)	n/a	12,956	9,902	660	n/a
Mean and SD	n/a	3,239 ± 2,544	4,951 ± 777.8	330 ± 445.4	n/a
Sand lance total	n/a	2	4	15	2
Mean and SD	n/a	1 ± 0	4 ± 0	7.5 ± 9.1	1 ± 0
Sand lance wgt. (g)	n/a	10	n/a	10	n/a
Mean and SD	n/a	5 ± 1.4	n/a	10 ± 0	n/a
Herring total	n/a	0	3	0	1
Mean and SD	n/a	0	3 ± 0	0	1 ± 0
Herring wgt. (g)	n/a	0	n/a	0	n/a
Mean and SD	n/a	0	n/a	0	n/a
Bycatch total	2	7	4	4	2
Mean and SD	0.03 ± 0.5	1.2 ± 1.5	0.7 ± 1.2	0.7 ± 1.0	0.3 ± 0.5

Appendix 29: Life history data from harbour porpoise captured in the Gulf of Maine/Jeffrey's Ledge gillnet fishery during 1993 (n=19). Fourteen porpoise were not retained. Sexual maturity categories: calf, immature and mature. A calf is designated as 0.

Date of capture	Animal number	Gender	Length (cm)	Weight (kg)	Estimated age (yrs)	Sexual maturity
10/17	1	m	122	34	2	immature
10/19	2	f	114	32	0	calf
10/24	3	f	126	37	2	immature
10/24	6	f	118	31	0	calf
10/25	7	m	126	45	2.5	immature
10/28	8	m	160	67	15	mature
10/28	9	m	130	37	3	mature
10/30	11	f	127	39	0	calf
11/ 3	12	m	114	31	0	calf
11/4	13	f	100	20	0	calf
11/4	14	m	110	29	1	immature
11/9	17	m	117	32	0	immature
11/9	18	m	124	37	1	immature
11/9	19	m	n/a	n/a	n/a	n/a
11/10	20	m	134	n/a	3	mature
11/15	21	m	133	43	3	mature
11/23	24	m	134	48	3	mature
11/23	25	m	138	45	4	mature
12/8	30	m	122	38	1	immature
12/18	31	m	146	51	10	mature

Appendix 30: Stomach content analysis by weight in grams (g) and the number of intact prey and otoliths from species of prey in stomachs of harbour porpoise captured in the Gulf of Maine/Jeffreys Ledge gillnet fishery during 1993. Fore-stomach weights are presented before and after emptying of contents. Species identified are Atlantic herring, euphausiids (Euph.), pearlsides (Pearl.), silver hake, pollock, mackerel, *Sebastes spp.*, and *Urophycis spp.* (red and white hake).

Animal number	Fore-stomach wgt. (g)	Empty wgt. of stomach (g)	Weight of contents	Atlantic herring	Euph.	Pearl.	Mackerel	Silver hake	Pollock	Sebastes spp.	Urophycis spp.
1	1,085	172	913	8	0	0	0	0	0	0	0
2	116	84	32	0	P	16	0	411	0	18	35
3	760	220	540	7	0	2	0	59	0	0	3
6	138	108	30	0	P	0	0	0	0	0	0
7	282	206	76	2	0	0	0	1	0	0	0
8	1,065	396	669	24	0	18	0	13	0	0	0
9	252	246	6	0	0	0	0	23	0	0	0
11	176	140	36	0	P	2	0	400	0	7	3
12	122	106	16	0	P	1	0	5	0	0	0

Appendix 30 (continued)											
13	154	74	80	0	0	1,800	0	75	0	0	0
14	272	160	112	6	0	286	0	14	0	0	1
17	156	104	52	2	0	10	0	0	0	0	0
20	1,050	215	835	26	0	0	0	0	0	0	0
21	330	230	100	4	P	7	0	0	7	0	0
24	1,050	224	826	32	P	265	0	9	0	0	2
25	860	335	525	4	0	200	1	2	0	0	0
30	276	192	84	0	0	140	0	46	0	0	0
31	412	232	180	0	0	1,506	0	21	121	0	11

Appendix 31: Mean and standard deviation (± SD) of stomach contents from harbour porpoise captured in the Gulf of Maine/Jeffreys Ledge gillnet fishery from 13 October-18 December, 1993. Full fore-stomach weight, empty and content weight are in grams (g) with the total remains frequency, mean and standard deviations for six day intervals. Week number eight did not have a bycatch (11/24-11/29). During week nine (11/30-12/5) all four animals were not retrieved. Bycatch=total captures during the specific time interval.

Date	N	Fore-stomach weight (g)	Mean ± SD fore-stomach weight (g)	Empty weight of stomach (g)	Mean ± SD empty stomach weight (g)	Stomach content weight (g)	Mean ± SD stomach content weight (g)	Total remains	Mean ± SD remains	Bycatch total
10/13-10/18	1	1,085	1,085 ± 0	172	0	913	913 ± 0	8	8 ± 0	1
10/19-10/24	3	1,014	338 ± 336	412	137 ± 73	602	201 ± 294	495	165 ± 229	5
10/25-10/30	4	1,775	444 ± 417	988	247 ± 109	787	197 ± 316	483	121 ± 189	5

Appendix 31 (continued)										
10/31-11/5	3	548	183 ± 79	340	113 ± 43.4	208	69.3 ± 49	4400	1,100 ± 1,098	3
11/6-11/11	2	1,206	603 ± 632	319	160 ± 78.4	887	444 ± 554	38	19 ± 10	6
11/12-11/17	1	330	330 ± 0	230	230 ± 0	100	100 ± 0	11	11 ± 0	2
11/18-11/23	2	1,910	955 ± 134	559	280 ± 78.4	1351	676 ± 213	512	256 ± 71	3
12/6-12/11	1	276	276	192	192 ± 0	84	84 ± 0	186	186 ± 0	1
12/12-12/18	1	412	412	232	232 ± 0	180	180 ± 0	1,521	1521 ± 0	3

Appendix 32: Mean daily target fish species stomach content analysis for forty-three of forty-six days of fishing from 13 October-18 December, 1993 in the Gulf of Maine/Jeffreys Ledge. Mean content weight are presented in grams (g). Ten stomachs per day were analysed total =430.

Date	Mean ± (SD) content weight (g)	Number of euphausiids	Number of herring	Number of shrimp	Observed bycatch
10/14	67 ± 43.1	0	7	16	0
10/15	117 ± 100.4	240	9	20	0
10/16	89 ± 73.9	0	11	27	0
10/17	77 ± 49.3	0	7	0	1
10/18	55 ± 65.2	22	4	14	1
10/19	95 ± 85.6	18	7	19	0
10/23	143 ± 84.8	26	21	10	0
10/24	64 ± 49.0	12	11	26	4
10/25	70 ± 47.1	38	9	18	1
10/26	74 ± 94.0	0	6	12	0
10/28	72 ± 46.7	18	7	9	2
10/29	95 ± 96.0	0	5	0	1
10/30	155 ± 181.2	14	11	23	1
11/3	46 ± 62.4	23	8	10	1
11/4	49 ± 52.2	0	9	0	2
11/5	59 ± 22.4	550	29	72	0
11/6	143 ± 65.7	32	18	15	0
11/7	43 ± 39.1	21	9	19	2
11/8	119 ± 89.0	68	9	26	0
11/9	88 ± 60.3	54	16	24	3
11/10	84 ± 65.2	52	15	34	1

Appendix 32: (continued)

11/11	81 ± 43.7	0	7	41	0
11/13	56 ± 54.9	0	4	15	0
11/15	125 ± 49.8	44	6	26	1
11/16	55 ± 33.5	0	4	0	0
11/17	80 ± 80.2	13	7	10	1
11/19	46 ± 39.6	0	7	127	0
11/22	54 ± 28.4	16	8	76	1
11/23	73 ± 41.4	34	11	54	2
11/24	43 ± 12.2	0	2	20	0
11/26	81 ± 61.3	0	10	8	0
11/27	67 ± 57.4	0	9	0	0
11/30	57 ± 48.1	0	8	4	1
12/1	23 ± 26.3	22	3	16	3
12/2	69 ± 57.1	144	6	68	0
12/3	71 ± 83.0	0	7	16	0
12/4	101 ± 74.3	36	12	45	0
12/6	11 ± 9.4	0	0	9	0
12/7	27 ± 33.0	0	2	26	0
12/8	95 ± 72.2	58	10	32	1
12/9	111 ± 58.5	0	8	0	0
12/10	49 ± 26.9	0	9	2	0
12/18	36 ± 28.1	0	3	8	3

Appendix 33: Mean and standard deviation (± SD) data for target species fish stomach content analysis for six day intervals (n=11) from 13 October-18 December, 1993 in the Gulf of Maine/Jeffreys Ledge gillnet fishery. Mean stomach content weight in grams (g). Total stomachs analysed =430. Bycatch indicates the number of captures during specific interval.

Date	Mean stomach weight (g)	Number of prey	Mean ± (SD) prey items	Number of stomachs	Bycatch
10/13-10/18	81 ± 23.7	377	75.4 ± 109.0	50	1
10/19-10/24	101 ± 39.8	150	50 ± 6.5	30	5
10/25-10/30	93 ± 35.9	170	34 ± 23.7	50	5
10/31-11/5	51 ± 6.8	701	233.6 ± 361.7	30	3
11/6-11/11	93 ± 34.4	460	76.6 ± 25.7	60	6
11/12-11/17	79 ± 32.7	129	32.2 ± 31.0	40	2
11/18-11/23	57.6 ± 13.8	333	111 ± 19.9	30	3
11/24-11/29	63 ± 19.2	49	16.3 ± 6.6	40	0
11/30-12/5	64 ± 28.1	387	77.4 ± 84.5	50	4
12/6-12/11	59 ± 43.0	156	31.2 ± 4.0	50	1
12/12-12/18	35.6 ± 28.1	11	3.6	10	3

Appendix 34: Life history data from harbour porpoise captured in the Grand Manan Island/Bay of Fundy gillnet fishery in 1994 (n=34). Sexual maturity categories are calf, immature, and mature. A calf is designated as 0 and equals under one year of age. Estimated age (Est.) is from Gompertz Growth Curves and age equations from Read and Tolley (1997). Equations for estimating body mass from length in harbour porpoise were derived from Worthy (1990) and Read and Tolley (1997). Length is in centimetres (cm), weight in kilograms (kg) and girth is in centimetres (cm).

Date of capture	Animal number	Gender	Length (cm)	Est. wgt. (kg)	Girth (cm)	Est. age	Sexual maturity
7/9	1	m	127	40	87	2	immature
7/14	2	f	138	40	89	2	immature
7/15	3	m	119	38	88	2	immature
7/17	4	f	157	37	94	4	mature
7/28	5	m	146	51	92	5	mature
8/1	6	m	111	28	77	0	calf
8/1	7	f	131	28	88	1	immature
8/1	8	m	153	51	98	5	mature
8/1	9	f	136	59	87	2.5	immature
8/1	10	f	161	43	99	> 7	mature
8/1	11	f	163	63	101	> 7	mature
8/1	12	m	156	58	95	6	mature
8/1	13	m	143	46	88	4	mature

Appendix 34: (continued)							
8/1	14	f	156	31	98	> 7	mature (L)
8/2	15	m	143	44	85	4	mature
8/2	16	m	126	36	83	2	immature
8/2	17	m	146	51	92	5	mature
8/6	18	f	131	51	81	2	immature
8/6	19	f	144	53	94	3	mature
8/6	20	m	148	53	94	5	mature
8/8	21	f	141	52	89	3	mature
8/8	22	m	139	45	88	4	mature
8/10	23	f	139	45	93	2.5	immature
8/10	24	f	141	45	87	3	mature
8/11	25	m	133	38	82	3	mature
8/15	26	m	113	31	81	1	immature
8/18	27	m	146	50	91	6	mature
8/23	28	m	109	27	79	0	calf
8/23	29	f	152	60	101	5	mature
8/26	30	f	153	62	87	5	mature
8/29	31	m	132	40	84	3	mature
9/2	32	f	171	41	97	> 7	mature
9/7	33	f	166	68	93	> 7	mature
9/7	34	m	117	60	79	0	calf

Appendix 35: Stomach content analysis by weight in grams (g), and the number of intact prey and otoliths from species of prey found in stomachs of harbour porpoise captured in the Grand Manan/ Bay of Fundy gillnet fishery in 1994 (n=27). Fore-stomach weights are presented before and after emptying of contents. Species identified are, Atlantic herring, cod, silver hake, mackerel, pollock, *Urophycis spp.* (red and white hake) euphausiids (Euph.) and squid beaks.

Date of capture	Fore-stomach wgt. (g)	Empty wgt. of stomach (g)	Weight of contents (g)	Atlantic herring	Silver hake	Cod	Mackerel	Pollock	*Uroph. spp.*	Euph.	Squid beaks
7/15	183.6	182.4	1.2	0	0	0	0	0	0	0	0
7/28	367.9	273.5	94.4	1	0	0	0	0	0	0	2
8/1	186.8	185.6	1.2	0	0	0	0	3	0	0	0
8/1	341.2	325.3	15.9	2	2	2	0	0	0	10	2
8/1	429.6	193.4	236.2	11	25	0	3	0	0	44	3
8/1	3,172	206	2,966	46	65	18	2	0	0	32	7
8/1	1,009	302.2	706	50	80	1	2	1	0	0	14
8/2	468.8	167.8	300.8	32	0	17	0	0	1	0	0
8/2	650	237	414	203	190	21	0	0	0	0	0
8/2	919.5	352.5	567	53	27	0	1	0	0	0	2

Appendix 35 (continued)											
8/6	541	346	195.2	5	10	1	0	0	0	0	0
8/6	237.2	221.1	16.1	0	0	0	0	0	0		0
8/6	1242	292	950	1	23	4	1	0	0	0	0
8/8	290	200.2	89.8	5	10	0	0	0	1	0	0
8/8	530.2	211.5	318.7	35	3	2	0	1	0	10	0
8/10	876	841.4	34.5	20	11	0	0	0	0	0	1
8/10	560.5	223.1	337.4	25	52	3	2	0	0	0	0
8/11	218.2	217	1.2	0	0	0	0	0	0	0	0
8/15	351	313.1	37.9	0	0	0	0	0	0	0	7
8/18	1 449	335.6	1113	5	1	3	1	0	1	0	0
8/23	82.4	68.8	13.6	0	0	0	0	0	0	0	0
8/23	250.7	224.2	26.5	1	13	0	0	0	0	0	3
8/26	418.4	276.7	141.7	5	1	0	0	0	1	0	6
8/29	206.9	181.4	25.5	0	0	0	0	0	0	0	0
9/2	931.3	391.1	540.2	12	11	1	0	0	0	0	0
9/7	83.5	75.7	7.8	0	0	0	0	0	0	0	0
9/7	628.1	395.9	232.2	2	0	9	0	0	0	0	0

Appendix 36: Mean and standard deviation (± SD) data for six day stomach content analysis from harbour porpoise captured in Grand Manan Island during the summer of 1994 (n=27). Full fore-stomach weight, empty and content weight are in grams (g) with total remains count, mean and standard deviations. Week three did not have a bycatch (7/13-7/18). Bycatch =total captures during the specific time interval.

Date of capture	N	Fore-stomach weight (g)	Mean ± SD fore-stomach weight (g)	Empty weight (g)	Content weight (g)	Mean ± SD content weight (g)	Total number remains	Mean ± SD number remains	Bycatch
7/7-7/12	0	0	0 ± 0	0	0	0 ± 0	0	0 ± 0	1
7/13-7/18	1	183.6	184 ± 0	182.4	1.2	1.2 ± 0	3	0.42 ± 0.7	4
7/19-7/24	0	0	0 ± 0	0	0	0 ± 0	0	0 ± 0	0
7/25-7/30	1	367.9	368 ± 0	273.5	94.4	94.4 ± 0	3	0.32 ± 0.7	1
7/31-8/5	8	7,76.9	897.1 ± 961	1,970	5,207.1	250.7 ± 895.8	809	101.1 ± 156	12
8/6-8/11	8	4,495.1	562 ± 351	2,552	1,943	242.8 ± 314.7	185	23.1 ± 33.6	10
8/12-8/17	1	351	351 ± 0	313.1	37.9	37.9 ± 0	7	0.8 ± 2.4	1
8/18-8/23	3	1,782.1	594 ± 745	6,286	1153	384.4 ± 631.1	36	4.5 ± 8.1	3
8/24-8/29	2	625.3	313 ± 150	458.1	167.2	83.6 ± 82.1	41	5.8 ± 12.1	3
8/30-9/4	1	931.3	931 ± 0	391.1	540.2	540.2 ± 0	24	3 ± 5.2	3
9/5-9/10	2	711.6	356 ± 385	471.6	240	120 ± 158.6	23	2.8 ± 7.3	4

Appendix 37: Mean (± SD) daily target species fish stomach content analysis (n=20 per day) for 32 of the 49 days of fishing effort for Grand Manan Island /Bay of Fundy during the summer of 1994. Mean content weight is in grams (g). Total stomachs analysed =640.

Date	Mean ± content weight	Number of euphausiids	Number of shrimp	Number of herring	Number of bycatch
7/14	87 ± 54.6	12	17	24	1
7/15	103 ± 61.4	0	13	4	1
7/16	84 ± 64.1	704	11	16	1
7/18	147 ± 127.7	1,362	40	27	0
7/19	90 ± 48.2	1,072	56	23	0
7/20	95 ± 78.2	1,566	36	11	0
7/21	75 ± 60.1	28	50	13	0
7/25	81 ± 30.9	42	0	21	0
7/27	129 ± 136.5	1,661	34	10	0
7/28	143 ± 104.5	113	40	14	1
7/29	115 ± 97.9	348	2	22	0
7/30	48 ± 18.7	216	0	22	0
8/1	85 ± 84.8	511	1	32	9
8/2	231 ± 175.5	1,966	53	13	3
8/3	105 ± 83.8	904	0	20	0
8/6	110 ± 89.9	1,603	4	10	4
8/8	119 ± 89.6	430	12	21	2
8/10	93 ± 80.6	1,725	18	10	2
8/11	78 ± 83.6	322	10	13	2

Appendix 37: (continued)

8/12	213 ± 178.1	45	26	14	0
8/13	101 ± 147.3	13	3	11	0
8/15	47 ± 23.4	219	11	8	1
8/17	107 ± 99.8	1,585	9	17	0
8/18	213 ± 148.6	1,375	0	12	1
8/19	193 ± 86.0	112	0	10	0
8/23	87 ± 93.5	19	1	6	2
8/24	96 ± 89.3	1,035	14	26	1
8/26	78 ± 58.9	99	15	17	1
8/29	66 ± 40.7	47	6	12	1
8/31	86 ± 60.7	820	14	10	2
9/2	73 ± 54.7	139	5	6	2
9/7	96 ± 67.8	932	61	10	3

Appendix 38: Mean and standard deviation (± SD) data for target species fish stomach content analysis for six day intervals from Grand Manan Island/Bay of Fundy, 1994. Mean stomach content weight is in grams (g).Total stomachs analysed =640. No stomachs were collected from 7/7-7/12. Bycatch indicates the number of captures during specific interval.

Date	Mean ± SD stomach content wgt. (g)	Number of prey	Mean ± (SD) prey items	Number of stomachs	Number of bycatch
7/13-7/18	105	2,230	558 ± 667.4	100	3
7/19-7/24	86.6 ± 10.4	2,855	952 ± 780	60	0
7/25-7/30	103 ± 38.4	2,545	509 ± 677.9	100	1
7/31-8/5	140 ± 79.1	3,500	1,166 ± 773.1	60	12
8/6-8/11	100 ± 18.2	4,178	1,045 ± 743.	80	10
8/12-8/17	117 ± 69.4	1,961	490 ± 752.4	80	1
8/18-8/23	164 ± 67.7	1,535	512 ± 760	60	3
8/24-8/29	80 ± 15.0	1,271	424 ± 565	60	3
8/30-9/4	79.5 ± 9.1	994	497 ± 490.7	40	4
9/5-9/10	96 ± 0	103	334 ± 518.2	20	4

Appendix 39: Life history data from harbour porpoise incidentally captured in the Grand Manan Island, 1995 (n=18) gillnet fishery. Sexual maturity categories: calf, immature and mature. L =lactating female. A calf is designated as 0. Weight is estimated from calculations from Worthy (1989) and Read and Tolley (1997).

Date of capture	Animal number	Gender	Length (cm)	Estimated weight (kg)	Girth (cm)	Estimated age (yrs)	Sexual maturity
7/6	1	f	149	43	81	4	mature
7/6	2	f	155	62	100	>6	mature
7/6	4	m	123	34	81	2	immature
7/10	5	m	152	54	92	>6	mature
7/10	6	f	144	49	91	3.5	mature
7/11	7	f	154	58	96	>6	mature
7/12	8	m	131	29	70	3	mature
7/17	14	m	148	51	92	>6	mature
7/19	16	m	140	44	86	4	mature
7/19	17	f	148	49	88	4	mature
7/20	18	m	155	62	99	>6	mature
7/20	19	m	139	46	90	4	mature
9/2	20	m	143	48	90	5	mature
9/2	21	f	160	65	100	>6	mature
9/3	22	f	152	59	99	5	mature
9/12	26	f	161	62	97	>6	mature (L)
9/15	27	m	106	23	71	0	calf
9/19	29	m	97	22	74	0	calf

Appendix 40: Stomach content analysis by weight in grams (g), and the number of intact prey and otoliths from species of prey found in stomachs of harbour porpoise captured in the Grand Manan/Bay of Fundy gillnet fishery in 1995 (n=18). Fore-stomach weights are presented before and after emptying of contents. Species identified are, Atlantic herring, silver hake, cod, pollock, squid beaks, euphausiids (Euph.) and hagfish.

Date of capture	Animal number	Fore-stomach wgt. (g)	Empty wgt. (g) of stomach	Weight of contents (g)	Atlantic herring	Silver hake	Cod	Pollock	Squid beaks (spp.)	Euph.	Hagfish
7/6	1	953	184	768	145	0	0	0	0	0	11
7/6	2	1,108	408	700	74	10	0	0	18	0	0
7/6	4	345	206	139	10	18	0	0	0	0	39
7/10	5	257	247	10.4	5	1	0	0	0	0	0
7/10	6	266	263	2.8	0	0	0	0	0	0	0
7/11	7	465	413	51.2	0	0	0	0	0	0*	0
7/12	8	792	346	446	24	0	0	0	0	0	0
7/17	14	529	246	283	33	0	0	0	27	0	0
7/19	16	271	261	10	0	0	0	0	0	0	0
7/19	17	260	205	55	0	0	0	0	0	0	9

Appendix 40 (continued)											
7/20	18	246	241	5	0	0	0	0	0	0	19
7/20	19	927	336	592	13	42	1	1	11	0	0
9/2	20	936	300	636	7	116	0	0	0	0	9
9/2	21	1,350	257	1,093	97	21	0	0	10	0	2
9/3	22	652	277	374	8	0	3	0	0	0	0
9/12	26	471	356	115	0	0	0	0	0	0	0
9/15	27	77	74	3	0	0	0	0	0	0	0
9/19	29	123	64	58	0	0	0	0	0	116	0

Appendix 41: Mean and standard deviation (± SD) data for six day stomach content analysis from harbour porpoise captured in Grand Manan Island during the summer of 1995 (n=18). Full fore-stomach weight, empty and content weight are in grams (g) with total remains count, mean and standard deviations.

Date	N	Fore-stomach weight (g)	Mean ± SD fore-stomach weight (g)	Empty weight (g) of stomach	Weight of contents (g)	Mean ± SD weight of contents	Harbour porpoise bycatch
7/3-7/8	3	2,406	802 ± 403	798	1,607	536 ± 345	4
7/9-7/14	4	1,780	445 ± 250	1,269	510	128 ± 213	9
7/15-7/21	5	2,233	447 ± 293	1,289	945	189 ± 253	6
9/1-9/6	3	2,938	979 ± 351	834	2,103	701 ± 364	4
9/7-9/12	1	471	471 ± 0	356	115	0	3
9/13-9/18	1	77	77 ± 0	74	3	0	1
9/19-9/24	1	123	123 ± 0	64	58	0	2

Appendix 42: Mean daily target species fish stomach content analysis (n=20 stomachs per day) for 15 of the 36 days of fishing effort for Grand Manan Island Bay of Fundy during 1995. Mean content weight in grams (g). Total stomachs analysed =300.

Date	Mean content weight	Number of euphausiids	Number of herring	Number of shrimp (spp.)	Number of bycatch
7/5	119 ± 80.8	567	9	0	0
7/9	119 ± 81.0	113	7	2	0
7/10	118 ± 86.7	844	35	13	2
7/12	117 ± 95.7	978	30	12	3
7/14	118 ± 101.5	1,563	17	15	1
7/16	430 ± 109.6	25	0	0	0
7/17	115 ± 99.8	1,312	17	10	2
7/19	134 ± 132.0	2,985	18	9	2
9/2	100 ± 90.9	22	0	0	2
9/3	102 ± 86.4	45	0	0	1
9/4	133 ± 80.8	1,925	4	1	1
9/6	47 ± 43.9	16	1	0	0
9/11	119 ± 113.4	825	8	18	0
9/14	144 ± 153.8	1,183	2	5	0
9/18	123 ± 113.2	468	2	0	0

Appendix 43: Mean and standard deviation (± SD) data for target species fish stomach content analysis for six day intervals from Grand Manan Island/Bay of Fundy, 1995. Mean stomach content weight is in grams (g). Total stomachs analysed =300. Bycatch indicates the number of captures during specific interval. No samples were procured during interval number 7 (9/19-9/24).

Date	Mean ± (SD) stomach content weight (g)	Number of prey	Mean ± (SD) prey items	Number of stomachs	Number of bycatch
7/3-7/8	119 ± 80.8	576	192 ± 324.7	10	4
7/9-7/14	118.0 ± 0.81	3,635	908.7 ± 606.7	80	9
7/15-7/21	226 ± 176.6	4,380	1,460 ± 1,498	60	6
9/1-9/6	95 ± 35.6	2,018	505± 951	80	4
9/7-9/12	119 ± 119.0	851	213 ± 408	30	3
9/13-9/18	134 ± 14.8	1,660	830 ± 509	40	1

Appendix 44: Summary of mean daily environmental and oceanographic data for waters adjacent to St. Bride's, Newfoundland in 1993.

Date	Bycatch occurrence	Water column clarity (m)	Cloud cover (%)	Wind speed (kn)	Sea condition (Beaufort Scale)	Water column temp. (^oC)	Salinity (%) ppt.
7/1	0	20	100	7	3	2.9	32.0
7/2	0	12	10	8	3	3.1	31.4
7/3	0	25	0	6	2	3.2	32.2
7/5	1	30	100	7	3	3.1	32.0
7/6	1	12.5	100	5	2	2.9	32.0
7/7	1	20	60	10	3	3.1	31.7
7/8	0	10	60	15	4	3.2	31.4
7/9	4	10	100	1	1	3.2	31.0
7/10	1	16	100	4	2	3.2	31.6
7/11	0	10	25	5	2	3.3	31.8
7/12	1	13	100	1	1	3.2	31.2
7/13	0	30	30	0	0	3.2	31.0
7/14	3	12.5	60	7	3	3.3	32.7
7/15	1	15	100	2	1	3.2	31.6
7/16	0	10.5	100	20	5	3.2	31.3
717	0	11	75	10	3	3.2	31.3
7/18	0	15.5	50	5	2	3.3	32.3
7/19	2	12	65	5	2	3.1	31.9
7/20	0	14	75	3	1	3.2	31.3

Appendix 44: (continued)

7/21	0	15	50	0	0	3.2	31.4
7/23	2	11.5	100	2	1	3.3	31.3
7/24	0	13.5	75	5	2	3.4	31.1
7/26	1	9.5	100	8	3	3.0	31.4
7/ 27	0	13	75	5	2	3.4	31.7
7/28	0	15	5	15	4	3.3	31.6
7/29	0	13.5	75	20	5	3.0	31.6
7/30	1	15.5	100	10	7	3.4	31.5

Appendix 45: Mean (± SD) environmental and oceanographic data calculated for six day intervals for waters adjacent to St. Bride's, Newfoundland in 1993. Bycatch signifies occurrence during specific interval.

Date	Bycatch occurrence	Water column clarity (m)	Cloud cover (%)	Wind speed (kn)	Sea condition (Beaufort Scale)	Water column temperature (^{0}C)	Salinity % ppt.
7/1-7/6	2	20 ± 8	82 ± 50	6 ± 2	2 ± 1	2.8 ± 0.12	31.1 ± 0.27
7/7-7/12	7	15 ± 4	65 ± 30	6 ± 6	2 ± 1	3.2 ± 0.06	31.3 ± 0.30
7/13-7/18	4	15 ± 7	70 ± 30	7 ± 7	3 ± 2	3.2 ± 0.51	31.6 ± 0.66
7/19-7/24	4	10 ± 2	80 ± 20	7.5 ± 11	3 ± 2	3.2 ± 0.10	31.5 ± 0.29
7/25-7/30	2	10 ± 2	70 ± 30	12 ± 5	4 ± 2	3.1 ± 0.20	31.5 ± 0.11

Appendix 46: Summary of daily mean environmental and oceanographic data for waters adjacent to the Gulf of Maine/Jeffreys Ledge in 1993.

Date	Bycatch occurrence	Cloud cover (%)	Wind speed (kn)	Sea condition (Beaufort Scale)	Water column temperature (°C)	Salinity (%) ppt.
10/13	0	n/a	30	6	n/a	n/a
10/14	0	10	5	2	9.4	32.1
10/15	0	100	8	3	9.7	32.1
10/16	0	100	5	3	9.4	32.1
10/17	1	100	10	3	10.2	32.0
10/18	0	50	10	3	9.1	32.1
10/19	1	10	10	4	n/a	n/a
10/23	0	20	20	5	9.2	32.2
10/24	4	10	15	5	9.9	32.1
10/25	1	10	8	3	8.8	32.1
10/26	0	80	10	5	9.0	32.2
10/28	2	75	8	3	11.3	31.3
10/29	1	50	10	3	9.2	32.1
10/30	1	100	8	3	7.7	32.3
11/3	1	90	10	4	7.4	32.3
11/4	2	50	12	5	7.3	32.3
11/5	0	85	15	6	7.6	32.2
11/6	0	50	15	4	n/a	n/a
11/7	2	75	20	5	n/a	n/a
11/8	0	10	7	3	n/a	n/a
11/9	3	30	8	3	7.5	31.5
11/10	1	40	8	4	7.5	32.3

Appendix 46: (continued)

11/11	0	20	10	5	7.0	32.4
11/12	0	60	20	6	9.4	31.4
11/13	0	60	10	4	7.2	32.3
11/14	0	40	10	3	n/a	n/a
11/15	1	100	3	2	6.7	32.4
11/16	0	5	12	5	6.7	32.5
11/17	1	60	14	4	6.8	32.4
11/19	0	80	16	6	n/a	n/a
11/22	1	30	15	5	7.0	32.3
11/23	2	50	11	4	6.9	32.3
11/24	0	100	8	3	6.8	32.3
11/26	0	40	6	2	n/a	n/a
11/27	0	35	14	3	6.6	32.3
11/30	1	10	18	5	8.0	31.3
12/1	3	10	10	4	8.6	30.1
12/2	0	55	10	4	6.5	32.4
12/3	0	80	15	5	6.6	32.4
12/4	0	100	1	2	6.5	32.4
12/6	0	40	15	3	6.7	32.3
12/7	0	50	12	4	n/a	n/a
12/8	1	98	13	4	6.5	32.4
12/9	0	20	10	3	6.7	32.4
12/10	0	80	15	4	6.2	32.7
12/18	3	80	12	3	6.5	32.4

Appendix 47: Mean (± SD) environmental and oceanographic data calculated for six day intervals for waters adjacent to the Gulf of Maine/Jeffreys Ledge from 13-October-18 December 1993 (week 11=7 days). Bycatch signifies occurrence during specific interval.

Date	Bycatch occurrence	Cloud cover (%)	Wind speed (kn)	Sea condition (Beaufort Scale)	Water column temperature (°C)	Salinity (%) ppt.
10/13-10/18	1	80 ± 40	10 ± 10	1 ± 3	9.5 ± 0.41	32.1 ± 0.04
10/19-10/24	5	15 ± 5	15 ± 5	5 ± 0.60	9.5 ± 0.50	32.2 ±0.07
10/25-10/30	5	55 ± 30	10 ± 1.0	3 ± 0.89	9.2 ± 1.30	32 ± 0.4
10/31-11/5	3	60 ± 20	12 ± 2.5	5 ± 1	7 ± 0.15	32.3 ± 0.05
11/6-11/11	6	35 ± 20	11 ± 5.0	4 ± 0.89	7.3 ± 0.28	32.1 ± 0.49
11/12-11/17	2	60 ± 30	10 ± 5	4 ± 1.4	7.4 ± 1.15	32.2 ± 0.45
11/18-11/23	3	60 ± 25	15 ± 3	5 ± 1	6.9 ± 0.07	32.3 ± 0
11/24-11/29	0	60 ± 40	10 ± 5	3 ± 0.57	6.7 ± 0.14	32.3 ± 0
11/30-12/5	4	60 ± 40	11 ± 6	4 ± 1.22	7.2 ± 0.99	31.7 ± 1.02
12/6-12/11	1	50 ± 30	13 ± 2	3 ± 0.50	6.5 ± 0.23	32.4 ± 0.17
12/12-12/18	3	80 ± 0	12 ± 0	3 ± 0	6.5 ± 0	32.4 ± 0

Appendix 48: Summary of daily mean environmental and oceanographic data for waters adjacent to Grand Manan Island in 1994.

Date	Bycatch occurrence	Water column clarity (m)	Cloud cover (%)	Wind speed (kn)	Sea condition (Beaufort Scale)	Water column temperature (°C)	Salinity (%) ppt.
7/9	1	8.0	100	3	1	9.3	32.1
7/11	0	7.0	10	3	1	8.7	33.1
7/12	0	8.0	15	2	1	9.5	33.4
7/14	1	8.0	15	7	3	9.4	33.4
7/15	1	7.5	60	1	1	9.5	32.0
7/16	1	7.0	100	3	1	10.0	33.1
7/17	1	7.5	50	1	1	n/a	n/a
7/18	0	7.5	80	2	1	9.1	32.1
7/19	0	8.5	90	3	1	9.4	33.4
7/20	0	8.5	60	2	1	9.6	33.1
7/21	0	7.5	98	2	1	9.7	32.6
7/26	0	8.0	100	3	1	n/a	n/a
7/27	0	8.0	100	4	2	9.8	32.6
7/28	1	8.5	98	2	1	9.8	33.2
7/29	0	8.5	100	4	2	9.2	32.6
7/30	0	7.0	30	2	1	8.4	33.8
8/1	9	8.5	30	5	2	10.0	32.4
8/2	3	8.0	70	6	2	10.2	32.4
8/3	0	7.5	100	1	1	10.1	32.6
8/4	0	8.5	95	3	1	n/a	n/a
8/6	4	8.5	95	5	2	10.4	32.6
8/8	2	8.0	10	5	2	11.3	32.3

Appendix 48: (continued)

8/9	0	8.5	5	2	1	n/a	n/a
8/10	2	8.0	70	4	2	10.8	32.6
8/11	2	8.0	50	4	2	10.1	32.3
8/12	0	9.0	10	4	2	10.7	32.6
8/13	0	10.0	98	3	1	9.9	32.4
8/15	1	10.0	50	4	2	10.8	32.7
8/16	0	9.0	1.5	4	2	n/a	n/a
8/17	0	7.5	35	4	2	11.1	32.6
8/18	1	9.0	100	2	1	10.8	33.1
8/19	0	7.5	98	2	1	9.7	32.4
8/20	0	8.0	100	0	0	n/a	n/a
8/22	0	8.0	70	3	1	11.0	32.6
8/23	2	8.0	20	6	2	10.3	32.4
8/24	1	7.5	5	3	1	11.3	33.1
8/25	0	7.5	10	5	2	n/a	n/a
8/26	1	8.0	75	5	2	10.9	32.6
8/27	0	8.0	100	4	2	n/a	n/a
8/28	0	9.0	10	2	1	n/a	n/a
8/29	1	6.0	30	4	2	n/a	n/a
8/30	2	6.0	5	6	2	9.4	32.4
8/31	0	6.0	50	4	2	11.2	32.8
9/1	1	6.0	95	5	2	11.4	32.2
9/2	2	6.0	5	6	2	10.6	32.5
9/3	0	6.5	10	4	2	11.8	32.6
9/7	3	6.0	30	5	2	11.8	32.8

Appendix 49: Mean (± SD) environmental and oceanographic data calculated for six day intervals for waters adjacent to Grand Manan Island in 1994. Bycatch signifies occurrence during specific interval.

Date	Bycatch occurrence	Water column clarity (m)	Cloud cover (%)	Wind speed (kn)	Sea condition (Beaufort Scale)	Water column temp. (^0C)	Salinity (%) ppt.
7/7-7/12	1	9.5 ± 0.5	100 ± 50	3 ± 0.5	1 ± 0	9.5 ± 0.41	32 ± 0.68
7/13-7/18	3	9.5 ± 0.3	100 ± 30	7 ± 2	3 ± 1	9.4 ± 0.37	33.4 ± 0.70
7/19-7/24	0	8 ± 0.5	80 ± 20	8 ± 0.5	3 ± 1	8.6 ± 0.15	33.2 ± 0.40
7/25-7/30	1	9 ± 0.6	75 ± 30	4 ± 1	2 ± 0.5	9 ± 0.6	33.6 ± 0.5
7/31-8/5	12	8 ± 0.5	70 ± 30	6 ± 2	2 ± 05	10.2 ± 0.1	32.5 ± 0.1
8/6-8/11	10	8.5 ± 0.2	50 ± 40	5 ± 1	2 ± 0.5	10.8 ± 0.5	33.4 ± 0.2
8/12-8/17	1	9 ± 1	40 ± 40	4 ± 0.4	2 ± 0.4	10.2 ± 0.5	32.6 ± 0.1
8/18-8/23	3	8 ± 0.5	60 ± 30	6 ± 2	2 ± 0.7	11 ± 0.5	32.4 ± 0.3
8/24-8/29	3	7 ± 0.9	30 ± 40	5 ± 1	2 ± 0.5	11.4 ± 0.2	33.4 ± 0.4
8/30-9/4	4	8.5 ± 0.2	30 ± 40	6 ± 1	2 ± 0	11.5 ± 0.9	32.6 ± 0.2
9/5-9/10	4	6 ± 0	60 ± 0	5 ± 0	2 ± 0	11.2 ± 0	32.8 ± 0

Appendix 50: Summary of mean environmental and oceanographic data for waters adjacent to Grand Manan Island in 1995. Water column salinity was not collected during this season.

Date	Bycatch total	Water clarity (m)	Cloud cover (%)	Wind speed (kn)	Sea condition (Beaufort Scale)	Water column temp. (^{0}C)
7/3	0	7.5	65	1	0	6.2
7/4	0	6.5	5	3	1	5.8
7/5	0	7.0	2	2	1	5.4
7/6	4	6.5	2	3	1	6.0
7/7	0	6.0	90	3	1	6.1
7/8	0	6.0	100	3	1	6.5
7/10	2	8.0	5	1	1	8.5
7/11	1	7.0	10	0	0	9.0
7/12	3	8.0	20	0	0	9.2
7/13	2	8.0	100	2	1	8.7
7/14	1	9.5	80	1	1	8.7
7/15	0	8.0	100	0	0	8.5
7/16	0	8.5	100	2	1	8.1
7/17	2	6.5	90	1	0	8.5
7/18	0	8.0	100	4	2	9.0
7/19	2	7.5	100	1	1	8.6
7/20	2	8.0	40	2	1	9.5

Appendix 50: (continued)

7/21	0	9.5	80	2	1	10.5
9/1	0	n/a	80	1	0	11.3
9/2	2	6.5	80	1	1	10.8
9/3	1	7.0	5	2	1	10.4
9/4	1	n/a	5	2	1	10.2
9/5	0	7.5	0	1	0	11.2
9/6	0	6.5	10	5	2	10.8
9/7	0	5.5	30	3	2	10.6
9/8	0	n/a	25	5	2	11.1
9/9	2	n/a	n/a	n/a	n/a	11.2
9/10	0	n/a	0	4	2	n/a
9/11	0	8.0	10	3	1	10.8
9/12	1	7.0	5	3	1	11.0
9/14	0	8.0	100	5	2	n/a
9/15	1	7.5	20	4	2	11.4
9/16	0	n/a	5	2	1	11.8
9/18	0	8.5	10	2	1	11.6
9/19	2	7.5	5	2	1	10.7
9/20	0	7.0	70	1	1	11.7

Appendix 51: Mean environmental (± SD) and oceanographic data calculated for six day intervals for waters adjacent to Grand Manan Island in 1995. Bycatch signifies occurrence during specific interval.

Date	Bycatch total	Water clarity (m)	Cloud cover (%)	Wind speed (kn)	Sea condition (Beaufort Scale)	Water column temp. (°C)
7/3-7/8	4	6 ± 0.6	30 ± 45	3 ± 0.8	1 ± 0.4	6.2 ± 0.4
7/9 -7/14	9	8.5 ± 1	40 ± 40	1 ± 0.8	1 ± 0.5	8.8 ± 0.3
7/15-7/21	6	8 ± 0.9	85 ± 20	2 ± 1	1 ± 0.7	9.2 ± 0.8
9/1-9/6	4	7 ± 0.5	30 ± 40	2 ± 1.5	1 ± 0.8	10.7 ± 0.4
9/7-9/12	1	7 ± 1	20 ± 12	3 ± 0.9	2 ± 0.5	10.9 ± 0.2
9/13-9/18	1	7.5 ± 0.5	40 ± 40	3 ± 1.5	2 ± 0.5	11.6 ± 0.2
9/19-9/24	2	7 ± 0.3	40 ± 45	1 ± 0.7	1 ± 0	11.2 ± 0.7