HARBOUR PORPOISE AND PEOPLE: STRATEGIES FOR BYCATCH REDUCTION IN THE BAY OF FUNDY

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by

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ABSTRACT

Interactions between marine mammals and fisheries are recognized as a global problem. About 1,000 - 2,000 harbour porpoise (*Phocoena phocoena*) are caught annually in groundfish gillnets in the Gulf of Maine and Bay of Fundy. This bycatch is not sustainable and reduction of it is necessary. However, fishers fear that measures to mitigate the bycatch will have a detrimental economic impact on them.

Solutions to the bycatch of marine mammals typically lead to restrictions on commercial fisheries. Managers, scientists and special-interest groups perceive fishers as part of the problem, and therefore, fishers are usually not consulted effectively in developing solutions . Consequently, fishers are reluctant to accept restrictions. Because of conflicting interests stakeholders refuse to communicate and distrust develops.

Fishers from Grand Manan Island, Bay of Fundy, and researchers at the Whale Research Group, Memorial University of Newfoundland, developed a management approach that would allow all stakeholders to participate in finding solutions to the problem of harbour porpoise bycatch. This approach consisted of five steps:

1. Education and information;
2. Trust-building;
3. Implementing solutions;
4. Developing and testing solutions; and

5. Ensuring recognition.

Gillnet fishers and scientists designed and carried out a study to assess the effectiveness of active acoustic devices ("alarms") in reducing harbour porpoise bycatch in 1994 and 1995. The objectives of the study were to develop and test a device that would

1. Eliminate or reduce the bycatch of harbour porpoise;
2. Be acceptable to all stakeholders;
3. Not interfere with the normal fishing process;
4. Not reduce catches of fish; and
5. Be enforceable by managers.

Alarms reduced the bycatch of harbour porpoise. Catches of commercially important fish species did not differ consistently between treatments. The study found that alarms were a suitable tool to reduce bycatch of harbour porpoise in groundfish gillnets without severely restricting fishing patterns. The inclusive management approach established stable and effective working relationships among fishers, scientists and managers, and will facilitate finding solutions for future problems.

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> When the net is full he drags it up onto the beach and sits down
> and sorts the eatable ones into crates and throws the others away.
>
> (Matthew 13:47–48)

Virtually no commercial fishery catches only targeted species. Instead, various species are caught, some of which are retained and used, others are discarded. The discarded part of the catch is generally referred to as "bycatch". Alverson *et al.* (1994, p. 6) defined bycatch as "discarded catch plus incidental catch". Incidental catch is "retained catch of non-targeted species" (Alverson *et al.*, 1994, p. 6). Fishers keep incidental catch because it has commercial value.

Bycatch for the most part is made up of fish species (Lien and Fawcett, 1986; Alverson *et al.*, 1994; Anonymous, 1996b; Norse, 1997) which usually attracts little attention. In addition to fish, birds, reptiles and mammals are also caught in fishing gear (Norse, 1993). It is estimated that 27,000 marine birds die each year as a result of incidental entrapment in fishing gear off Newfoundland's East coast alone (Lien *et al.*, 1986). Driftnets are estimated to annually kill hundreds of thousands of marine birds (Norse, 1993). Marine turtles, such as green turtles (*Chelonia mydas*), loggerheads (*Caretta caretta*) and Kemp's ridley turtles (*Lepidochelys kempi*) are also incidentally captured (Norse, 1993). The U.S. shrimp trawl fishery catches each year 5,500 - 55,000 turtles; most of them die as a result and are discarded (Norse, 1993). The bycatch of many species of marine mammals in fishing gear has attracted much attention and some research (Lien *et al.*, 1986; Hofman, 1990; Jefferson and Curry, 1994; Perrin *et al.*, 1994).

Small cetaceans are particularly threatened by incidental capture since they can not free themselves once they are entrapped. At least 80,000 small cetaceans die annually as a result of bycatch in passive fishing gear (Kraus *et al.*, 1997) .

Incidental entrapments of these long-lived, air-breathing animals usually become visible as problems when interest groups with differing views, goals and perceptions take sides on the issue. Often, these interactions present a characteristic pattern of development from first records of bycatch to searches for solutions. Following the advice of scientists, public groups become aware of the bycatch and usually mount campaigns for the protection of the species involved. Politicians and/or managers respond with changes to regulations when pressure or threats from these campaigns can no longer be ignored (Manzer, 1984). With minimal input in the decision making process, fishers have few options but to follow imposed regulations (Steele *et al.*, 1992; Lien, 1996). Since direct violations of these regulations would likely result in legal reprisals, fishers try to circumvent them (Charles, 1995). Managers, in turn, respond with tighter enforcement (Lien, 1996). As a result, fishers are given neither the responsibility nor the power to solve the problem. Instead, non-governmental organizations (NGOs) and management agencies take over and reap the reward of having solved the problem. Fishers remain as the 'bad guys' who were not willing or able to eliminate the problem (Lien, 1996). In this spiral of ineffective regulation and communication, distrust of those involved and polarized positions become a shared attribute of the stakeholders.

This traditional, top-down management approach has serious consequences for effective problem solving. Information used in the decision process comes almost exclusively from scientists; knowledge of fishers is only rarely taken into account (Lien, 1996). Managers talk with scientists regularly, but less frequently with fishers, and scientists have minimal contact with fishers. Consequently, solutions tend to reflect biological considerations, while social and economic issues are neglected or deemed less important. Incidental catches of harbour porpoise in the Gulf of Maine/Bay of Fundy (GoM/BoF) are an example of this scenario.

1.1 THE HARBOUR PORPOISE

The harbour porpoise (*Phocoena phocoena*) is one of the smallest toothed whales (suborder Odontoceti): adult animals are between 1.4 - 1.7 m long and weigh 60 - 90 kg (Geraci and Lounsbury, 1993). They occur in the northern temperate Atlantic and Pacific where they typically prefer shallow coastal waters (Gaskin, 1992; Geraci and Lounsbury, 1993). The largest population in the Atlantic (47,200 animals) frequents the GoM/BoF and has been well studied since the 1970s (Gaskin, 1984; Read and Gaskin, 1990b; Gaskin, 1992; Donovan and Bjørge, 1995; Palka *et al.*, 1996).

In GoM/BoF harbour porpoise are common between July and September; they migrate away from the coast to more southerly areas in fall and winter (Read and Gaskin, 1988; Read and Gaskin, 1990b; Gaskin, 1992; Katona *et al.*, 1993; Read *et al.*, 1993; Smith *et al.*, 1993; Read, 1994; Donovan and Bjørge, 1995; Read and Hohn, 1995; Palka *et al.*, 1996). The porpoise reach sexual maturity at 3 - 4 years of age, and most of them are younger than ten years old. The majority of females reproduce annually (Gaskin and Blair, 1977; Gaskin, 1992; Katona *et al.*, 1993; Read and Hohn, 1995; Palka *et al.*, 1996).

Harbour porpoise feed on a variety of prey species (Donovan and Bjørge, 1995). In the GoM/BoF silver hake (*Merluccius bilinearis*) and cod (*Gadus morhua*) are common stomach contents. However, their dominant prey is Atlantic herring (*Clupea harengus*)

(Smith and Gaskin, 1974; Recchia and Read, 1989; Smith and Read, 1992).

Herring, in turn, are the principal prey for various fish species, many of which are commercially important for the gillnet fishery (Scott and Scott, 1988). Thus, areas with high concentrations of porpoise are likely to be the same as, or to overlap with, areas of high fishing effort, placing the porpoise in direct competition for space and/or prey with gillnet fishers (Gaskin, 1992; Brodie, 1995). In the BoF, the groundfish gillnet fishery near Grand Manan Island exemplifies this overlap.

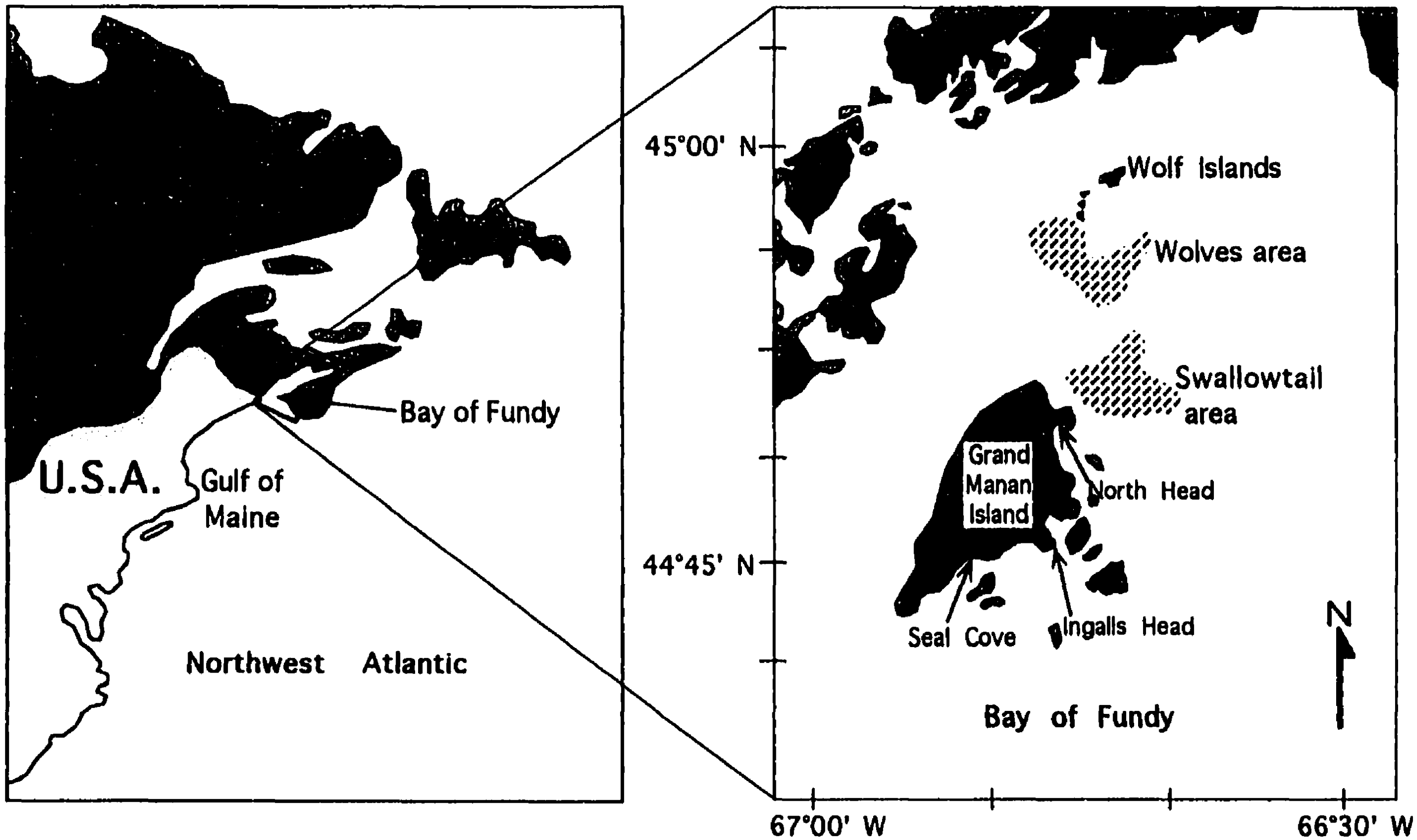
1.2 THE FISHERS OF GRAND MANAN ISLAND, BoF

Fishers on Grand Manan Island, BoF, work out of three community harbours : North Head, Ingalls Head and Seal Cove and fish mainly in the Swallowtail and Wolves areas (Fig. 1.1). Fisheries depend on season, quota allocations and catch rates. The winter fishery is dominated by lobster (*Homarus americanus*). During the summer season fishers drag for scallops (*Placopecten magellanicus*), use weir nets to catch herring, or harvest groundfish using hook and line or gillnets.

Gillnet fishery in the BoF is relatively recent (Read, 1994) and is economically less important than the lobster fishery (T. Frost, Grand Manan, N.B., Anonymous, 1996a).

Nevertheless, it has become a crucial part of the annual incomes of fishers. Many fishers from Grand Manan Island are now dependent on groundfish revenues and could not sustain their enterprises without the income from this fishery.

Figure 1.1: Map of the Bay of Fundy. Detail shows location of Grand Manan Island and its main ports. Monitoring effort was concentrated in the Wolves and Swallowtail areas.


U.S.A.
Gulf of Maine
Bay of Fundy
Northwest Atlantic
45°00' N
44°45' N
67°00' W
66°30' W
Wolf Islands
Wolves area
Swallowtail area
Grand Manan Island
North Head
Seal Cove
Ingalls Head
Bay of Fundy
N

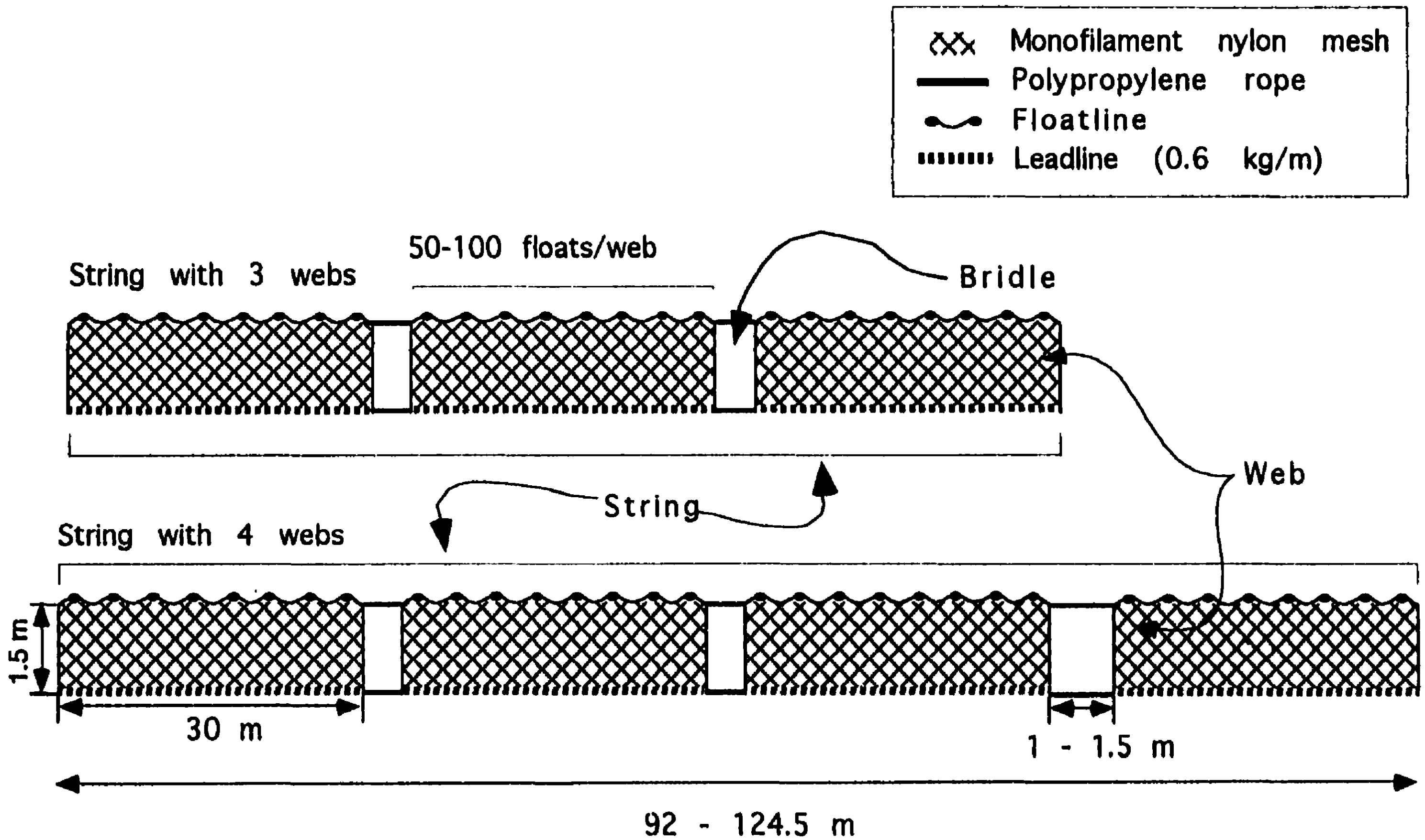
1.2.1 THE GILLNET

The basic design of the gillnets used by Grand Manan fishers is shown in Figure 1.2. Nets are made from monofilament nylon with a mesh size of 6 inch (15.2 cm). They are hung from the floatline at a ratio of two-thirds, which means that a net taken off the floatline and stretched would be two thirds longer than the length of the floatline to which it was attached. Most fishers use double lead lines to speed up the sinking process to the bottom. Strings are secured at the bottom with anchors weighing between 15 - 27 kg and net positions are marked with "hi-fliers" and buoys.

Hauling the net

'Hauling' is the process of retrieving a net from the water. The end of the net downstream of tides is hauled first by taking the hi-flier out of the water. The anchor attached to this first hi-flier is then pulled up, replaced with a large buoy and returned to the water. Thus, this end of the string does not drag across the ocean floor during the upcoming haul. The second hi-flier at the other end of the string is brought aboard and the second anchor is hauled. The line to which this last anchor is attached is then hooked onto a large hydraulic-powered spool which pulls the net onto the boat over the 'spreading bar', a metal bar at the stern of the boat. As the net is being pulled in, fish or bycatch such as other animals or debris, are taken out of the net. Hauling ceases when the large buoy comes on board. Generally, hauls last 20 – 60 min., depending on the number of fish, condition of the string and presence of bycatch.

Figure 1.2: Sketches of a gillnet design used in the Grand Manan Island groundfish fishery.


Monofilament nylon mesh
Polypropylene rope
Floatline
Leadline (0.6 kg/m)
50-100 floats/web
String with 3 webs
Bridle
Web
String
String with 4 webs
1.5 m
30 m
1 - 1.5 m
92 - 124.5 m

Setting the net

Following a haul. fishers either haul other strings or set the string back immediately. In the latter case the string is "flaked out" which means that the net is folded in layers onto the deck floor or into a tub which prevents tangles during the setting process. Setting a string is basically the reverse of the hauling process. It starts with the first hi-flier going overboard followed by the first anchor and the net. While the boat steams with the current. the net runs out over the spreading bar at the stern. Once the end of the string is reached the second anchor and hi-flier are dropped into the water. This terminates the setting process. which typically lasts 3 – 10 min. long.

The time a string remains in the water between a set and the following haul is referred to as 'soak-time'. For the purpose of this thesis. soak-time begins with the end of the setting process and ends with the start of the hauling process. Average soak-time for both years was 31.0 ± 0.47 hours and ranged from 1.8 - 102.3 hours.

1.3 BYCATCH OF HARBOUR PORPOISE IN GROUNDFISH GILLNETS

Bycatch of harbour porpoise in fishing gear in BoF is not a recent phenomenon. Porpoise probably became entangled in fishing gear since people began using nets in areas where porpoise commonly occurred. Early on, bycatch was not perceived as a problem. It occurred only sporadically with little loss in money or time to the fishers. At best. entangled harbour porpoise were a source of meat; at worst. they were an irritation and a nuisance. comparable to occasional bycatch of crustaceans or sea grass. At this time. incidental catches did not attract attention outside the industry (Read. 1994).

Following the publication of estimates of harbour porpoise bycatch in groundfish gillnets (Tab. 1.1). concern for the conservation of the GoM/BoF harbour porpoise population began to grow in the scientific community. It was felt that the population could not sustain a continued incidental mortality estimated to be over 4 % of its size (Woodley and Read. 1991; Palka. 1996). Changes in life history parameters. such as age at sexual maturity and size at birth, were interpreted as signs of a decreasing population (Read and Gaskin. 1990a; 1990b). Incidental mortality in gillnets was assumed to be the reason for this decline (Gaskin. 1992). These conclusions were questioned by Brodie (1995) who believed that changes in population parameters such as the ones observed by Read and Gaskin (1990b) could be explained alternatively by changes in abundance and energy density of herring. In addition. increases in the abundance of predators of the harbour porpoise. such as sharks (Arnold. 1972), could also cause shifts in population characteristics similar to the ones reported (Brodie. 1995).

Table 1.1: Summary of bycatch estimates and method of data collection for the Gulf of Maine and the Bay of Fundy from 1980 - 1994. Values in brackets provide mean ± 1 SE, except where indicated otherwise.

	Gulf of Maine			Bay of Fundy		
Year	Estimate	Method	Source	Estimate	Method	Source
1980	300	anecdotal evidence	1	N/A	N/A	
1982	ca. 118	interviews	2	N/A	N/A	
1986	N/A	N/A		105 (95% CI: 94-116)	reward system, interviews	3
1987	> 600	logbook data	4	N/A	N/A	
1986-89	N/A	N/A		80-129 annually	interviews	5
1989	100 - 600	N/A	6	130	N/A	6
1990	2,900 (1,500-5,500)	observer program, fisheries statistics	7	N/A	N/A	
1991	2,000 (1,000-3,800)	observer program, fisheries statistics	7	N/A	N/A	
1992	1,200 (800-1,700)	observer program, fisheries statistics	7	100	N/A	8
1993	1,400 (1,000-2,000)	observer program, fisheries statistics	7	424 (95 % CI: 200-648)	observer program, fisheries statistics	9
1994	N/A	N/A		101 (80-122)	observer program, fisheries statistics	9
1995	N/A	N/A		87	observer program, fisheries statistics	10

Sources: 1 Prescott and Fiorelli, 1980; 2 Gilbert and Wynne, 1983; 3 Read and Gaskin, 1988; 4 Gilbert and Wynne, 1987; 5 Read and Gaskin, 1990b; 6 Polacheck, 1989; 7 Bravington and Bisack, 1996; 8 Gaskin, 1992; 9 Trippel *et al.* 1996b; 10 Trippel *et al.* 1996a.

Researchers have recommended temporal or spatial gear restrictions, gear modifications, reforms of management processes and structures and amendments to legal documents to reduce incidental bycatch of harbour porpoise in GoM/BoF (Gaskin, 1984; Jefferson and Curry, 1994). As a consequence, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) has listed the GoM/BoF harbour porpoise population as "threatened" (Gaskin, 1992; Campbell, 1997). In 1991 the U.S. government began reviewing the status of harbour porpoise to determine whether it should be classified as threatened under the Endangered Species Act (Fox 1991, as cited in Read *et al.*, 1993). No decision regarding this classification has yet been made. Scientists also agreed that research effort had to increase significantly in order to assess the status of the population and the effects of and causes for the incidental capture (Read and Gaskin, 1988; Read and Gaskin, 1990b; Bravington and Bisack, 1996). Most of these recommendations, however, neglected to enlist fishers in the effort to understand and solve the problem.

Scientists were not the only group concerned with harbour porpoise. Conservation of marine mammals is a major interest for many non-governmental organizations, such as Greenpeace (Brown and May, 1989), the World Wildlife Fund for Nature (WWF), the International Wildlife Coalition and the Cetacean Society International (Kalland, 1993). Cetaceans in general have attained a high cultural value (Peterson, 1993). Accordingly, protection of marine mammals has often gained paramount importance for NGOs, while considerations of the impact of gear restrictions on fishers and their communities were placed as lower priorities.

In light of incomplete data and other uncertainties. NGOs called for application of the precautionary principle and argued for the elimination of harbour porpoise bycatch in gillnets. if necessary by closing fisheries. Much of the pressure they exerted was directed at those responsible for fisheries management. Faced with mounting public pressure. managers at times responded by downplaying or minimizing the extent of bycatch in gillnets.

Public pressure was much stronger in the U.S.A. than in Canada due to differences in environmental laws. In Canada. marine mammals are protected from direct fishing by the 'Cetacean Protection Regulation of 1982' under the 'Fisheries Act of Canada'. However. this legislation does not cover incidental capture in fisheries targeting other species. Hence. no legal responsibility currently exists to reduce or eliminate interactions between marine mammals and fisheries. A proposed 'Canadian Endangered Species Protection Act' would protect wild species from threat of extinction through human impact. If accepted. the harbour porpoise would come under this protection. To date. the Canadian government has not enacted this legislation (Campbell. 1997).

Consequently, Canadian fisheries management became involved only after pressure from U.S.-based environmental groups lead politicians to threaten Canada with fisheries embargoes if no effort was made to reduce harbour porpoise bycatch in the BoF. Resulting management plans focussed on time/area closures and were not accepted by the industry.

Laws pertaining to bycatch in the U.S.A. differ considerably from those in Canada. The 'Marine Mammal Protection Act' (MMPA), in effect since 1972, explicitly states the goal to eliminate any incidental bycatch of marine mammals in fishing gear, or to reduce it to insignificant numbers. The Act forces government and management agencies to monitor bycatch and initiate mitigation efforts and increases research on the extent and causes of incidental captures of marine mammals in fishing gear. In addition, the Act allows interest groups to participate in public consultations and to exert considerable influence. Moreover, public groups can sue government agencies if those agencies do not react to reported bycatch. The reduction of dolphin bycatch in the purse seine fishery for yellowfin tuna (*Thunnus albacares*) is probably the best known example of actions taken under the MMPA (Coe *et al.*, 1984).

The MMPA also played an important role for reduction of harbour porpoise bycatch in the GoM. In the late 1980s, the Conservation Law Council sued the National Marine

Fisheries Service (NMFS) for not taking action to mitigate the incidental capture of harbour porpoise. Subsequently, the New England Harbour Porpoise Working Group (HPWG) was formed. The group consisted of representatives of the fishing industry, scientists, environmental groups and resource managers (Smolowitz and Wiley, 1992). The group's goals were to document harbour porpoise bycatch and to reduce it to the levels required by the MMPA.

Fishers often did not believe that the severity of the bycatch could seriously impact porpoise populations (Polacheck, 1989; Hall, 1995). Some simply denied its occurrence (Lien and Hood, 1994). Large fluctuations in bycatch and population estimates were interpreted by fishers as reflections of poor data quality and incompetence ; calls for management measures despite this uncertainty were seen as malevolent (Hall, 1995). Fishers believed management measures proposed from outside their industry were unsuitable and would have severe economic consequences for them (Lien and Hood, 1994).

Concerns of the fishing community were strengthened by their experience with structures and processes in Canadian fisheries management. Fisheries are governed in a hierarchical fashion with limited possibility for effective feedback from the fishing community (Parsons, 1993). Although fishers and their representatives are members of advisory committees. they are not equal partners in the decision making process (Steele *et al.*. 1992). Input from fisheries scientists and managers is commonly considered the most important information for the decision making process (Lane and Stephenson. 1995: Stephenson and Lane. 1995). The final decision. in any event. lies with the federal government (Steele *et al.*. 1992: Parsons. 1993).

Accordingly. fishers often felt that many regulations and rules were imposed on them inappropriately. saw few reasons to comply and found ways to circumvent them (Doulman. 1993). Managers. in turn. responded with a heavy emphasis on enforcement and additional regulations. Given such tendencies. the public perceived fishers as part of the problem who must be forced to comply with new regulations (Parsons. 1993).

The behaviour of scientists working on porpoise bycatch did not improve the communication between stakeholders . Little effort was made to explain standard scientific procedures. scientific uncertainties were not admitted and fishers were blamed for the bycatch problem (B. Carey. Grand Manan Island. pers. comm.). After initial failures. few attempts were made to revive communication. Hence. fishers held the notion that science and the management of the harbour porpoise problem. like most fishery problems. was carried out in a 'black box' (Steele *et al.*. 1992) which prevented anybody outside this box to understand how data were obtained and conclusions were drawn.

Differences in value systems and in the approach to natural processes also hindered communication between fishers and scientists from the outset. Scientists value the life of a porpoise differently than a fisher does (Hall. 1995). In addition. scientists typically perceive nature as predictable and describe natural processes as linear; fishers. in contrast. see nature as largely unpredictable. As a consequence. scientists and fishers typically do not agree on which data is crucial and how to interpret them (Smith. 1995). In addition. due to the different approaches. scientists tend to "fine tune". while fishers "play it by ear" (Smith. 1995. p. 212)

The increasing public pressure organized by NGOs was not only effective with managers and politicians. Fishers were also aware of public opinion and recognized possible consequences (Smolowitz and Wiley. 1992). but perceived mounting pressure as a foreign intrusion to their work and way of life. Since most campaigns were carried on outside of the affected community. and only rarely involved local people. fishers did not see any reason to respond to the accusations in a critical or cooperative way.

However. reactions to pressure to reduce harbour porpoise bycatch is usually not uniform within fishing communities. On Grand Manan Island. some fishers operate whale watching tours during the summer instead of gillnetting although their fishing cycle during the rest of the year is similar to that of their gillnetting peers. Tourism is an important source of revenue for these fishers. Reports of large porpoise mortalities was likely to have a negative effect on their business. In addition, sector competition within the fishing industry might also have contributed to the development of opposing views as to what actions, if any, to take (J. Lien, pers. comm.). Distrust, polarized opinions and limited communication between fishers, managers and scientists about the bycatch made the situation emotional and prevented effective development of solutions.

The work presented in this thesis was carried out in the midst of an emotional conflict between fishers, conservation groups and managers. The objective was to develop a process dealing with the conflict between stakeholders and to evaluate a specific solution to reduce bycatch of harbour porpoise in groundfish gillnets.

2. THE MANAGEMENT AND SCIENCE PROCESS

"The point is not how to eliminate or prevent conflict but how to make it productive" (Deutsch, 1973)

In a situation of distrust, polarization and lack of communication, finding solutions to harbour porpoise bycatch becomes difficult. If fishers do not agree that bycatch constitutes a problem or if they doubt its severity, they are less likely to support efforts to develop solutions. Similarly, if managers perceive fishers as part of the problem, they are not likely to accept fishers as partners in developing solutions (Lien, 1996). It is necessary to change such attitudes with incessant and open communication.

The objective of this component of the project was to develop a management scheme which included relevant stake holders in a productive search for effective and accepted tools to mitigate bycatch of harbour porpoise in groundfish gillnets.

2.1 AN APPROACH TO MANAGE HARBOUR PORPOISE BYCATCH ON GRAND MANAN ISLAND

In 1993, the Whale Research Group (WRG) was approached by fishers from Grand Manan Island in search of possible solutions to mitigate harbour porpoise bycatch in groundfish gillnets (Lien and Hood. 1994). A five stage plan was used to establish communication and trust, and to find a solution and ensure recognition for the fishers. Essential to this process was a partnership between fishers and scientists which involved continuous dialogue and a shared interest in finding an appropriate solution.

The five stages can be described as follows:

1. Education and Information.

   The goal of this stage was the exchange of information between fishers and scientists involved in the project, establishing a common ground to develop solutions. During this stage, it was important that responsibilities for the problem were understood to rest with fishers alone and that the role of scientists was to assist them in solving it.

2. Trust building.

   It was necessary to create an atmosphere which allowed an open exchange and discussion of ideas, problems and criticism. Individual visits, meetings and phone conversations were all used to facilitate this discussion. As contacts deepened and expanded, personal relationships developed between scientists and fishers.

3. Implementing solutions.

   The development of procedures and rules of conduct for both fishers and scientists, and the maintenance of working relationships were the results of this stage.

4. Developing and testing solutions.

   The practicality and effectiveness of options for dealing with bycatch were evaluated during this stage. The goal was to choose suitable techniques to mitigate porpoise bycatch and to develop a scientific study of their effectiveness.

5. Ensuring recognition.

   A key component in this process was to ensure that both the public and managers were aware of the fishers' effort and work. Fishers were acknowledged for taking responsibility for 'the problem' and were recognized for finding a solution.

Activities and processes of the above stages did not automatically end with the beginning of the next stage. In particular, the activities of the information and education stage and the trust building stage continued throughout the entire project.

These steps are based on three premises. First, the approach recognizes the existence of different value systems and perceptions held by fishers, scientists, the public and managers. Secondly, it emphasizes the importance of communication and partnership. Stakeholders should not be adversaries at opposite sides of the table but rather 'problem-solvers' sitting at the same side of the table and working on a solution to a common problem. Thus, negotiations and discussion should have always two objectives: to find a solution to the problem and to remain in good terms with the other problem-solvers (Fisher *et al.*, 1991).

Thirdly, the inclusive approach acknowledges the value of fishers' expertise. Reviews of sentinel fisheries have shown that fishers' processes of evaluating knowledge provides reliable, insightful and important information (Lien, 1996). Typically, vernacular fishery science used by fishers is based on trial and error processes. For example, fishing gear or practices may be changed and found to be more effective. Such a change becomes only accepted after other fishers have tried similar alterations since fishers are reluctant to change gear which has worked for them. They have to be convinced of the improved effectiveness before they use the altered gear themselves. This process of communally evaluating changes on the basis of their collective experience ensures reliable and credible results (Saul, 1992). Fishery technology and patterns, particularly that of small-scale, local fisheries have been perfected through this process. This project attempted to use fishers knowledge in developing bycatch solutions.

2.2 THE FIVE-STEP APPROACH ON GRAND MANAN

Personnel from the WRG visited Grand Manan Island for the first time at the end of the 1993 fishing season to meet with fishers and to compile a list of those interested in cooperating with a project to mitigate harbour porpoise bycatch. Initial discussions about the bycatch problem were held only with individual fishers and managers.

Fishers and scientists exchanged information on the extent, scale and reasons for the porpoise bycatch as well as possible solutions during meetings and systematic phone calls in February and March 1994. Through further telephone communication, fishers were informed about plans and meeting schedules. They, in turn, could provide continuous feed-back about the planning process. All fishers interested in participating received a letter outlining the project in detail in 1994.

A meeting with interested fishers was arranged for early June 1994. During this meeting the fishers were provided with information about biology and ecology of harbour porpoise; views on the problem as expressed by NGOs, scientists and managers; and with potential solutions tested under comparable conditions. Options to deal with the problem were assessed and views on the effectiveness and practicality of solutions were solicited. Fishers provided information about the fishing process and problems with net modifications. Net modifications, such as passive reflectors, active acoustic devices (alarms) of various designs, or modifications in fishing practices were discussed. Alarms offered a promising tool to fishers and potential problems in pursuing such a solution were considered. Fishers were also introduced to the requirements for data collection that would be necessary in the investigations.

Continuous contact and dialogue between fishers and scientists facilitated the development of trust between participants. Similarly, the use of impartial observers that were credible to all stakeholders to collect and record data was important in building and maintaining an atmosphere of trust. A meeting at the end of June 1994 initially introduced the newly-arrived observers to the fishers. Observers accompanied trips during early summer lobster fishing and assisted fishers in preparing the gillnet gear for the fishing season. Thus, fishers and observers quickly became familiar with each other. Frequent contact also was common between fishers, scientists and observers outside the project requirements.

Fishers, scientists and observers agreed on rules of conduct. Observers were urged to follow all advice given by the captain, especially regarding the use of navigational equipment, and to observe all rules and regulations on board vessels. Also, data were not to be communicated to any other entity or person outside the project during the course of the study.

During stage three, specific details of the ensuing experiment were discussed. Scientists and fishers agreed on procedures and rules which ensured scientific reliability and a minimum of interference with the normal fishing process.

Stage four consisted of the testing of an active, acoustic device to reduce harbour porpoise bycatch and is described in the following chapter.

While writing the ensuing reports, drafts were given to fishers to elicit feedback and they completed sections outlining their views and interpretation of the project and its results (Lien and Hood, 1994; Whale Research Group, 1996). Moreover, the study was consistently presented as a cooperative project between fishers and scientists at scientific meetings and conferences (Lien *et al.*, 1995a; Lien *et al.*, 1995c; Lien *et al.*, 1996).

A similar process was followed during 1994 and 1995. Although the scientists and most of the fishers remained the same, observers changed between years.

2.2.1 RESULTS OF THE MANAGEMENT APPROACH

At the outset of this experiment, the relationship among fishers, managers and scientists was characterized by distrust. Nevertheless, all of them shared a similar interest - reduction of harbour porpoise bycatch in groundfish gillnets. By the end of 1994, working relationships had developed between Grand Manan gillnetters and scientists and to a limited extent between fishers and management. This continued into the 1995 season. Fishers who had participated in 1994 recruited new participants and relations between fishers and management kept improving in 1995.

As a result, a solid partnership developed between fishers, scientists, observers and managers which was marked by respect for each others work, backgrounds, and value systems. Observers frequently became very interested in the fishing operations they monitored. In turn, fishers inquired about the observers' backgrounds. This was exemplified by frequent, private contact between fishers, scientists and observers. Fishers extended invitations for both private and community events to scientists and observers, and frequently presented gifts of fish to the observers and scientists. In turn, scientists and observers organized events for fishers and their families.

All stakeholders exchanged knowledge and gained experience during the process. For example, while fishers perceived previous observers as intruders, their attitude towards monitoring changed over the course of the experiment. They became aware of the advantages and purpose of scientific monitoring. Scientists, on the other hand, learned about traditional knowledge, fishers' experience and practices, perception of management practices and cultural values which differed considerably from those of many scientists. In both reports fishers positively evaluated the communication, relationship and the experiment (Lien and Hood, 1994; Whale Research Group, 1996). The partnership among fishers, scientists, managers and observers allowed the integration of a broad, practical knowledge base which combined the strengths and experiences of all stakeholders.

The public began to share this recognition as illustrated by the production of a Canadian Broadcasting Corporation 'Land and Sea' show about the Grand Manan Alarm experiment (Hall, 1995).

2.2.2 DISCUSSION

Stable partnerships between all stakeholders increases the chance of preventing a problem by recognizing early warning signs. It also allows management to adapt continuously to changing circumstances. For example, instead of reacting to alarming numbers of by-caught harbour porpoise by closing the fishery for a specified time or area, our approach allowed for an improvement of bycatch estimates and the development of measures which do not require fishery closure. In an inclusive approach, groups of people with different, sometimes very different, interests have to cooperate. This ensures that management is aimed at a mutually agreed goal and this goal is continually reassessed allowing long-term goals in management.

The current atmosphere which characterizes the relationships between stakeholders on Grand Manan Island, makes it be possible to develop solutions for further issues. One of them is the financing of alarms for future use, since the devices in this project were provided by the WRG. In addition, agreements about enforcement of alarm use have to be made. A potential solution could be the formation of a co-operative of fishers for purchase and maintenance of alarms, such as established in New Hampshire (J. Lien and C. Hood, pers. comm.).

Some people doubt that a management approach such as the one used on Grand Manan can actually be used in the tough environment of fisheries management. If, for instance, decisions result in fishery closures, it is assumed that fishers would either not agree or end their cooperation (A. J. Read, Nicholas School of The Environment, Duke University Marine Laboratory, Beaufort, N.C., pers. comm.).

Two arguments counter these concerns. First, if employed for extended time periods, the inclusive management scheme may be able to prevent a situation in which such drastic measures as fishery closures are necessary. Due to the broad knowledge base, the involvement of many different interest groups and the emphasis on communication, inclusive management may be able to react in a more flexible way than traditional regimes. Secondly, since fishers are involved in the management process, decisions would not come as a surprise, but rather as measures which are viable and necessary. Cases in point are the recent experiments in Eastern Canada, where in light of the widespread closure of the groundfish fisheries, many groups have come together to develop sentinel fisheries, community-based management initiatives and innovations in conservation management (Fisheries Resources Conservation Council, 1997a).

The major disadvantage of working cooperatively with fishers is the limitations which this relationship imposes on scientific evaluations of solutions. These limitations will be discussed in the conclusions of this thesis.

3. THE EXPERIMENT

Finding a solution to the problem of harbour porpoise bycatch is difficult. Circumstances which lead to porpoise entanglement in gillnets are not well known. In addition, proposed solutions depend on fishing gear, available information and on views about the involved species (Todd and Nelson, 1994). Nevertheless, potential solutions should meet several basic requirements:

1. Elimination or substantial reduction of bycatch;
2. Acceptability to all stakeholders;
3. Minimal interfere with the day-to-day fishing processes;
4. Minimal reduction of fish catches (*e.g.* altering fish behaviour or net hydrodynamics);
5. Enforceability.

3.1 POTENTIAL SOLUTIONS

3.1.1 GEAR CHANGE

Hook and line fisheries have been proposed as an alternative to gillnets, since hook and line generally has less bycatch (Fisheries Resources Conservation Council, 1997b).

Although fishers from Grand Manan Island occasionally use this gear, it is likely not a suitable option. Hook and line fisheries usually do not target pollock (*Pollachius virens*) (Kenchington and Halliday, 1994), which constitutes an important part of fish catches off Grand Manan Island. Similarly, dogfish (*Squalus acanthias*) frequently damage target fish on hooks and when they become captured themselves, hooks are often spoiled (Kenchington and Halliday, 1994). In addition, Grand Manan Island fishers traditionally prefer gillnets (Kenchington and Halliday, 1994) and it is unlikely that fishers on the island would agree to abandon this gear type.

3.1.2 NET MODIFICATIONS

Todd and Nelson (1994) reviewed net modifications to reduce marine mammal bycatch. The authors divide potential modifications according to three categories: setting strategies, passive reflectors and active acoustic devices.

SETTING STRATEGIES

Studies using pelagic gillnets set between 2 - 4.5 m below the water surface generally resulted in reduced bycatch (Todd and Nelson, 1994). However, this reduction in bycatch was parallelled by reduced fish catches. Similarly, floatlines of groundfish gillnets could be lowered reducing net height (Todd and Nelson. 1994). This modification likely results also in decreased fish catches. since the lower portion of groundfish gillnets catches most of the cod. whereas the upper half contains most of the pollock (P. He and J. Foster. Marine Institute. St. John's. pers. comm.).

Although time and/or area closures may minimize bycatch. such a restriction often results in major decreases in fish catches since the highest bycatch coincides in time with fish catches and occurs on the most important fishing grounds (Parsons. 1993). On Grand Manan Island no specific setting strategy. except time/area closures have been identified.

Considering the requirements for potential solutions listed earlier. changing setting strategies was not a satisfactory solution for all stakeholders on Grand Manan.
While changing setting strategies should prevent harbour porpoise from encountering fishing gear. net modifications might make nets easier to detect or easier to define for porpoise (Au and Jones. 1991; Jefferson *et al.*. 1992; Lien. 1995; Lien *et al.*. 1995b).

Harbour porpoise are assumed to use visual senses to aid navigation (Kastelein *et al.*. 1995a; Kastelein *et al.*. 1995b; Kastelein *et al.*. 1995d). However. due to limitations imposed by the visual apparatus and environmental factors. such as low light levels or murkiness of the water, echolocation seems to be the most important sensory system to detect objects (Kröger and Kirschfeld. 1993; Kastelein *et al.*, 1995b). Considering theoretical calculations, comparisons with closely related species and results from captive as well as field studies, echolocating harbour porpoise should be able to detect nets or parts thereof (Hatakeyama and Soeda, 1990; Au and Jones, 1991; Au, 1994; Hatakeyama *et al.*, 1994; Busnel and Dziedzic, 1967, as cited in Kastelein *et al.*, 1995b; Verboom and Kastelein, 1995).

Porpoise, however, do not echolocate all the time. Bottlenose dolphins (*Tursiops truncatus*) are believed to use their memory when navigating in areas they repeatedly visit (Bloom *et al.*, 1995); this reduces frequency of echolocation. It is possible that harbour porpoise may use echolocation in a similar way. In addition, porpoise might limit their echolocation in order not to be detected by predators, such as killer whales (*Orcinus orca*), which have been shown to identify their prey by passive listening (Barrett-Lennard *et al.*, 1996). Thus, porpoise may fail to detect the presence of the net.

Even when a target is detected, porpoise could still become entangled since they have to define nets correctly in order to react appropriately. Natural barriers in the ocean, such as bubble screens, deep scattering layer, or seaweed, are penetrable. In contrast, solid, temporary barriers, such as gillnets, likely are novel to harbour porpoise, and they must develop the appropriate skills in avoiding such barriers (Au and Jones, 1991; Lien, 1996).

As encounters with nets usually are fatal, no such learning can occur. Although porpoise mimic the behaviour of other porpoise in captivity, it is questionable if this could help porpoise to avoid entanglement in the wild (Kastelein *et al.*, 1995b).

Captive and field studies on responses of harbour porpoise to barriers report mixed results ranging from lack of obvious response, to learning and avoidance behaviour. Curiosity, lack of experience with nets or the presence of conspecifics or prey also influence responses to barriers (Au and Jones, 1991; Jefferson *et al.*, 1992; Silber, 1994; Kastelein *et al.*, 1995a; Kastelein *et al.*, 1995b; Lien, 1995; Lien *et al.*, 1995b; Kastelein *et al.*, 1997; Koschinski, in press). A fair summary at present is that it is not clear what determines if and how harbour porpoise react to barriers.

PASSIVE REFLECTORS

Passive reflectors are intended to increase acoustic detectability of the gear by reflecting echolocation signals (Goodson *et al.*, 1994a). Most of the published experiments did not produce significant bycatch reduction, were inconclusive or did not evaluate fish catches (Goodson *et al.*, 1994b; Todd and Nelson, 1994; Goodson and Mayo, 1995). Passive reflectors often cause operational problems. Since they need to be attached to the webbing of the net, they influence gear operations (Goodson *et al.*, 1994b; Goodson and

Mayo. 1995). Fishers on Grand Manan Island tested small plastic floats intended as passive reflectors on gillnets (see Goodson *et al.*. 1994b) on land. After attaching the reflectors. the net was repeatedly folded into a tub and pulled out again to simulate the flaking and setting process on board ship. During these trials. the reflectors became frequently entangled in the webbing. Changing the attachment of the reflectors did not eliminate this problem (pers. observation).

Generally. the ability of passive reflectors to reduce bycatch of harbour porpoise is questionable. First. reflectors are only effective if porpoise echolocate when approaching the net (Goodson *et al.*. 1994b). Secondly. passive reflectors present clearly defined signals for echolocating porpoise. Consequently. reflectors would not present a closed continuous barrier to porpoise. Thus. even with attachment of close rows of reflectors (which would render the net unmanageable). certain parts of the net would not reflect signals and these spaces could be perceived by the porpoise as potential passages.

ACTIVE, ACOUSTIC DEVICES

Active. acoustic devices generate sounds and can have several effects on the behaviour of approaching cetaceans. They can remain undetected or be ignored. They could also produce avoidance by scaring the animals away. Similarly, they could draw the attention of the approaching cetacean towards the obstacle and thus prevent entanglement (Dawson, 1994).

Many studies employing active devices were inconclusive or showed no significant bycatch reduction (Todd and Nelson, 1994). However, several authors reported significant reduction of cetacean bycatch in nets equipped with active deterrents. Todd *et al.* (1992) showed that humpback (*Megaptera novaeangliae*) and minke whales (*Balaenoptera acutorostrata*) reacted to broadband sound generators. Humpbacks collided significantly less with cod traps equipped with alarms (Lien *et al.*, 1990; Lien *et al.*, 1992). Lien and coauthors (1995b) caught significantly fewer porpoise in nets with acoustic deterrent devices. However, catches of pollock and cod also were significantly lower. Using half-ensonified nets during the second year of the study, Lien (1995b) observed higher bycatch rates in the net immediately adjacent to the ensonified section of the net. Fish catches did not differ between treatments (Lien *et al.*, 1995b).

An experimental fishery using a double blind design found significant reduced bycatch of harbour porpoise in nets with alarms (Kraus *et al.*, 1997). In an experiment using the acoustic devices developed by Kraus *et al.* (1997), Hector's dolphins (*Cephalorhynchus hectori*) avoided the vicinity of working alarms (Stone *et al.*, 1997).

Alarms offer several advantages over passive net modifications. Sounds of active sound generators are distributed along the length of the net and define a complete net. Alarms do not require the porpoise to echolocate when approaching the net. and instead. may incite the porpoise to echolocate at the net. In addition. characteristics of the sound produced by active devices can be designed to minimize or avoid effects on fish catches.

Therefore. active acoustic deterrent devices promise to effectively reduce harbour porpoise bycatch in groundfish gillnets. Fishers strongly approve of this approach as it allows their established fishery pattern to persist.

A scientific experiment was designed in cooperation with Grand Manan Island fishers to test the effectiveness of active. acoustic devices. The goal of this experiment was to answer two questions:

1. Can the alarms reduce bycatch of harbour porpoise in gillnets significantly in comparison to unmodified gillnets?
2. Do the alarms alter fish catches in the gillnets? Particularly. do the alarms affect catches of cod and pollock?

The hypotheses were that catches of porpoise in modified nets would be lower than in control nets. whereas fish catches would not differ between treatments.

3.2 DESCRIPTION OF THE ALARMS

Alarms were built by the WRG and had been used previously on Jeffrey's Ledge, off the coast of New Hampshire in 1993 (Lien *et al.*, 1995b). The housing of the alarms consisted of a 9 cm ABS pipe, capped on one end. The other end was closed with a standard screw cap fitted with an O-ring (Fig. 3.1). A 9 volt piezo buzzer (Radio Shack, Archer Cat. No. 273-068) was glued to the inside of the permanent cap. Material and assembly of the alarms were inexpensive (approximately $ 10) and locally available.

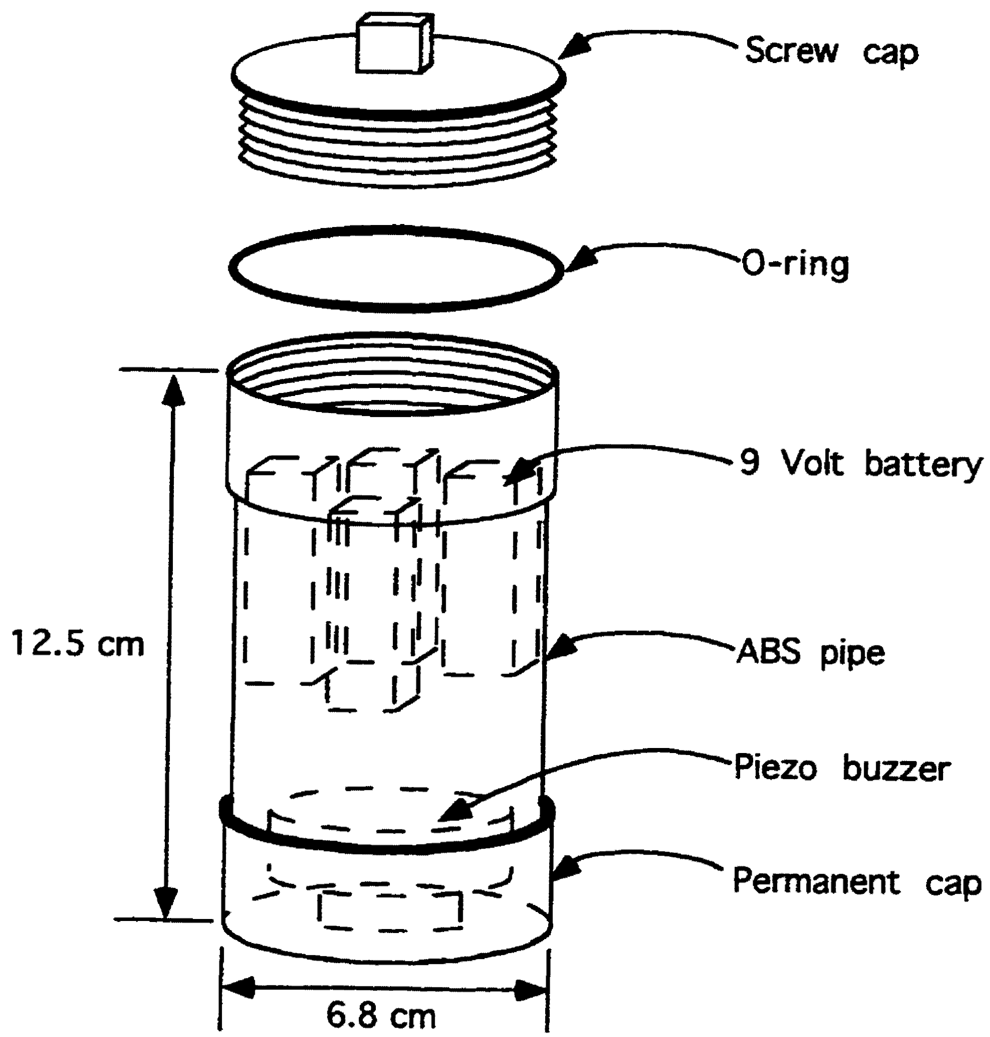


Figure 3.1: Sketch of an alarm showing placement of buzzer and batteries

Sound was produced at approximately 2.5 kHz and source level was 115 dB re 1 μPa at 1 m at this frequency (Lien *et al.*, 1995b). Harmonics of individual alarms varied due to the degree of attachment of the buzzer to the bottom of the housing, variable volumes of the housing or other characteristics of the components (Lien and Hood, 1994; Kastelein *et al.*, 1995c; Lien *et al.*, 1995b). Tones lasted for approximately 150 ms and were presented at intervals of 415 ms with a duty cycle of 40 % (Kastelein *et al.*, 1995c). Power was provided by four 9 Volt batteries.

Alarm sounds were within the audible range of harbour porpoise (Andersen, 1970; Popov *et al.*, 1986; Popov and Supin, 1990; Verboom and Kastelein, 1995), and outside that of target fish species (Chapman, 1973; Hawkins and Myrberg Jr., 1983; Fay, 1988). Alarms caused minimal or no interference with the normal fishing process and handling procedures.

3.3 METHODS

The experiment was carried out during summer 1994 and 1995 on Grand Manan Island. Observers accompanied fishers on their daily operations and recorded data on weather, gear characteristics, fish catches and harbour porpoise bycatch (see Appendix A). Information from these sheets was later entered into computer spreadsheets.

3.3.1 THE OBSERVERS

During both 1994/1995 seasons volunteers worked as observers. Most were college or university students with a background in biology and strong interests in marine mammals. Volunteers arrived several weeks before the fishing season began and participated in classes on the biology of harbour porpoise, bycatch problems , fishery and fishing culture, sampling techniques, identification of fish species, ethics and principles of the experiment, and onboard safety.

3.3.2 EFFORT MONITORED

In both years, attempts were made to observe all gillnet effort from Grand Manan ports. However, complete coverage was not possible due to: a) some fishers refusal to allow observers on board, b) insufficient numbers of observers, c) changes in the fishery due to management decisions, d) changes in fishers' plans. Only data from observed trips were used in this analysis.

3.3.3 EXPERIMENTAL CONDITIONS

The alarms were attached horizontally to the floatline with duct tape. The devices were distributed at equal distance along the string, and at each end of the string (Fig. 3.3). In

1994, the alarms were placed at each bridle ("alarmed bridle strings"). Thus, strings with three webs carried four alarms and strings with four webs had five alarms (Fig. 3.3). In 1995, experimental strings were equipped with ten alarms ("10 alarm string"), irrespective of the number of webs (Fig. 3.3). Unmodified strings served as controls.

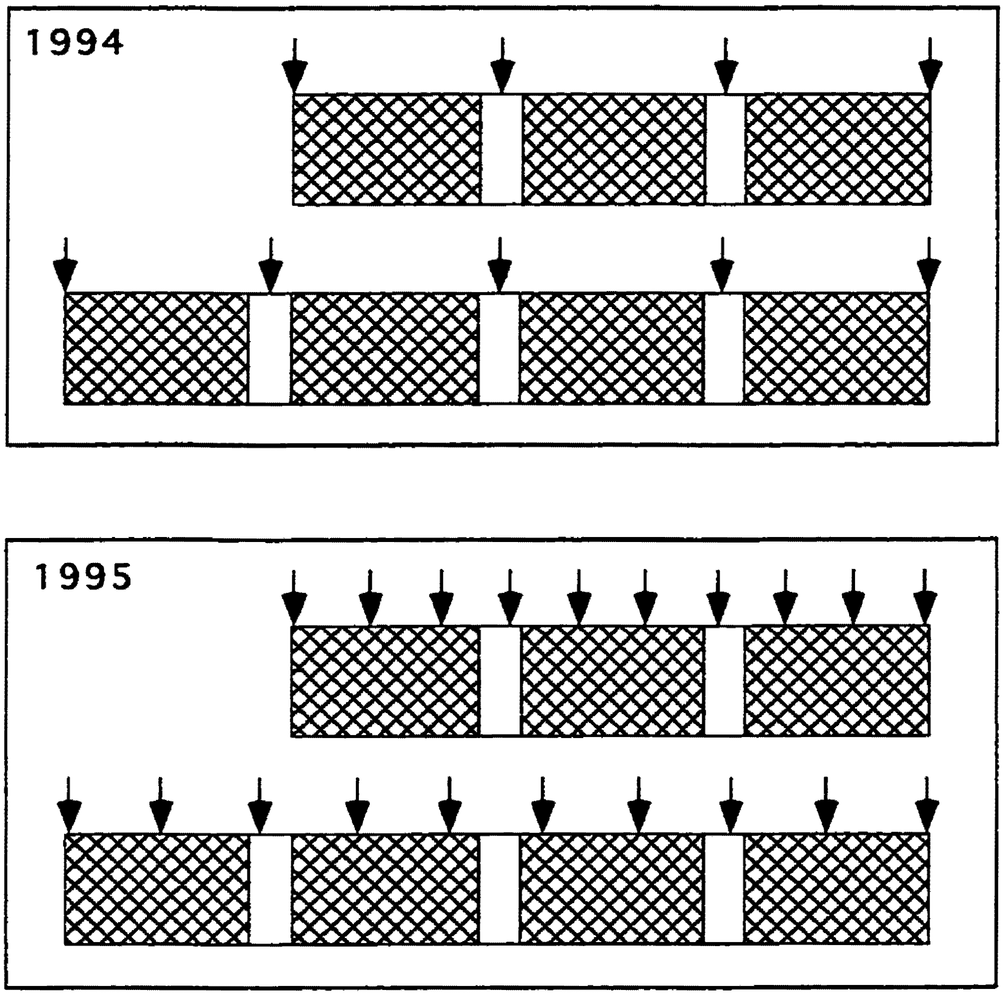


Figure 3.2: Alarm placement on gillnets in 1994 and 1995. Arrows show approximate positions of alarms. Cross-hatched boxes represent webs, empty squares represent bridles.

A second control treatment was used in 1994. Some nets were fitted with "silent alarms" at each bridle ("silent alarm string"). Silent alarms were identical to working alarms except that the devices did not produce sound. Placement of alarms corresponded with the working alarms. This treatment was not used in 1995 due to limited numbers of alarms.

Before fishing commenced, strings were randomly assigned to treatment conditions. Typically, the number of strings on a particular vessel was divided by the number of treatments available (three treatments in 1994, two in 1995). Most vessels carried strings with at least two treatment conditions. One fisherman refused to use alarms but allowed observers on board.

3.3.4 DATA RECORDING

Data recorded by observers on data sheets ("haul sheet" and "set sheet": see Appendix) included haul information, gear characteristics and catches:

Haul Information:

1. Start time: Time of day when the first hi-flier was taken on board and the hauling process began.
2. Finish time: Time of day (hr:min) when the large buoy was hauled on board

and the hauling process ended.

3. Total time of hauling: Difference between start and finish times.
4. Soak-time: Time the net remained in the water, beginning with end of setting process and ending with start of hauling process. Soak-times were calculated by comparing set and haul sheets and were recorded to the nearest hour.
5. Position of vessel: Positions were recorded at the beginning of the haul from a Global Positioning System (GPS) device, or from a Loran device.
6. String number: Strings were numbered sequentially as they appeared during the hauling process on each trip. This number made it possible to link fish catches or porpoise bycatch with information on haul sheets.
7. Net depth: Depth (in m) displayed on fish finders during the beginning of hauling process.
8. Treatment: Treatment to which the string belonged (alarmed bridle string, 10 alarm string, silent alarm string, control string).
9. Number of webs per string.
10. Colour of webs: blue, green and clear.
11. Hi-flier number: Fishermen use numbers on hi-fliers to identify strings. This number was used to link information relating to strings.
12. Number and species of caught fish per web: If identification was not possible, general categories (flatfish, crustacea, birds) were used.

Information on weather and oceanography was also recorded (Hood, in prep.) but is not included in this thesis.

Information recorded during the setting process was identical to that taken during the haul. Start and end times for sets were taken when the first and last hi-flier were dropped into the water, respectively.

In the event of a porpoise bycatch, the following data were recorded on "bycatch sheets" (see Appendix D):

1. Time of day (hr:min);
2. Vessel position;
3. Water depth (m);
4. String number;
5. Web number;
6. Net treatment;
7. Web colour.

3.3.5 ANALYSIS

Harbour porpoise bycatch was known to be common in the Swallowtail and Wolves areas (Fig. 1.1) (Lien and Hood. 1994). Therefore. observation effort was concentrated in these areas.

A "web-day". defined as the time a web remained in the water expressed in days or fractions thereof. served as unit of effort. Although this differs from other studies (Kraus *et al.*. 1997) several points made this necessary. Not all fishermen used strings with three webs; a few of them occasionally employed strings with 4 webs. In addition. colour often varied within a string. For example. the first web of a string could have been clear. the second blue and the third web might have been clear again. In order to analyse these characteristics. web-days had to be used in the analyses. Consequently. some of the web characteristics may not be independent. For instance. a particular net treatment may occur more often in webs of one colour than another colour.

Only webs with a complete set of data were included in the analysis. All data pertaining to webs with incomplete information were excluded from the analysis in order to keep the sample size constant within data sets.

Nets were hauled after approximately 24 hours or multiples thereof. and soak-times were grouped into four categories following their frequency distribution (Fig. 3.3). Thus. soak-time categories reflected whole days with cut-off points at 36. 60 and 84 hours. Category 4 contained soak-times longer than 84 hours.

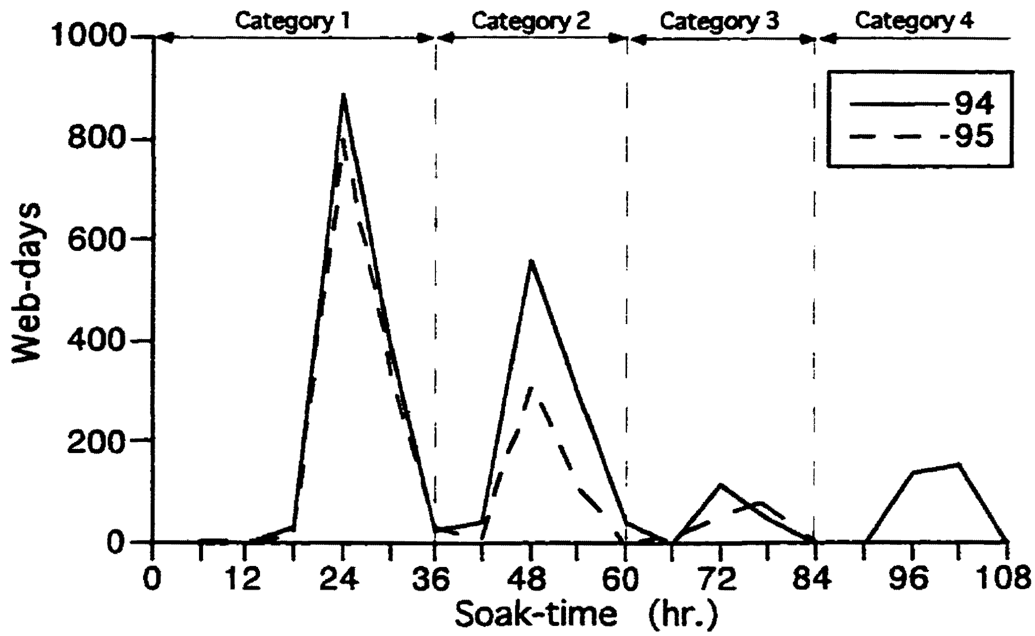


Figure 3.3: Effort distribution (web-days) according to soak-time (hrs.). Horizontal arrows indicate soak-time categories used in analyses.

For both fish catches and harbour porpoise bycatch. the null hypothesis was that there would be no difference in number of fish or porpoise caught between alarmed and control strings.

To test these hypotheses. the following General Linear Model (GLM) was used:

(1) $Y = \beta_0 + \beta_{Date}Date + \beta_{Treatment}Treatment + \beta_{Depth}Depth + \beta_{Soak\text{-}time}Soak\text{-}time + \beta_{Position}Position + \beta_{Colour}Colour + e.$

where Y = response variable (CPUE)

β_0 = grand mean.

$\beta_{Date}Date$ = variable Date (Julian date).

$\beta_{Treatment}Treatment$ = variable Treatment (alarmed bridle. 10 alarms. silent alarm. control).

$\beta_{Depth}Depth$ = variable Depth (in metres).

$\beta_{Soak\text{-}time}Soak\text{-}time$ = variable Soak-time (group 1-4).

$\beta_{Position}Postition$ = variable Web position (middle web in a string. end web in a string)

$\beta_{Colour}Colour$ = variable Colour (clear. green or blue).

e = error term.

Analysis of fish catches using Data Desk (Data Description Inc.. Ithaca. N.Y.) was done separately for each of the following fish species: cod, pollock, herring and spiny dogfish. Fish catches per web-day were not distributed normally, thus the response variable was transformed as follows:

(2) $$Y_{transf.} = \ln (Y+1).$$

Since this transformation may alter results, the same analyses were repeated adding 0.1 and 0.01 to Y instead of 1 (D. Schneider, Memorial University of Newfoundland, pers. comm.). Significance changed only in two out of 120 potential cases (6 factors/species/year/transformation) so the original transformation was deemed appropriate.

Few harbour porpoise were caught. Entrapment per web typically involved a single animal. Thus, a binary response variable was defined for the analysis of porpoise bycatch. Webs with bycatch were labelled '1', webs without porpoise catch were assigned 'O' values. Thus, catch distribution could be analysed by a logistic regression (Everitt, 1994), employing the same model as outlined above. Analysis was carried out with S-Plus software (Statistical Sciences, Inc., Seattle, WA). Significance level was set at 95%.

To test the null hypothesis that fish and porpoise catches were independent, fish catches were randomly assigned to webs with or without bycatch and entered into a 1-way Anova analysis. This randomization was repeated 1.000 times. The proportion of randomizations yielding test statistics (F-value) at least as extreme as the original data arrangement provided the p value (Crowley. 1992).

String and bycatch positions were transferred to a nautical chart (L/C 4340) which was overlaid by a grid. The height and width of the grid boxes corresponded to 1° latitude and longitude. respectively (Fig. 3.4). The total number of web-days. the number of web-days per treatment and the number of porpoise caught in each grid box was then counted.

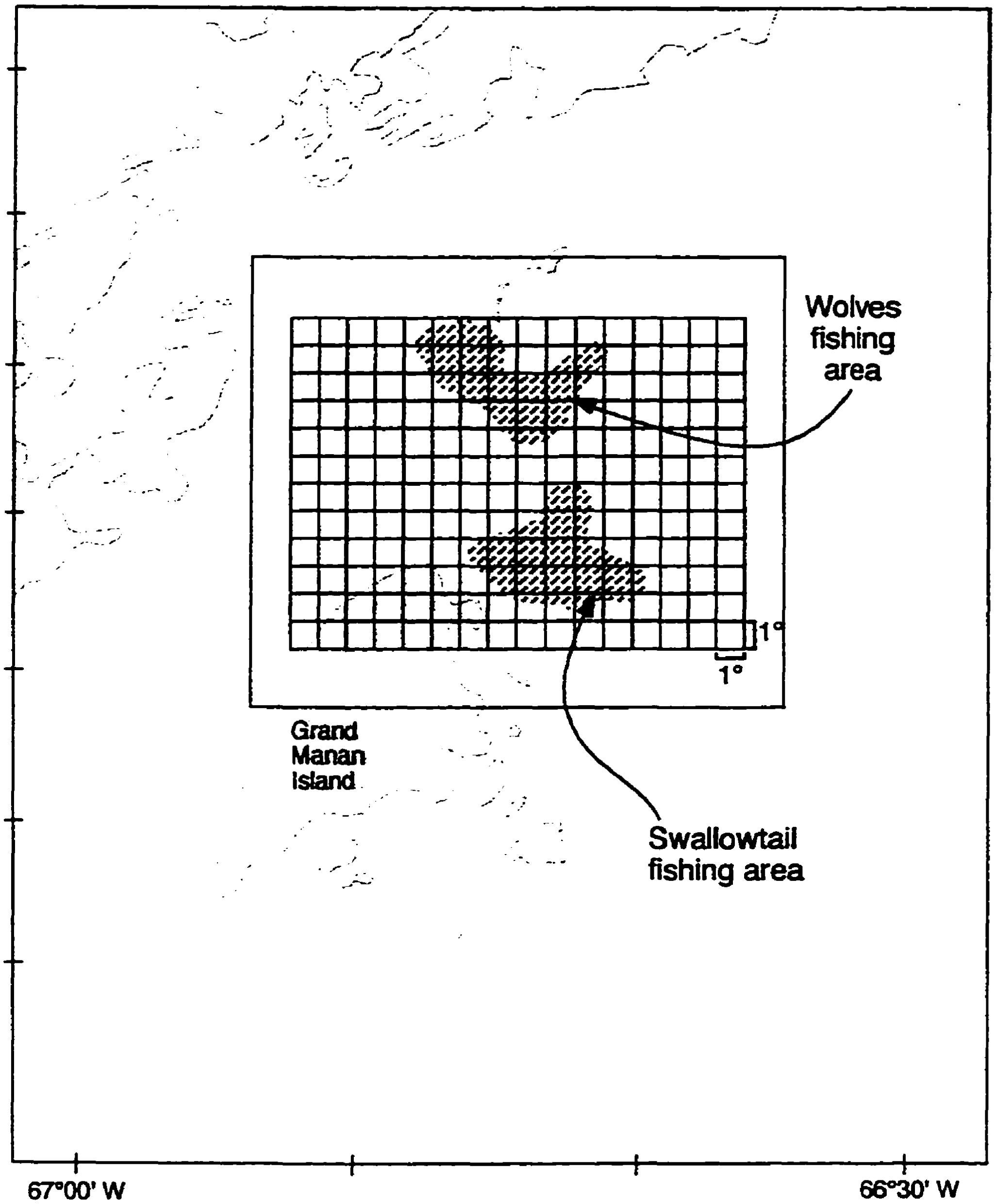


Figure 3.4: Map of the Bay of Fundy showing grid used to plot fishing effort and bycatch locations.

3.3.6 RESULTS

FISHING EFFORT - 1994

The fishing season began in early July. The first observed trip was recorded on July 9, the last trip was made on September 10. Interruptions of varying length were mainly due to weather conditions. During this season, a total of seven fishermen were monitored throughout the season (Lien and Hood 1994) on 148 trips. They hauled 678 strings with 2,080 webs. A total of 2,740 web-days was monitored. Complete data sets were available from 1932 webs reflecting 96% of total annual effort. These were included in the analysis.

Web treatment was not equally distributed: 40% of total effort was with active alarms, 26% was carried out with silent alarms and the remaining effort served as control (Tab. 3.1). No spatial or temporal differences in effort between treatments were obvious (see Appendix B).

Table 3.1: Summary of effort (web-days) according to treatment in 1994 and 1995.

Year	Treatment	Web-days	% of effort
1994	alarmed bridle	1,053	40
	silent alarm	700	26
	control	889	34
1995	alarmed bridle	85	6
	10 alarm	445	30
	control	947	64

The mean fishing depth was 101 m (± 0.4 m, range: 51.2 - 173.9 m). Silent alarm nets (101.0 ± 0.76 m) and control nets (101.9 ± 0.69 m) were set at comparable depths. Nets with alarmed bridles were set at shallower depth (99.2 ± 0.62 m).

On average, webs remained in the water for 32.8 hours (± 0.70, range: 1.8 hr. - 102.3 hr.) (Fig. 3.3) and proportions of soak-time categories were approximately the same between treatments ($Chi^2 = 6.9$, $df = 6$, $p > 0.05$).

Clear webs were used for most of the effort (1639 web-days, 62%); 37.6% (993 web-days) of effort was carried out with green webs, and only 0.4% (10 web-days) were blue webs. Colour and treatment were not independent ($Chi^2 = 77.83$, $df = 4$, $p \leq 0.001$); alarmed webs were more frequently green than expected and control webs were more often clear.

FISHING EFFORT – 1995

The fishing season lasted from July 1 – September 30 and was divided in trimesters with separate quotas. During the second trimester, the allocated quota was caught before the end of the trimester and fishing activities were suspended from July 21 – September 1 for vessels < 45 feet in length. One trip of a vessel > 45 feet in length was monitored.

Additional smaller interruptions were due to weather . Of the total fishing effort from Grand Manan Island, 89% were observed in July and 48% in September.

Observers were regularly on 12 boats. During 113 trips, 1,549 webs were hauled (1,798 web-days). Only 1,253 webs (81%; 1,477 web-days, 82% of total annual effort) could be included in the analysis due to missing information in some haul and set sheets . Most strings had 3 webs (98%).

Until July 9, experimental strings carried alarms at each bridle. After July 5, some strings were equipped with ten alarms per string. Thus, during the ten days between July 6 - 16, two experimental treatment conditions were used: alarmed bridle nets and 10 alarm nets. This transitional period was necessary since not all nets could immediately be equipped with ten alarms due to a shortage of devices. After July 16, all experimental strings carried ten alarms. The majority of webs were control webs. Webs carrying 10 alarms made up 30%, and 6% carried four alarms (Tab. 3.1).

Mean depth of all webs for the whole season was 101.0 m (± 0.37 m, range 47.6 - 162.9 m). Alarmed bridle nets were set deepest (102.7 ● 1.25 m). Control nets were intermediate (101.8 ● 0.43 m) and 10 alarm nets were set in the shallowest waters (99.0 ± 0.57 m).

On average, webs were hauled after 28.8 hours (± 0.55 hrs.): soak-times ranged from 3.3 – 77.5 hours (Fig. 3.3). Proportion of treatments did not differ between soak-time categories (Chi^2 = 5.012, df = 4, p = 0.29).

Clear webs were used most frequently (991 web-days, 67%), followed by green webs (334 web-days, 23%). Blue webs were used for only 10% of total effort (151 web-days). Colour and treatment were not independent (Chi^2 = 78.67, df = 4, $p \leq 0.001$); 10 alarm webs were more often clear than expected and control webs were disproportionally more blue.

FISH CATCHES

There were large differences in overall proportions of fish species caught . In both years, over half of the fish caught were dogfish. In 1994, approximately one third of catches were herring and only few cod were caught. Cod was the second most caught species in 1995. Proportion of pollock catches remained constant in both years (Tab. 3.2).

Although most species showed pronounced fluctuations in weekly catch rates only herring and dogfish catches did not vary significantly between days (Tab. 3.3).

Table 3.2: Summary of fish catches in 1994 and 1995.

Year		Species			
		Cod	Pollock	Herring	Dogfish
1994	N	6,088	3,540	20,760	36,554
	% of total annual catch	9	5	31	55
	Catch per web-day	2.9	1.6	9.2	16.0
	1 S.E.	0.09	0.08	0.58	0.74
1995	N	7,450	1,1613	6,045	18,665
	% of total annual catch	22	5	18	55
	Catch per web-day	5.4	1.1	4.1	12.1
	1 S.E.	0.16	0.07	0.25	0.62

Table 3.3: Statistical results of the GLM for fish catches in 1994 and 1995.

Year	Variable	df	Species			
			Cod	Pollock	Herring	Dogfish
1994	Date	1	***	*	n.s.	n.s.
	Treatment	2	**	n.s.	n.s.	**
	Depth	1	n.s.	***	***	n.s.
	Soak-time	3	***	***	***	***
	Web position	1	n.s.	*	n.s.	n.s.
	Web colour	2	**	n.s.	n.s.	***
1995	Date	1	***	***	n.s.	***
	Treatment	2	n.s.	n.s.	***	*
	Depth	1	**	n.s.	***	n.s.
	Soak-time	3	***	n.s.	n.s.	n.s.
	Web position	1	n.s.	n.s.	n.s.	*
	Web colour	2	*	*	n.s.	n.s.

n.s. = $p > 0.05$
* = $p < 0.05$
** = $p < 0.01$
*** = $p < 0.001$

Fish catches of only two species varied with treatment in 1994 (Tab. 3.3). Cod and dogfish were caught more frequently in silent alarm webs than in alarmed bridle webs and control webs (Tab. 3.4).

In 1995, treatment did not influence catches of target species (Tab. 3.3). Herring was caught less in alarmed bridle webs compared to other treatments. Herring catches also showed significant differences between 10 alarm webs and control webs (Tab. 3.4).

Dogfish catches were the only ones not affected by depth in both years. Cod and pollock catches were not affected by depth in 1994 and 1995, respectively (Tab. 3.3)

In 1994, the most important factor influencing catches was soak-time (Tab. 3.3) with lowest catches in webs soaking longer than 84 hours. In contrast, in 1995 soak-time was only a significant factor in the cod model (Tab. 3.3).

Web position affected only pollock catches in 1994 and dogfish catches in 1995 (Tab. 3.3).

Cod catches showed consistently differing catch rates with web colour (Tab. 3.3). Dogfish and pollock catches were affected by this factor only in 1994 and 1995.

respectively (the response of pollock to colour was one of the factors which was not significant when the data were reanalyzed with the Y+ 0.01 and Y+ 0.1 transformations ; Y+0.01: $p > 0.05$; Y + 0.1: $p > 0.05$).

Table 3.4: Statistical comparison of fish catches according to treatment categories in 1994 and 1995 (GLM. Scheffé post-hoc comparisons). CPUE = Catch per web-day. Matching superscript letters denote significant differences. Level of significance for matching letters is provided below table.

Year	Treatment (web-days)	Species							
		Cod		Pollock		Herring		Dogfish	
		CPUE	1 S.E.	CPUE	1 S.E	CPUE	1 S.E.	CPUE	1 S.E.
1994	alarmed bridle (1,053)	2.9	0.14	1.9	0.13	9.4	0.75	14.8[b]	1.03
	silent alarm (700)	3.3[a]	0.21	1.4	0.13	7.5	0.69	19.1[b,c]	1.61
	control (889)	2.5[a]	0.15	1.4	0.13	10.3	1.38	15.1[c]	1.33
1995	alarmed bridle (85)	6.2	0.67	0.6	0.15	1.6[d]	0.38	9.7	1.47
	10 alarm (445)	5.4	0.30	0.9	0.07	3.3[e]	0.43	14.6	1.39
	control (947)	5.3	0.20	1.3	0.10	4.7[d,e]	0.34	11.1	0.69

[c] $p<0.05$
[b, d] $p< 0.01$
[a, e] $p< 0.005$

HARBOUR PORPOISE BYCATCH

A total of 43 harbour porpoise were caught in 1994. In 1995. only 29 porpoise were retrieved from gillnets. Two of them were caught during unobserved trips and information on the bycatch of three harbour porpoise was incomplete. Thus. information on 24 animals was included in the analysis.

In both years. most bycatch occurred in the area of highest effort. just off Swallowtail (Figs. 3.5 and 3.6).

In 1994. Porpoise bycatch rates peaked at the beginning of August and then dropped. followed by a smaller increase in the beginning of September (Fig. 3.7). The peak during the first week was caused by a single animal caught during a period when few nets were set and many haul sheets were incomplete as observers were still learning. Therefore. the catch rate in this period is inflated. During the 1995 season. most bycatch occurred during the last half of July (Fig. 3.7).

Figure 3.5: Spatial distribution of total harbour porpoise bycatch . and bycatch by treatment in 1994. Numbers denote bycatch/100 web-days.

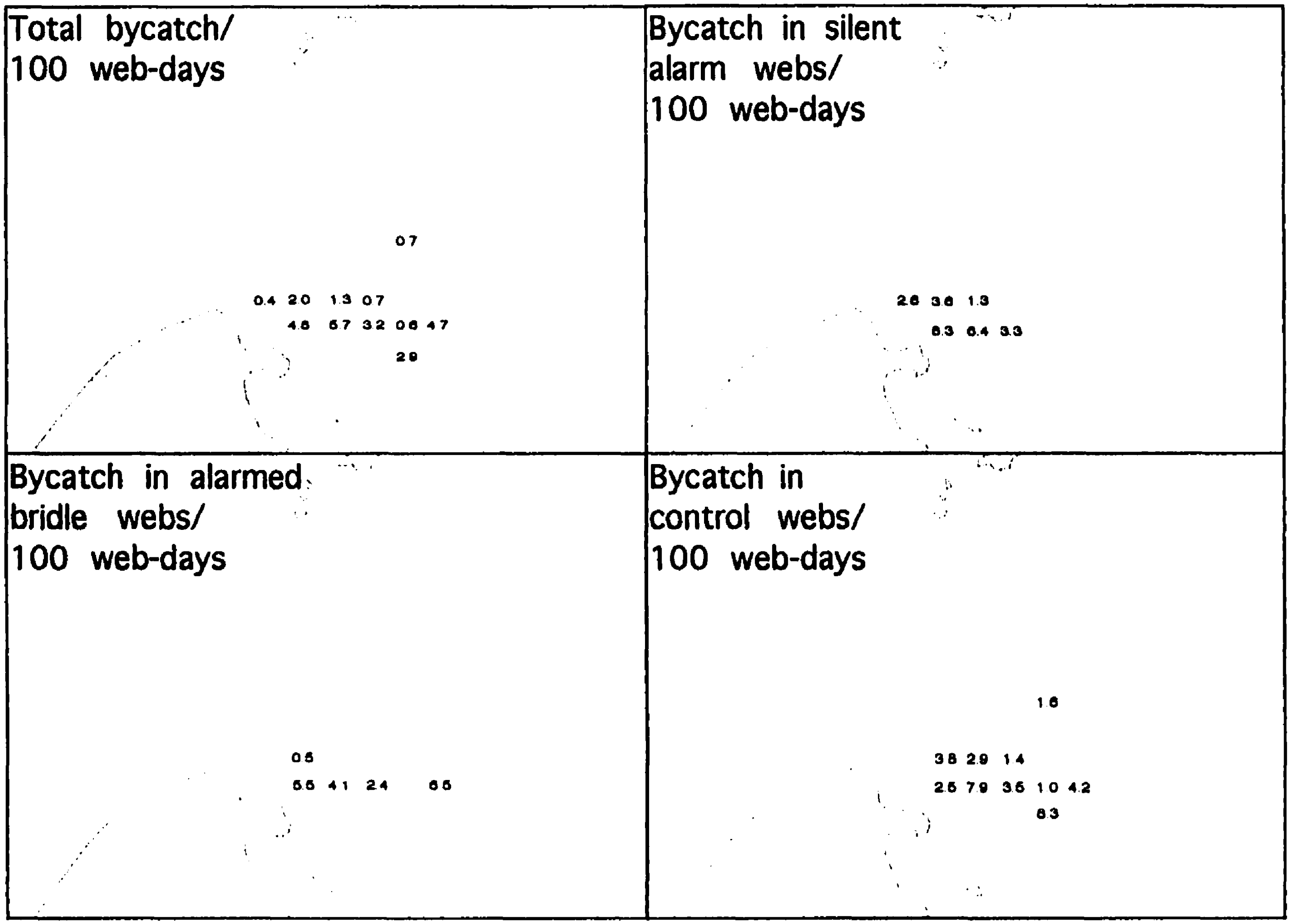
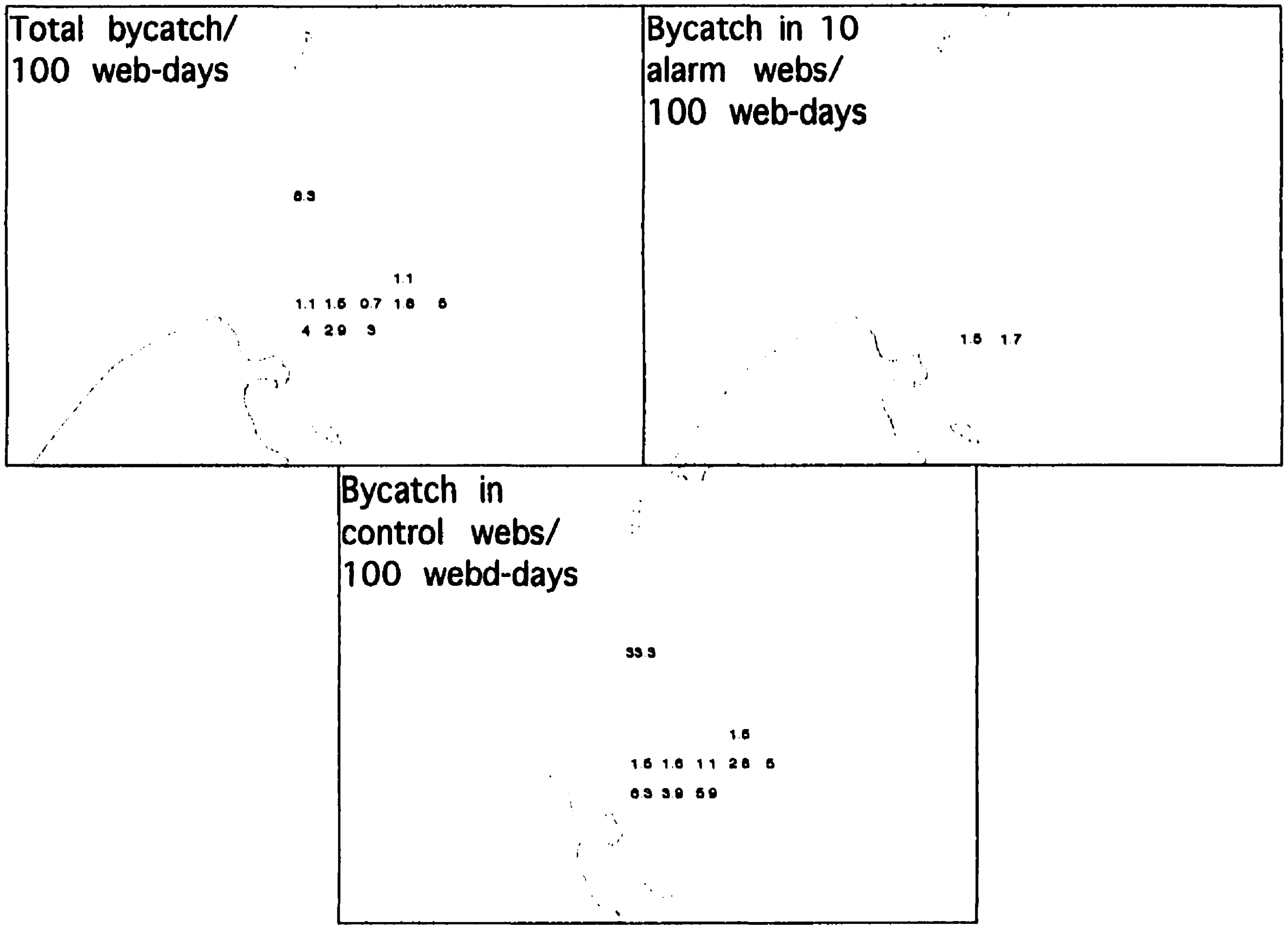

Total bycatch/
100 web-days
07
0.4 2.0 1.3 0.7
4.8 6.7 3.2 0.6 4.7
2.9
Bycatch in silent
alarm webs/
100 web-days
2.8 3.6 1.3
8.3 6.4 3.3
Bycatch in alarmed
bridle webs/
100 web-days
0.5
5.5 4.1 2.4 6.5
Bycatch in
control webs/
100 web-days
1.6
3.8 2.9 1.4
2.5 7.9 3.5 1.0 4.2
8.3

Figure 3.6: Spatial distribution of total harbour porpoise bycatch . and bycatch by treatment in 1995. Numbers denote bycatch/100 web-days.


Total bycatch/
100 web-days
6.3
1.1
1.1 1.5 0.7 1.8 5
4 2.9 3
Bycatch in 10
alarm webs/
100 web-days
1.5 1.7
Bycatch in
control webs/
100 webd-days
33.3
1.5
1.5 1.6 1.1 2.8 5
6.3 3.9 5.9

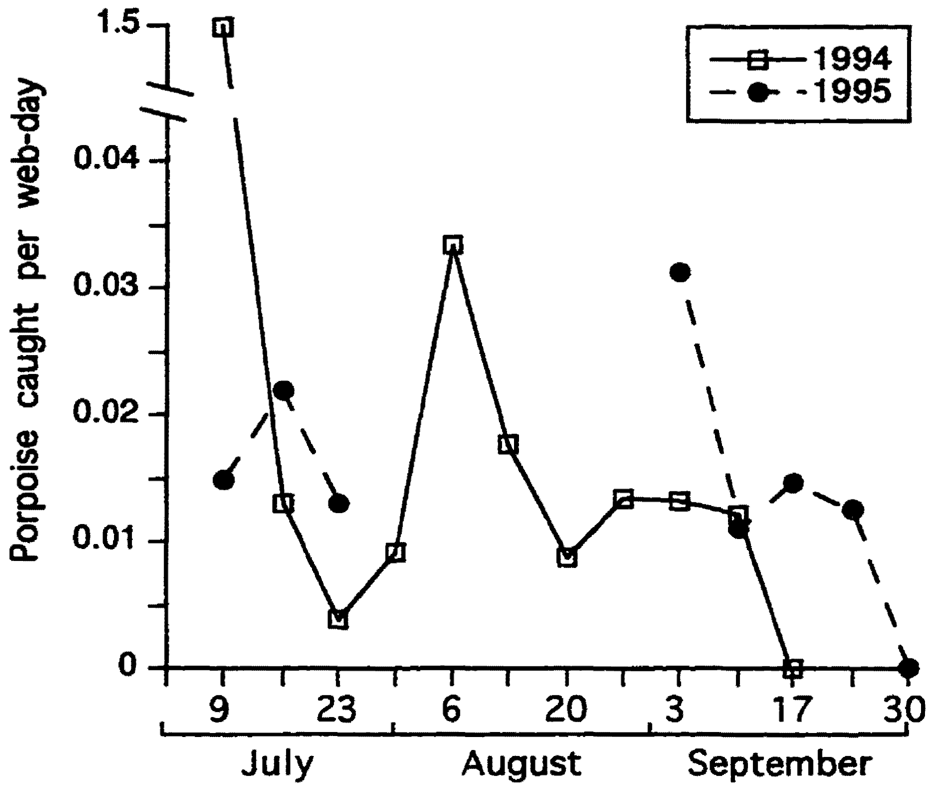


Figure 3.7: Changes of harbour porpoise catch rate in 1994 and 1995.

Although treatment did not significantly affected porpoise catch rates in 1994 (Tab. 3.5) alarms nevertheless influenced catch rates. Almost half of the porpoise were caught in control webs, while catches in alarmed bridle webs and silent alarm webs were similar (Tab. 3.6). Catch per web of alarmed bridle webs was 48% lower compared to control webs. Silent alarms reduced the catch rate by 6% compared to control webs (Tab. 3.6). As a result, harbour porpoise were 2.3 times more likely to be caught in control webs than in alarmed bridle webs (odds ratio test: 95% confidence interval (CI) = 1.07 - 4.94). The odds of being incidentally caught in a control web and a silent alarm web were comparable (odds ratio tests = 1.18: CI = 0.57 - 2.45).

Treatment was a significant factor in the 1995 analysis (Tab. 3.5). Only 2 porpoise were caught in alarmed strings and this treatment reduced bycatch by 79% compared to catch rates of control webs (Tab. 3.6). Harbour porpoise were 5.13 (odds ratio test: CI = 1.38 - 19.04) times more likely to become entangled in a control web than in a web carrying 10 alarms.

Depth influenced porpoise bycatch in both years while soak-time was a significant factor only in 1994 (Tab. 3.5).

Table 3.5: Statistical results of Logistic Regression Analysis for harbour porpoise bycatch in 1994 and 1995

Variable	df	1994	1995
Date	1	n.s.	n.s.
Treatment	2	n.s.	**
Depth	1	**	**
Soak-time	3	**	n.s.
Web position	1	n.s.	n.s.
Web colour	2	n.s.	n.s.

n.s. = $p > 0.05$
** = $p < 0.01$;

Table 3.6: Summary of harbour porpoise bycatch according to treatment in 1994 and 1995.

	1994			1995	
	alarmed bridle	silent alarm	control	10 alarm	control
Web-days	1,073	702	965	513	1,179
No. of porpoise caught	11	13	19	2	22
% of total annual bycatch	26	30	44	8	92
Catch per web-day	0.01	0.02	0.02	0.004	0.02
% reduction to catch per web-day in control webs	48	6	–	79	–

Webs with entrapped harbour porpoise contained significantly more herring (randomization: 1,000 replications; $F = 47.51$; $p < 0.05$) than webs without porpoise bycatch only in 1994. Catch rates for the other fish species did not differ between webs with and without porpoise bycatch.

COMPARISON BETWEEN YEARS

Total fishing effort in 1995 was less than in 1994 due to the closure of the gillnet fishery in August. Treatment conditions also varied between years. In 1994, alarms were attached to each bridle; in 1995, 10 alarms per string were employed. Due to the increased number of alarms needed to equip the appropriate strings with ten alarms, silent alarms could not be used in 1995.

Strings were set on average 0.9 m deeper in 1995 than in 1994 but this difference was not significant (pooled t-test: $t = 0.88$; $df = 3187$; $p > 0.05$). The time strings remained in the water differed between 1994 and 1995 ($Chi^2 = 118$; $df = 3$; $p < 0.05$). Whereas over half of the webs were set for more than 36 hours in 1994, such long soak-times were observed less in 1995. Use of colour also differed between the years ($Chi^2 = 237.08$; $df = 2$; $p < 0.05$): Blue mesh was used in only 0.4% in 1994 and increased to 10% in 1995. Fewer green webs were employed in 1995 while the proportion of clear webs remained approximately the same in both years. Catch rates of cod were higher in 1995. while herring catches declined by approximately 5 fish per web-day from 1994 to 1995.

3.3.7 DISCUSSION

Because the experiment was done in cooperation with fishers seeking to maximize commercial fish catches and certain factors could not be controlled in the field setting. there were potential sources of bias in the testing. It is best that these are first examined and practical as well as honest answers are given to these problems.

Many studies of acoustic net modifications are poorly designed and lack statistical power (Reeves *et al.*. 1996). Usually. these problems arise from the small probability of catching cetaceans. unbalanced designs and biases. As a result. power analyses. careful study design and double-blind experiments have been suggested (Reeves *et al.*. 1996).

No power analyses was conducted before the beginning of the present study. This was not necessary since the potential number of participating boats was small and quota restrictions limited effort. Unbalanced design and potential setting bias could have been avoided by a double-blind design ensuring that fishers and observers would not recognize net treatment. However. this was not possible due to voluntary participation and the cooperative nature of the work.

Decisions regarding net characteristics, such as mesh colour and number of webs per net, and set location were at the discretion of fishers. Their decision reflected attempts to maximize groundfish catches and minimize bycatch. It is safe to assume that fishers may have set alarmed nets preferably in areas where they expected frequent porpoise bycatch, however, since virtually all fishing effort occurred in a small area, it is not likely that location of nets influenced likelihood of harbour porpoise bycatch.

Despite these potential biases, this study shows that alarms reduced bycatch of harbour porpoise in groundfish gillnets. Moreover, since it was carried out in cooperation with an unrestricted commercial fishery, it is unique in demonstrating effectiveness and suitability of an acoustic device under normal, day-to-day conditions in a gillnet fishery.

Influences of the factors examined in this thesis vary considerably between species and years. Moreover, most of them are difficult, if not impossible, to control (Appendix C). Therefore, only treatment offers a suitable management tool. Fishers accepted alarms readily, the devices did not interfere with standard fishing methods and use is easily controllable. The following section discusses the effectiveness of alarms in reducing harbour porpoise bycatch and their influence of commercial fish catches.

EFFECTS OF ALARMS

Results suggest that porpoise reacted to alarms. Results in 1994 overall were not significant, yet porpoise were 2.3 times more likely to be caught in control webs than in alarmed webs. In 1995, with ten alarms per string, bycatch was reduced significantly. Only 8% of catches occurred in alarmed webs and the catch per web-day of webs with ten alarms was 79% lower than in control webs. Porpoise were approximately 5 times more likely to be caught in control webs than in webs with ten alarms.

Fish catches did not show consistent effects of alarms. Pollock catches did not differ between net treatment in 1994 and 1995. This was not true for cod in 1994. Cod catches per web-day were 22% higher in webs with silent alarms than in control webs. Herring catches were influenced by treatment only in 1995, showing highest catches in control webs. In contrast, dogfish seemed to be attracted to webs equipped with alarms.

Results for harbour porpoise bycatch can be best explained by effects of alarm sounds. The increased effectiveness of the alarms in reducing harbour porpoise bycatch in 1995 compared to 1994 could be due to the higher number of alarms used per string which increased the total sound emitted by a string. Louder alarm sounds decreased masking of alarm sounds by background noise and may have allowed porpoise to perceive alarm sounds more easily or from farther distance.

Alternatively, sound of alarms placed at the bridles may not overlap and instead, present "holes" in the acoustic barrier. In a preliminary experiment, alarm sounds were barely audible just one net away from the sound source (Lien and Hood, 1994). Such gaps represent incomplete barrier definitions and could incite the porpoise to try to pass through the 'barrier' and consequently become entangled. Such behaviour has been described for harbour porpoise and humpback whales (Lien *et al.*, 1992; Lien *et al.*, 1995b; Lien, 1996). In contrast, sounds emitted by ten alarms are more likely to overlap and thus, present a continuous sound pattern along the string.

The fact that herring is one of the major prey species for porpoise in the BoF may offer an alternative explanation. Reduction of harbour porpoise catches in alarmed webs could have resulted from herring avoiding alarmed nets. If indeed porpoise became entrapped in nets while following herring, one would expect to find more herring in nets that entrapped porpoise than in nets without porpoise. However, results only supported this hypothesis in 1995.

It is often feared that active, acoustic devices could serve as "dinner bells" for marine mammals by indicating the location of nets with potential prey caught in it. However, we did not observe such an effect. Most damaged fish were scavenged by hagfish. Generally, number of scavenged fish did not markedly differ between experimental and control nets.

In addition, proportion of hagfish in porpoise stomachs did not vary depending on treatment of nets with porpoise bycatch (C. Hood, pers. comm.).

In contrast to the observed influence of alarm sounds on porpoise catch rate, changes in catch rates for most fish species are unlikely to be caused by the sound of the alarms or by any physical characteristic of the alarms, such as buoyancy changes.

If cod had responded to sounds, a difference between alarmed bridle webs and webs with silent alarms should have been detected, as well as differences between alarmed bridle webs and controls. However, no such differences were observed.

Similarly, if alarms had caused changes in the hydrodynamic characteristics of webs, differences between webs with alarms (silent and working) and control webs should be expected. Cod catches per web-day did not differ between treatments in 1995, when webs were much more ensonified than in 1994. It follows then that cod did not respond to the acoustic properties of alarmed webs in 1994.

It remains unclear what caused dogfish to approach webs with alarms more often than other webs. Particularly surprising is the attraction of dogfish to silent alarms in 1994. Dogfish may have perceived the electrical currents caused by the batteries in the alarms.

Ampullar receptors of sharks can detect DC fields mainly below 8 Hz (Zakon. 1981; Kalmijn. 1988; Heiligenberg, 1993) and smooth dogfish (*Mustelus canis*) responded in sea trials to electric fields from up to 40 cm away (Kalmijn. 1988). Since the batteries in the alarms were not connected to the buzzer. no current was produced and thus. dogfish could not have detected a magnetic field (J. de Bruyn. Dep. of Physics and Physical Oceanography. Memorial University of Newfoundland. pers. comm.). Nonetheless. the two terminals of each battery carry different voltages and could produce an electric field through movements of sea water ions corresponding to the voltage difference. Such a field would extend only a few centimetres away from the alarm and it is unlikely that dogfish could react to electric properties of alarms (J. de Bruyn and S. Morris. Dep. of Physics. University of Toronto. pers. comm.). Therefore. shark attraction to alarms remains unclear.

It is clear. however. that herring responded to alarm sounds. In 1995. catch rates of herring were lower in alarmed webs than in controls and Kraus *et al.* (1997) reported similar results. The difference between catch rates in alarmed bridle nets and 10 alarm nets can be explained by the short time alarmed bridle webs were employed. and by the few herring that were caught in these webs (156 fish. approximately 3% of herring catches in 1995). Alternatively. herring may have avoided the sound of alarmed bridle webs more than that of 10 alarm webs. since herring avoid pulsed sounds more than continuous sounds (Blaxter *et al.*, 1981).

Responses of fish to treatment were variable and generally inconclusive. However, since minimizing the effects of alarms was an important objective of this study, it is worth considering if fish could potentially hear alarm sounds and how they may respond.

Most marine teleosts can hear frequencies up to 1,000 Hz and a few species react to sounds up to 3,000 Hz (Chapman, 1973; Hawkins and Myrberg Jr., 1983). While cod is most sensitive to frequencies around 160 Hz, its sensitivity decreases markedly above 250 Hz (Hawkins, 1981; Hawkins and Myrberg Jr., 1983; Fay, 1988). The audiogram of pollock is similar, showing the highest sensitivity between 100 - 200 Hz and no reaction to sounds above 500 Hz (Chapman, 1973; Fay, 1988). The reaction of cod and pollock to sound varies, and although they generally avoid sounds below 160 Hz (Chapman, 1976), cod is attracted to pure, pulsed tones between 20 - 380 Hz (Blaxter, 1981a).

The hearing range of herring is wider and encompasses higher frequencies than those of other fish. This is due to the orientation of hair cells in the utricle, which is unique in vertebrates (Popper and Platt, 1979; 1993). Highest sensitivity lies between 30 - 120 Hz but herring also react to sounds of up to 10 kHz (Schwarz and Greer, 1984; Nestler *et al.*, 1992). Pulsed high frequency sounds elicit strong avoidance reaction in herring (Blaxter *et al*., 1981; Schwarz and Greer, 1984). Fishers use the fact that herring habituate to sounds (Blaxter, 1981a) to accustom the fish to vessel noise (Schwarz and Greer, 1984).

Sharks are most sensitive to low frequencies, with their highest sensitivity ranging from 100 - 1500 Hz (Nelson and Gruber, 1963; Myrberg *et al*., 1978; Hawkins and Myrberg Jr., 1983). They are generally attracted by low frequency, irregularly pulsed sounds that do not consist of pure tones (Nelson *et al*., 1969; Banner, 1972; Myrberg, 1972; Myrberg *et al*., 1972; Nelson and Johnson, 1972; Myrberg *et al*., 1976; Myrberg *et al*., 1978). The attractiveness of these sounds may be caused by their similarity to sounds produced by potential prey (but see Banner, 1972; Myrberg *et al*., 1976; Nelson and Johnson, 1976).

In sum, only herring is able to hear the sounds produced by the alarms. Therefore, with the exception of herring, differences in catch rates between webs of different treatments can not be explained by alarm sound.

4. CONCLUSIONS

4.1 CONSERVATION CONSIDERATIONS

This thesis is about a conservation effort. However. the concept of conservation often does not mean the same for the public. scientists. managers and fishers. During our research in the BoF. we observed several tens of thousands of dogfish being caught as bycatch. Most of them were dead when removed from the net (Anonymous. 1996b). In addition. some fishers mutilate surviving individuals since dogfish are considered to be a nuisance. as they have no commercial value for them (Anonymous. 1996b). Research and action to reduce this bycatch is desirable but there are no initiatives from fishers. scientists. managers or NGOs.

Like harbour porpoise. dogfish are long-lived. slowly reproducing animals with a life-span of up to 40 years and a gestation period lasting approximately 22 months (Scott and Scott. 1988). Although dogfish populations are not known to be endangered. it is important to pay attention to the relatively massive dogfish bycatch. Ignoring it would suggest narrowly focussed and unbalanced conservation efforts.

4.2 ACTIVE ACOUSTIC ALARMS

This study, along with others (Lien *et al.*, 1995b; Gearin *et al.*, 1996; Kraus *et al.*, 1997), showed that active acoustic devices can significantly reduce bycatch of harbour porpoise in groundfish gillnets. Nevertheless, use of active acoustic alarms to mitigate marine mammal bycatch is still viewed with skepticism (Dawson, 1994). It has been argued that even reduced bycatch may impact certain populations of marine mammals too much (Dawson, 1991; Dawson, 1994). Another line of argument maintains that alarms introduce yet another sound source into an environment that is already heavily burdened with anthropogenic sounds (Richardson *et al.*, 1995). For example, in the BoF, introduction of noise may impact negatively on the right whale (*Eubalaena glacialis*) population. In addition, the BoF supports an important herring fishery (Stephenson *et al.*, 1993). Fishers using herring weirs have expressed concern that ensonified gillnets could alter herring schooling behaviour and thus, reduce catches in weirs (Trippel *et al.*, 1996a).

Such arguments should not result in the dismissal of alarms as unsuitable management tools, but these concerns should be carefully addressed if alarms are to be considered for long-term use. Nonetheless, this study concludes that, until better means are developed, active acoustic devices are the most suitable, single tool to reduce harbour porpoise bycatch in groundfish gillnets without severely restricting fishing patterns.

4.3 THE MANAGEMENT APPROACH

The inclusive approach to manage the marine mammal/fisheries interaction on Grand Manan Island was successful in establishing a sound basis for cooperation and understanding between stakeholders. Fishers requested that the monitoring program continue and expressed that they consider alarms as a suitable tool to keep bycatch of harbour porpoise as low as possible (Whale Research Group. 1996).

However. working with actual fishery operations severely limits scientific work by introducing many potential sources of bias. If the inclusive approach is to be successful in future fisheries conflicts. understanding of and compliance with requirements of scientific processes have to be ensured since accepted solutions develop only from valid and reliable scientific results.
Paying fishers for their cooperation. or opening the fishery only to cooperating fishers causes problems regarding budget constraints. enforceability and acceptance by fishers. The MMPA. requiring fishers and managers to reduce marine mammal mortality to zero within a certain time frame. could offer a different way to motivate them to cooperate. If fishers initiate searches for solutions for bycatch. they usually are willing to accept certain negative impacts on their fishing. Similar results could be obtained by community-based approaches which turn fishers from resource-users only to users of as well as stewards for the resource.

However, the first step towards effective cooperation in any potential framework should be education. Only when fishers understand scientific processes and the reasons for the underlying rules, will they follow them. Similarly, only when scientists cooperate with fishers will they be able to effectively use the vast traditional knowledge of the fishing community. Consequently, long-term and stable relationships between scientists, fishers and managers are crucial and should not end with the completion of a project. Continuous and regular contact should become a standard tool to educate about and increase awareness of issues, results, opinions and values on all sides. Such contacts could be facilitated by workshops, news letters, TV and radio broadcasts c and similar tools.

5. REFERENCES

Alverson, D. L., Freeberg, M. H., Pope, J. G., and Murawski, S. A. 1994. A global assessment of fisheries bycatch and discards. Food and Agriculture Organization of the United Nations. Fisheries Technical Paper. 339. 233 pp.

Amundin, M., and Amundin, B. 1974. On the behaviour and study of the harbour porpoise, *Phocoena phocoena*, in the wild. Invest. Cetacea. 5: 317 - 328.

Andersen, S. 1970. Auditory sensitivity of the harbour porpoise *Phocoena phocoena*. Pp. 255 - 259. In *Investigations on Cetacea* 2 (Ed. Pilleri, G.). Institute for Brain Research, Bern.

Anonymous. 1996a. Annual Report 1995 - 1996. Fisheries and Aquaculture New Brunswick. P.O. Box 6000, Fredericton, N.B., E3B 5H1. 60 pp.

Anonymous. 1996b. Northwest Atlantic spiny dogfish. Maritimes Regional Advisory Process, Department of Fisheries and Oceans. DFO Atlantic Fisheries Stock Status Report. 96/76E. 3 pp.

Anthony, P. D. 1981. Visual contrast thresholds in the cod *Gadus morhua* L. J. Fish. Biol., 19: 87 - 103.

Arnold, P. W. 1972. Predation on harbour porpoise, *Phocoena phocoena*, by a white shark, *Carcharodon carcharias*. J. Fish. Res. Board Canada. 29: 1213 - 1214.

Au, W. W. L. 1994. Sonar detection of gillnets by dolphins: theoretical predictions. Rep. Int. Whal. Commn., Special Issue 15: 565 - 571.

Au, W. W. L., and Jones, L. 1991. Acoustic reflectivity of nets: implications concerning incidental take of dolphins. Mar. Mammal Sci., 7: 258 - 273.

Banner, A. 1972. Use of sound in predation by young lemon sharks, *Negaprion brevirostris* (Poey). Bull. Mar. Sci., 22: 251 - 283.

Barrett-Lennard, L. G., Ford, J. K. B., and Heise, K. A. 1996. The mixed blessing of echolocation: differences in sonar use by fish-eating and mammal-eating killer whales. Anim. Behav., 51: 553 - 565.

Blaxter, J. H. S. 1981a. Sensory performance, behavior, and ecology of fish. Pp. 203 - 232. In *Hearing and sound communication in fishes.* Eds. Tavolga, W. N., Popper, A. N., and Fay, R. R.). Springer-Verlag, New York.

Blaxter, J. H. S. 1981b. The swimbladder and hearing. Pp. 61 - 71. In *Hearing and sound communication in fishes.* Eds. Tavolga, W. N., Popper, A. N., and Fay, R. R.). Springer-Verlag, New York.

Blaxter, J. H. S., Denton, E. J., and Gray, J. A. B. 1981. Acousticolateralis system in clupeid fishes. Pp. 39 -61. In *Hearing and sound communication in fishes.* Eds. Tavolga, W. N., Popper, A. N., and Fay, R. R.). Springer-Verlag, New York.

Bloom, P. R. S., Goodson, A. D., Klinowska, M., and Sturtivant, C. R. 1995. The activities of a wild, solitary bottlenose dolphin (*Tursiops truncatus*). Aquat. Mamm., 21: 19 - 42.

Bravington, M. V., and Bisack, K. D. 1996. Estimates of harbour porpoise bycatch in the Gulf of Maine sink gillnet fishery, 1990-1993. Rep. Int. Whal. Commn., 46: 567 - 574.

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

Brown, M., and May, J. 1989. *The Greenpeace Story.* Prentice-Hall, Scarborough, ON. 160 pp.

Campbell. 1997. Rare and endangered fishes and marine mammals of Canada: COSEWIC Fish and Marine Mammal Subcommittee Status Reports: XI. Can. Field-Nat., 111: 249 - 257.

Chapman, C. J. 1973. Field studies of hearing in teleost fish. Helgolaender wiss. Meeresunters., 24: 371 - 390.

Chapman, C. J. 1976. Some observations on the reactions of fish to sound. Pp. 241 - 255. In *Sound Reception in Fish* Eds. Schuijf, A. and Hawkins, A. D.). Elsevier, Amsterdam.

Charles, A. T. 1995. The Atlantic Canadian groundfishery: roots of a collapse. Dalhousie Law Journal, 18: 65 - 83.

Cockcroft, V. G., and Ross, G. J. B. 1990. Bottlenose dolphins in Natal shark nets, 1980 through 1987: Catch rates and associated contributing factors. Pp. 115 - 127. In *Cetaceans and Cetacean Research in the Indian Ocean Sanctuary.* Marine Mammal Technical Report Number 3 Eds. Leatherwood, S. and Donovan, G. P.). United Nations Environment Programme, Nairobi, Kenya.

Coe, J. M., Holts, D. B., and Butler, R. W. 1984. The "tuna-porpoise" problem: NMFS dolphin mortality reduction research, 1970-81. Mar. Fish. Rev., 46: 18 - 33.

Crowley, P. H. 1992. Resampling methods for computation-intensive data analysis in ecology and evolution. Annu. Rev. Ecol. Syst., 23: 405 - 447.

Cui, G., Wardle, C. S., Glass, C. W., Johnstone, A. D. F., and Mojsiewicz, W. R. 1991. Light level thresholds for visual reaction of mackerel, *Scomber scombrus* L., to coloured monofilament nylon gillnet materials. Fish. Res., 10: 255 - 263.

Dawson, S. M. 1991. Modifying gillnets to reduce entanglement of cetaceans. Mar. Mammal Sci., 7: 274 - 282.

Dawson, S. M. 1994. The potential for reducing entanglement of dolphins and porpoises with acoustic modifications to gillnets. Rep. Int. Whal. Commn., Special Issue 15: 573 - 578.

Deutsch, M. 1973. *The resolution of conflict: constructive and destructive processes.* Yale University Press, New Haven, CT. 420 pp.

Dickson, W. 1989. Cod gillnet simulation model. Fish. Res., 7: 149 - 174.

Donovan, G. P., and Bjørge, A. 1995. Harbour porpoise in the North Atlantic: edited extract from the report of the IWC Scientific Committee, Dublin 1995. Rep. Int. Whal. Commn., Special Issue 16: 3 - 25.

Douglas, R. H., and Hawryshyn, C. W. 1990. Behavioural studies of fish vision: an analysis of visual capabilities. Pp. 373 - 418. In *The visual system of fish* Eds. Douglas, R. H. and Djamgoz, M. B. A.). Chapman and Hall, London.

Doulman, D. J. 1993. Community-based fishery management. Marine Policy, 17: 108 - 117.

Everitt, B. S. 1994. *A Handbook of Statistical Analyses using S-Plus.* Chapman and Hall, London. vi + 143 pp.

Fay. R. R. 1988. *Hearing in vertebrates: A psychophysics databook*. Hill-Fay Associates. Winnetka. Ill.

Fisher. R.. Ury. W.. and Patton. B. 1991. *Getting to Yes*. (2nd ed.). Penguin Books. New York. xix + 200 pp.

Fisheries Resources Conservation Council. 1997a. A groundfish conservation framework for Atlantic Canada. Report to the Minister of Fisheries and Oceans. Fisheries Resources Conservation Council. FRCC.97.R.3. 50 pp.

Fisheries Resources Conservation Council. 1997b. A report on gear technology in Eastern Canada. Report of the Gear Technology Subcommittee. Fisheries Resources Conservation Council. FRCC.97.R.1. 25 pp.

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

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

Gaskin. D. E.. and Blair. B. A. 1977. Age determination of harbour porpoise. *Phocoena phocoena* (L.). in the western North Atlantic. Can. J. Zool.. 55: 18 - 30.

Gearin. P. J.. Gosho. M. E.. Cooke. L.. DeLong. R.. Lake. J.. and Greene. D. 1996. Acoustic alarm experiment in the 1995 northern Washington marine setnet fishery. prepared by U.S. Department of Commerce. National Oceanic and Atmospheric Administration. National Marine Fisheries Service. National Marine Mammal Laboratory. Seattle. and Makah Tribal Fisheries Management Division. Neah Bay. 16 pp.

Geraci. J. R.. and Lounsbury. V. J. 1993. *Marine Mammals Ashore – A Field Guide for Strandings*. Texas A&M Sea Grant College Program. Galveston. Tex. xi + 305 pp.

Gilbert. J. R.. and Wynne. K. M. 1983. Harbor seal populations and marine mammal fisheries interactions. 1982. Northeast Fisheries Center. Second Annual Report. Contract NA-80-FA-C-00029. 52 pp.

Gilbert. J. R.. and Wynne. K. M. 1987. Harbor seal populations and fisheries interactions with marine mammals in New England. Final Report. Contract NA-84-EA-C-00070. ?? pp.

Goodson, A. D., Klinowska, M., and Bloom, P. R. S. 1994a. Enhancing the acoustic detectability of gillnets. Rep. Int. Whal. Commn., Special Issue 15: 585 - 595.

Goodson, A. D., and Mayo, R. H. 1995. Interactions between free-ranging dolphins (*Tursiops truncatus*) and passive acoustic gill-net deterrent devices. Pp. 365 - 379. In *Sensory Systems of Aquatic Mammals* Eds. Kastelein, R. A., Thomas, J. A., and Nachtigall, P. E.). DeSpil Publishers, Woerden, The Netherlands.

Goodson, A. D., Mayo, R. H., Klinowska, M., and Bloom, P. R. S. 1994b. Field testing passive acoustic devices designed to reduce the entanglement of small cetaceans in fishing gear. Rep. Int. Whal. Commn., Special Issue 15: 597 - 605.

Hall, P. (1995). *Land and Sea* [video]. Halifax: Canadian Broadcasting Corporation.

Hatakeyama, Y., Ishii, K., Akamatsu, T., Soeda, H., Shimamura, T., and Kojima, T. 1994. A review of studies on attempts to reduce the entanglement of the Dall's porpoise, *Phocoenoides dalli*, in the Japanese salmon gillnet fishery. Rep. Int. Whal. Commn., Special Issue 15: 549 - 563.

Hatakeyama, Y., and Soeda, H. 1990. Studies on echolocation of porpoise taken in salmon gillnet fisheries. Pp. 269 - 281. In *Sensory abilities of cetaceans: Laboratory and field evidence* Eds. Thomas, J. and Kastelein, R.). Plenum Press, New York.

Hawkins, A. D. 1981. The hearing abilities of fish. Pp. 109 - 137. In *Hearing and sound communication in fishes.* Eds. Tavolga, W. N., Popper, A. N., and Fay, R. R.). Springer-Verlag, New York.

Hawkins, A. D., and Myrberg Jr., A. A. 1983. Hearing and sound communication under water. Pp. 347 - 405. In *Bioacoustics: A Comparative Approach* (Ed. Lewis, B.). Academic Press, London.

Heiligenberg, W. 1993. Electrosensation. Pp. 137 - 160. In *The Physiology of Fishes* (Ed. Evans, D. H.). CRC Press, Boca Raton.

Hofman, R. J. 1990. Cetacean entanglement in fishing gear. Mammal Rev., 20: 53-64.

Hood, C. (in prep.). Unpublished Ph.D. thesis, Memorial University of Newfoundland, St. John's, NF.

Jefferson, T. A., and Curry, B. E. 1994. A global review of porpoise (*Cetacea: Phocoenidae*) mortality in gillnets. Biol. Conserv., 67: 167-183.

Jefferson, T. A., Würsig, B., and Fertl, D. 1992. Cetacean detection and responses to fishing gear. Pp. 663 - 684. In *Marine Mammal Sensory Systems* Eds. Thomas, J. A., Kastelein, R. A., and Supin, A. Y.). Plenum Press, New York.

Kalland, A. 1993. Management by totemization: whale symbolism and the anti-whaling campaign. Arctic, 46: 124 - 133.

Kalmijn, A. J. 1988. Detection of weak electric fields. Pp. 151 - 186. In *Sensory Biology of Aquatic Animals* Eds. Atema, J., Fay, R. R., Popper, A. N., and Tavolga, W. N.). Springer-Verlag, New York.

Karlsen, L. 1988 . Influence of the materials on the performance of fishing gears. Proceedings of the World Symposium on Fishing Gear and Fishing Vessel Design. St. John's, NF., 255 - 258.

Kastelein, R. A., de Haan, D., and Staal, C. 1995a. Behaviour of harbour porpoises (*Phocoena phocoena*) in response to ropes. Pp. 69 - 90. In *Harbour Porpoises - Laboratory Studies to reduce Bycatch* Eds. Nachtigall, P. E., Lien, J., Au, W. W. L., and Read., A. J.). DeSpil Publishers, Woerden, The Netherlands.

Kastelein, R. A., de Haan, D., Staal, C., Nieuwstraten, S. H., and Verboom, W. C. 1995b. Entanglement of harbour porpoises (*Phocoena phocoena*) in fishing nets. Pp. 91 - 156. In *Harbour Porpoises - Laboratory Studies to reduce Bycatch* Eds. Nachtigall, P. E., Lien, J., Au, W. W. L., and Read., A. J.). DeSpil Publishers, Woerden, The Netherlands.

Kastelein, R. A., Goodson, D. A., Lien, J., and de Haan, D. 1995c. The effects of acoustic alarms on harbour porpoise (*Phocoena phocoena*) behaviour. Pp. 157 - 167. In *Harbour Porpoises - Laboratory Studies to reduce Bycatch* Eds. Nachtigall, P. E., Lien, J., Au, W. W. L., and Read., A. J.). DeSpil Publishers, Woerden, The Netherlands.

Kastelein, R. A., Haan, D. D., Staal, C., and Goodson, A. D. 1997. The response of a harbour porpoise (*Phocoena phocoena*) to nets of various mesh sizes, with and without deterring sound. Pp. 385 - 409. In *The Biology of the Harbour Porpoise* Eds. Read, A. J., Wiepkema, P. R., and Nachtigall, P. E.). DeSpil Publishers, Woerden, The Netherlands.

Kastelein, R. A., Nieuwstraten, S. H., and Verboom, W. C. 1995d. Echolocation signals of harbour porpoises (*Phocoena phocoena*) in light and complete darkness. Pp. 55 - 67. In *Harbour Porpoises - Laboratory Studies to reduce Bycatch* Eds. Nachtigall, P. E., Lien, J., Au, W. W. L., and Read, A. J.). DeSpil Publishers, Woerden, The Netherlands.

Katona, S. K., Rough, V., and Richardson, D. T. 1993. *A Field Guide to Whales, Porpoises and Seals from Cape Cod to Newfoundland.* (4th ed.). Smithsonian Institution Press, Washington. xix + 316 pp.

Kenchington, T. J., and Halliday, R. G. 1994. A survey of fishing practices in the Scotia-Fundy Region groundfish longline fisheries. Can. Manuscr. Rep. Fish. Aquat. Sci., 2225: 642.

Koschinski, S. in press. Deterring harbour porpoises (*Phocoena phocoena*) from gillnets: passive reflectors vs. pingers. Pp. 19 pp. In *European Research on Cetaceans* (Ed. Evans, P. G. H.). European Cetacean Society, Cambridge.

Kraus, S. D., Read, A. J., Solow, A., Baldwin, K., Spradlin, T., Anderson, E., and Williamson, J. 1997. Acoustic alarms reduce porpoise mortality. Nature, 388: 525.

Krebs, J. R., and Davies, N. B. 1987. *An Introduction to Behavioural Ecology.* (2 ed.). Blackwell Scientific Publications, Oxford. ix + 389 pp.

Kröger, R. H. H., and Kirschfeld, K. 1993. Optics of the harbor porpoise eye in water. J. Opt. Soc. Am. A, 10: 1481 - 1489.

Lane, D. E., and Stephenson, R. L. 1995. Fisheries management science: the framework to link biological, economic and social objectives in fisheries management. Aquat. Living Resour., 8: 215 - 221.

Lien, J. 1980. Whale collisions with fishing gear in Newfoundland. Final Report to the Department of Fisheries and Oceans. 316 pp.

Lien, J. 1995. Conservation aspects of fishing gear: Cetaceans and gillnets. University of Alaska Fairbanks. Alaska Sea Grant College Program Report. No. 96-03: 219 - 224.

Lien, J. 1996 . The human and biological context of marine mammal by-catch, and a review of information on large whale collisions with fishing gear. Proceedings of the Workshop to assess the effectiveness and effects of acoustic devices for preventing or reducing the adverse effects of marine mammal-fishery interactions., Seattle, WA, March 20-22, 1996.

Lien, J., Barney, W., Todd, S., and Seton, R. 1992. Effects of adding sounds to cod traps on the probability of collisions by humpback whales. Pp. 701 - 709. In *Marine Mammal Sensory Systems* Eds. Thomas, J. A., Kastelein, R. A., and Supin, A. Y.). Plenum Press, New York.

Lien, J., and Fawcett, L. 1986. Distribution of basking sharks, *Cetorhinus maximus*, incidentally caught in inshore fishing gear in Newfoundland. Canadian Field Naturalist 100: 246 - 252.

Lien, J., and Hood, C. 1994. An investigation of acoustic devices to prevent harbour porpoise by-catch in groundfish gillnets, and recommendations from fishermen in the Bay of Fundy for future by-catch mitigation. Report to the Department of Fisheries and Aquaculture, Government of New Brunswick and the Department of Fisheries and Oceans, Scotia-Fundy Region. 23 pp.

Lien, J., Hood, C., Pittman, D., Borggaard, D., and Richter, C. 1995a . Field tests of acoustic devices on groundfish gillnets: assessment of effectiveness in reducing harbour porpoise by-catch. Proceedings of the NAFO/ICES Symposium on the Role of Marine Mammals in the Ecosystem, Dartmouth, N.S., September 6-8, 1995.

Lien, J., Hood, C., Pittman, D., Ruel, P., Borggaard, D., Chisholm, C., Wiesner, L., Mahon, T., and Mitchell, D. 1995b. Field tests of acoustic devices on groundfish gillnets: assessment of effectiveness in reducing harbour porpoise by-catch. Pp. 349 - 364. In *Sensory Systems of Aquatic Mammals* Eds. Kastelein, R. A., Thomas, J. A., and Nachtigall, P. E.). DeSpil Publishers, Woerden, The Netherlands.

Lien, J., Hood, C., and Richter, C. 1995c . Treating fishermen as people: an effective approach to solutions of whale by-catch problems. Proceedings of the Sixth International Symposium on Society and Resource Management, Pennsylvania State University, University Park, PA, May 18 - 23, 1995.

Lien, J., Hood, C., and Richter, C. 1996 . An inclusive approach to solving harbour porpoise (*Phocoena phocoena*) incidental capture in groundfish gillnets. Proceedings of the Annual Meeting of the Society for Conservation Biology, Victoria, B.C., June 7 - 9, 1997.

Lien, J., Stenson, G. B., and Ni, I. H. 1986 . A review of incidental entrapment of seabirds, seals and whales in inshore fishing gear in Newfoundland and Labrador: A problem for fishermen and fishing gear designers. Proceedings of the Worldwide Symposium on Fishing Gear and Fishing Vessel Design, Marine Institute, St. John's, NF: 67 - 71.

Lien, J., Todd, S., and Guigne, J. 1990. Inferences about perception in large cetaceans. especially humpback whales, from incidental catches in fixed fishing gear, enhancement of nets by 'alarm' devices and the acoustics of fishing gear. Pp. 347 - 362. In *Sensory Abilities of Cetaceans: Laboratory and Field Evidence* Eds. Thomas, J. A. and Kastelein, R.). Plenum Press, New York and London.

Manzer, R. 1984. Public policy-making as practical reasoning. Canadian Journal of Political Sciences. 17: 577 - 594.

Myrberg, A. A., Jr. 1972. Using sound to influence the behavior of free-ranging marine animals. Pp. 435 - 468. In *Behavior of Marine Animals - Current Perspectives in Research* 2 Eds. Winn, H. E. and Olla, B. L.). Plenum Press, New York.

Myrberg, A. A., Jr., Gordon, C. R., and Klimley, A. P. 1978. Rapid withdrawal from a sound source by open-ocean sharks. J. Acoust. Soc. Am., 65: 1289 - 1297.

Myrberg, A. A., Jr., Ha, S. J., Walewski, S., and Banbury, J. C. 1972. Effectiveness of acoustic signals in attracting epipelagic sharks to an underwater sound source. Bull. Mar. Sci., 22: 926 - 949.

Myrberg, A. A. J., Gordon, C. R., and Klimley, A. P. 1976. Attraction of free ranging sharks by low frequency sound, with comments on its biological significance. Pp. 205 - 228. In *Sound Reception in Fish* Eds. Schuijf, A. and Hawkins, A. D.). Elsevier, Amsterdam.

Nelson, D. R., and Gruber, S. H. 1963. Sharks: Attraction by low-frequency sounds. Science. 142: 975 - 977.

Nelson, D. R., and Johnson, R. H. 1972. Acoustic attraction of Pacific reef sharks: Effect of pulse intermittency and variability. Comp. Biochem. Physiol., 42A: 88 - 95.

Nelson, D. R., and Johnson, R. H. 1976. Some recent observations on acoustic attraction of Pacific Reef sharks. Pp. 229 - 239. In *Sound Reception in Fish* Eds. Schuijf, A. and Hawkins, A. D.). Elsevier, Amsterdam.

Nelson, D. R., Johnson, R. H., and Waldrop, L. G. 1969. Responses in Bahamian sharks and groupers to low-frequency, pulsed sounds. Bull. So. Calif. Acad. Sci., 68: 131 - 137.

Nestler, J. M., Ploskey, G. R., Pickens, J., Menezes, J., and Schilt, C. 1992. Responses of blueback herring to high-frequency sound and implications for reducing entrainment at hydropower dams. N. Am. J. Fish. Manag., 12: 667 - 683.

Norse, E. A. (Ed.) 1993. *Global Marine Biological Diversity*. Island Press, Washington, D.C. xxxii + 383 pp.

Norse, E. A. 1997. Bottom trawling: The unseen worldwide plowing of the seabed. The NEB Transcript, 8: 8 - 9.

Palka, D. 1996. Effects of Beaufort Sea State on the sightability of harbor porpoise in the Gulf of Maine. Rep. Int. Whal. Commn., 46: 575-582.

Palka, D. L., Read, A. J., Westgate, A. J., and Johnston, D. W. 1996. Summary of current knowledge of harbour porpoises in US and Canadian Atlantic waters. Rep. Int. Whal. Commn., 46: 559 - 565.

Parsons, L. S. 1993. Management of marine fisheries in Canada. Can. Bull. Fish. Aquat. Sci., 225: 763 p.

Partridge, J. C. 1990. The colour sensitivity and vision of fishes. Pp. 167 - 184. In *Light and Life in the Sea* Eds. Herring, P. J., Campbell, A. K., Whitfield, M., and Maddock, L.). Cambridge University Press, Cambridge.

Perrin, W. F., Donovan, G. P., and Barlow, J. (Eds.). 1994. *Gillnets and Cetaceans*. Rep. int. Whal. Commn. (Special Issue 15), Cambridge. 629 pp.

Peterson, J. H., Jr. 1993. Epilogue: Whales and elephants as cultural symbols. Arctic, 46: 172 - 174.

Polacheck, T. 1989. Harbor porpoises and the gillnet fishery. Oceanus, 32: 63-70.

Popov, V. V., Ladygina, T. F., and Supin, A. Y. 1986. Evoked potentials of the auditory cortex of the porpoise, *Phocoena phocoena*. J. comp. Physiol. A, 158: 705 - 711.

Popov, V. V., and Supin, A. Y. 1990. Electrophysiological studies of hearing in some cetaceans and a manatee. Pp. 405 - 415. In *Sensory Abilities of Cetaceans* Eds. Thomas, J. A. and Kastelein, R. A.). New Plenum Press, New York.

Popper, A. N., and Platt, C. 1979. The herring ear has a unique receptor pattern. Nature, 280: 832 - 833.

Popper, A. N., and Platt, C. 1993. Inner ear and lateral line. Pp. 99 - 136. In *The Physiology of Fishes* (Ed. Evans, D. H.). CRC Press, Boca Raton.

Prescott, J. H., and Fiorelli, P. M. 1980. Review of the harbor porpoise (*Phocoena phocoena*) in the US northwest Atlantic. Final Report to the US Marine Mammal Commission. NTIS PB80-176928 (unpubl.). 64 pp.

Read, A. J. 1994. Interactions between cetaceans and gillnet and trap fisheries in the Northwest Atlantic. Rep. Int. Whal. Commn., Special Issue 15: 133 - 147.

Read, A. J., and Gaskin, D. E. 1988. Incidental catch of harbour porpoises by gill nets. J. Wildl. Manage., 52: 517 - 523.

Read, A. J., and Gaskin, D. E. 1990a. Changes in growth and reproduction of harbour porpoises, *Phocoena phocoena*, from the Bay of Fundy. Can. J. Fish. Aquat. Sci., 47: 2158- 2163.

Read, A. J., and Gaskin, D. E. 1990b. The effects of incidental mortality on harbour porpoise (*Phocoena phocoena*) in the Bay of Fundy and Gulf of Maine. International Whaling Commission. SC/42/SM21. 18 pp.

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

Read, A. J., Kraus, S. D., Bisack, K. D., and Palka, D. 1993. Harbor porpoises and gillnets in the Gulf of Maine. Conserv. Biol., 7: 189 - 193.

Recchia, C. A., and Read, A. J. 1989. Stomach contents of harbour porpoises, *Phocoena phocoena* (L.), from the Bay of Fundy. Can. J. Zool., 67: 2140 - 2146.

Reeves, R. R., Hofman, R. J., Silber, G. K., and Wilkinson, D. 1996. Acoustic deterrence of harmful marine mammal-fishery interactions: proceedings of a workshop held in Seattle, Washington, 20-22 March 1996. U.S. Department of Commerce, National Oceanic and Atmospheric Administration. NMFS-OPR-10. 68 pp.

Richardson, W. J., Greene, C. R., Jr., Malme, C. I., and Thomson, D. H. 1995. *Marine Mammals and Noise*. Academic Press, San Diego. xi +576 pp.

Saul, J. R. 1992. *Voltaire's Bastards*. Vintage Books, New York. 640 pp.

Schwarz, A. L., and Greer, G. L. 1984. Responses of Pacific herring, *Clupea harengus pallasi*, to some underwater sounds. Can. J. Fish. Aquat. Sci., 41: 1183 - 1192.

Scott, J. S. 1982. Depth, temperature and salinity preferences of common fishes of the Scotian Shelf. J. Northw. Atl. Fish. Sci., 3: 29 - 39.

Scott. W. B.. and Scott. M. G. 1988. Atlantic Fishes of Canada. Can. Bull. Fish. Aquat. Sci.. 219: 731 pp.

Silber. G. K.. K. A. Waples and P. A. Nelson. 1994. Response of free-ranging harbour porpoises to potential gillnet modifications. Rep. Int. Whal. Commn.. Special Issue 15: 579 - 584.

Smith. G. J. D.. and Gaskin. D. E. 1974. The diet of harbor porpoises (*Phocoena phocoena* (L.)) in coastal waters of Eastern Canada. with special reference to the Bay of Fundy. Can. J. Zool.. 52: 777 - 782.

Smith. G. J. D.. and Gaskin. D. E. 1983. An environmental index for habitat utilization by female harbour porpoises with calves near Deer Island. Bay of Fundy. Ophelia. 22: 1 - 13.

Smith. G. J. D.. Read. A. J.. and Gaskin. D. E. 1983. Incidental catch of harbor porpoise. *Phocoena phocoena* (L.), in herring weirs in Charlotte County. New Brunswick. Canada. Fish. Bull.. U.S.. 81: 660 - 662.

Smith. R. J.. and Read. A. J. 1992. Consumption of euphausiids by harbour porpoise (*Phocoena phocoena*) calves in the Bay of Fundy. Can. J. Zool.. 70: 1629 - 1632.

Smith. T.. Palka. D.. and Bisack. K. 1993. Biological significance of bycatch of harbor porpoise in the Gulf of Maine demersal gillnet fishery. NOAA/NMFS/NEFSC. Northeast Fisheries Science Center. Reference Document. 93-23. 15 pp.

Smolowitz. R. J.. and Wiley. D. N. 1992 . Model for conflict resolution in marine mammal/fisheries interactions: The New England Harbor Porpoise Working Group. Proceedings of the Global Ocean Partnership Conference. Washington. D. C..19-21 October. 1992: 354 - 360.

Steele. D. H. 1963. Pollock (*Pollachius virens* (L.)) in the Bay of Fundy. J. Fish. Res. Bd. Canada. 20: 1267 - 1314.

Steele. D. H.. Andersen. R.. and Green. J. M. 1992. The managed commercial annihilation of northern cod. Newfoundland Studies. 8: 34 - 68.

Stephenson. R. L.. and Lane. D. E. 1995. Fisheries management science: a plea for conceptual change. Can. J. Fish. Aquat. Sci.. 52: 2051 - 2056.

Stephenson. R. L., Power, M. J.. Sochasky. J. B., Buerkle. U., Fife. F. J.. and Melvin. G. D. 1993. Biological evaluation of the 1992 4VWX herring fishery. DFO Atl. Fish. Res. Doc. 93/76. 80 pp.

Stone. G., Kraus. S.. Hutt. A.. Martin. S., Yoshinaga. A.. and Joy. L. 1997. Reducing by-catch: Can acoustic pingers keep Hector's dolphins out of fishing nets? MTS Journal. 31: 3 - 7.

Strong, M.. and Hanke. A. 1995. Diversity of finfish species in the Scotia-Fundy region. Can. Tech. Rep. Fish. Aquat. Sci., 2017: viii + 106 pp.

Todd. S.. Lien. J.. and Verhulst. A. 1992. Orientation of humpback whales (*Megaptera novaeangliae*) and minke whales (*Balaenoptera acutorostrata*) to acoustic alarm devices designed to reduce entrapment in fishing gear. Pp. 727 - 739. In *Marine Mammal Sensory Systems* Eds. Thomas. J. A.. Kastelein. R. A.. and Supin. A. Y.). Plenum Press. New York.

Todd. S.. and Nelson. D. 1994. A review of modifications to the webbing and setting strategies of passive fishing gear to reduce incidental bycatch of cetaceans. Rep. Int. Whal. Commn., Special Issue 15: 67 - 69.

Trippel. E. A.. Strong. M. B.. Hood. C.. Richter. C.. and Lien. J. 1996a. By-catch of harbour porpoise (*Phocoena phocoena*) in the lower Bay of Fundy gillnet fishery in 1995. DFO Atl. Fish. Res. Doc. 96/110. 13 pp.

Trippel. E. A.. Wang. J. Y., Strong. M. B., Carter. L. S.. and Conway. J. D. 1996b. Incidental mortality of harbour porpoise (*Phocoena phocoena*) by the gill-net fishery in the lower Bay of Fundy. Can. J. Fish. Aquat. Sci.. 53: 1294 - 1300.

Verboom. W. C.. and Kastelein. R. A. 1995. Acoustic signals by harbour porpoises (*Phocoena phocoena*). Pp. 1 - 39. In *Harbour Porpoises - Laboratory Studies to reduce Bycatch* Eds. Nachtigall. P. E.. Lien. J.. Au. W. W. L.. and Read. A. J.). DeSpil Publishers. Woerden. The Netherlands.

Wardle. C. S.. Cui. G.. Mojsiewicz. W. R.. and Glass. C. W. 1991. The effect of colour on the appearance of monofilament nylon under water. Fish. Res.. 10: 243 - 253.

Watts. P.. and Gaskin. D. E. 1985. Habitat index analysis of the harbor porpoise (*Phocoena phocoena*) in the southern coastal Bay of Fundy, Canada. J. Mamm.. 66: 733 - 744.

Westgate. A. J., Read. A. J., Berggren. P., Koopman, H. N., and Gaskin. D. E. 1995. Diving behaviour of harbour porpoises. *Phocoena phocoena*. Can. J. Fish. Aquat. Sci., 52: 1064 - 1073.

Whale Research Group. 1996. Further investigations of harbour porpoise by-catch in groundfish gillnets in the Bay of Fundy; and recommendations from fishermen fro future investigations and mitigation efforts. unpubl.: 16 pp.

Woodley. T. H., and Read. A. J. 1991. Potential rates of increase of harbour porpoise (*Phocoena phocoena*) population subjected to incidental mortality in commercial fisheries. Can. J. Fish. Aquat. Sci., 48: 2429 - 2435.

Zakon. H. H. 1981. The electroreceptors: diversity in structure and function. Pp. 814 - 850. In *Hearing and Sound Communication in Fishes.* Eds. Tavolga. W. N., Popper. A. N., and Fay. R. R.). Springer-Verlag, New York.

6. APPENDIX A: Data sheets

Data sheets used on Grand Manan Island in 1994 and 1995 to record haul information (haul sheet, Fig. 6.1), set information (set sheet, Fig. 6.2) and information on harbour porpoise bycatch (bycatch sheet, Fig. 6.3). Data sheets varied slightly between years due to changing experimental design.

MUN Whale Research - Summer of 1995 Grand Manan/Campobello
Daily Gear Characteristics and Haul Log

General Information

Observer		Date		Trip #	
Vessel #		Vessel Name		Prey?	

Hauling Time

Start		Finish		Total Time	

Net Location

Latitude		Longitude	

Net Information

# of Webs		Colour of Webs	
No. of Torn Webs		% of torn Webs	
Dist. to Shore		High Flyer #	
String #		Soak Time	
	LORAN		

ALARMED? NON-ALARMED? SILENT?

Samples

Fish Stomach Samples Taken? per string)	YES NO	Species
Harbour Porpoise By-Catch?	YES NO	Total

Surroundings Information

Weather		Cloud Cover		Visibility	
Wind Direction		Wind Speed		Tide Direction	
Tide R. or F.?		Secchi Depth		Bottom Topo.*	

CTD/Probe

CTD Cast Taken?	YES NO	Cast #		Time	
Probe on String?	YES NO				

*Sed. Types (for Bottom Topo.)
Mud Gravel SAnd
Rocky Clay SHells

Figure 6.1: Data sheet used to record information on hauling processes (haul sheet).

MUN Whale Research - Summer of 1995 Grand Manan/Campobello
Daily Gear Characteristics and Set Log

General Information

Observer		Date		Trip #	
Vessel #		Vessel Name		Prey?	

Set Time/Location

Start		Finish		Total Time	
Lat. & Long.		Net Depth		Set Orient.	

Net Information

# of Webs		String #	
Colour of Webs		LORAN	
Dist. to Shore		High Flyer #	

ALARMED? NON-ALARMED?

Weather Information

Weather		Cloud Cover		Visibility	
Wind Direction		Wind Speed		Tide Direction	
Tide R. or F.?		Secchi Depth		Bottom Topo.*	

CTD/Probe

CTD Cast Taken?	YES	NO	
Probe on String?	YES	NO	

Cast #	Time

Comments

*Sed. Types (for Bottom Topo.)
Mud Gravel SAnd
Rocky Clay Shells

Figure 6.2: Data sheet used to record information on setting processes (set sheet).

A alarmed
B silent alarm
C control

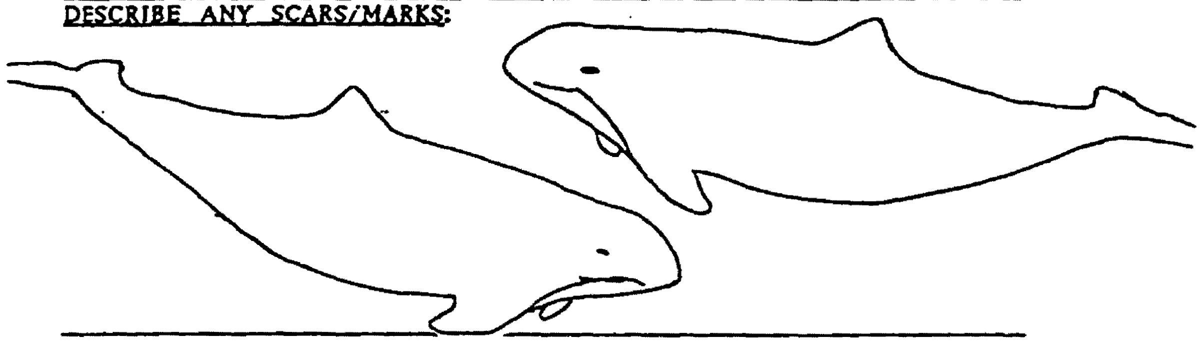
Harbour Porpoise By-Catch Record

Trip #:	Date:	Vessel:	Observer:
Haul #:	# of Nets:	Treatment Code:	Mesh Colour:
Species:	Time:	Lat.:	Long.:
Porpoise Take #:	Web # of Take:	# Floats/Web:	LORAN:

_____ Alarmed Net/
# of Floats to Next Bridle: _____

Distance from hole in net: _____
Dropout Rate: _____

DESCRIBE ANY SCARS/MARKS:



BIOLOGICAL DATA:

Sex: __________
Length: __________
Blubber: __________
Girth: __________

SAMPLES?:

Blubber: __________
Muscle: __________
Teeth: __________
Stomach: __________

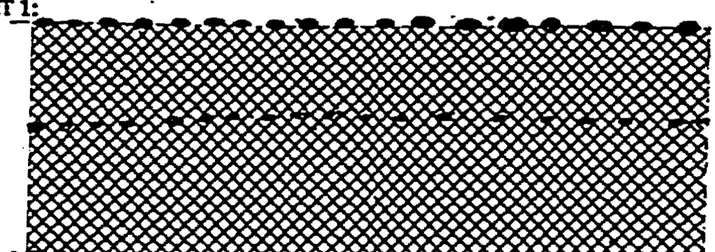
ANIMAL CONDITION:

Deg. of Decomp.: F M S
Deg. of Entg.: __________
How Entg.?: __________

10 Nearest fish stomachs?: Y _____ N _____
Species: __________

LOCATION OF PORPOISE IN NET:

NET 1:



COMMENTS:

Record on sample bags and on logs:
date/trip #/obser./haul or string #/web #/vessel/alarmed or non-alarmed/animal #

Figure 6.3: Data sheet used to record information on harbour porpoise bycatch (bycatch sheet).

7. APPENDIX B: Details of fishing effort in 1994 and 1995

Detailed summaries of fishing effort in 1994 and 1995 are provided in Tables 7.1 and 7.2, respectively. In 1994, most effort was concentrated in August and early September: only little fishing was carried out in 1995 after the temporary closure (Fig. 7.1). Spatial distribution of effort was similar in both years with most fishing being carried out in the Swallowtail area. Also, spatial distribution of treatments corresponded well with total effort in both years (Figs. 7.2 and 7.3). In addition, proportional effort per treatment varied only slightly over the course of the two seasons (Figs. 7.4).

Average depth varied considerably between weeks. Fishers preferred waters deeper than 100 m in August 1994 and moved into increasingly deeper waters in September 1995 (Fig. 7.5).

In general, soak-times longer than 60 hours were rare compared to shorter soak-times. In both years, most effort was carried out with webs soaking less than 36 hours (Tab. 7.3). Nevertheless, each soak-time category contained approximately the same proportion of effort per treatment (Tab. 7.3).

Use of the different coloured webs in 1994 and 1995 is shown in Figure 7.6. In both years, clear webs were used most frequently and blue webs were employed only rarely.

Colour and treatment were not independent (1994: $Chi^2 = 77.8$. $df = 4$. $p < 0.001$; 1995: $Chi^2 = 78.7$. $df = 4$. $p < 0.0001$). Alarmed bridle webs were more often green than expected in 1994. In the following year, 10 alarm webs were clear too often while control webs were clear less than expected (Tab. 7.4).

Table 7.1: Summary of observed effort in 1994.

Month	Day	No. of Trips	No. of Strings	No. of Webs	No. of web-days
July	9	1	5	15	10
"	11	3	15	46	73
"	12	3	16	51	46
"	14	4	21	66	65
"	15	4	17	53	50
"	16	3	15	48	68
"	17	1	2	6	5
"	18	4	22	69	128
"	19	4	13	42	40
"	20	3	17	51	66
"	21	1	5	18	18
"	27	3	15	48	49
"	28	2	8	25	23
"	29	2	9	29	28
"	30	1	4	14	12
August	1	5	26	80	116
"	2	5	26	80	78
"	3	4	16	48	49
"	4	4	21	65	77
"	5	1	5	17	33
"	6	4	21	63	126
"	8	4	20	62	120
"	9	4	18	54	40
"	10	5	22	68	65
"	11	4	18	54	68
"	12	2	11	33	30
"	13	1	5	15	14
"	15	3	15	45	76
"	16	3	15	45	41
"	17	3	16	48	45
"	18	2	11	33	31
"	19	2	10	30	28
"	20	1	3	9	9
"	22	1	1	3	9
"	23	4	21	63	51
"	24	5	25	75	69
"	25	5	25	75	71
"	26	6	24	74	68
"	27	2	8	24	42
"	29	3	11	33	67
"	30	5	17	52	133
"	31	4	13	39	49
September	1	4	18	55	100
"	2	4	16	50	72
"	3	4	13	38	37
"	7	4	21	63	247
"	10	1	2	6	6
TOTAL		148	678	2080	2740

Table 7.2: Summary of observed fishing effort in 1995.

Month	Day	No. of Trips	No. of Strings	No. of Webs	No. of Web-days
July	3	3	14	42	71
"	4	3	11	33	78
"	5	3	14	42	32
"	6	4	19	57	71
"	7	4	19	57	54
"	8	4	19	57	52
"	10	3	15	45	54
"	11	5	23	69	70
"	12	5	24	72	72
"	13	5	23	69	70
"	14	4	18	54	52
"	15	4	19	57	56
"	17	6	27	85	145
"	18	6	19	61	58
"	19	6	25	79	106
"	20	6	27	85	83
"	21	6	27	85	83
August	28	1	5	20	20
September	1	1	5	16	10
"	2	5	30	92	102
"	3	4	18	57	56
"	4	2	12	36	44
"	5	1	5	15	15
"	6	1	2	6	6
"	7	1	3	9	15
"	8	1	2	6	6
"	11	1	5	15	15
"	12	4	18	54	36
"	14	2	2	6	12
"	15	3	12	36	107
"	16	1	5	15	14
"	19	3	15	45	93
"	20	1	4	12	11
"	21	1	5	15	15
"	22	1	5	15	14
"	25	1	5	15	24
"	26	1	5	15	11
TOTAL		113	506	1549	1798

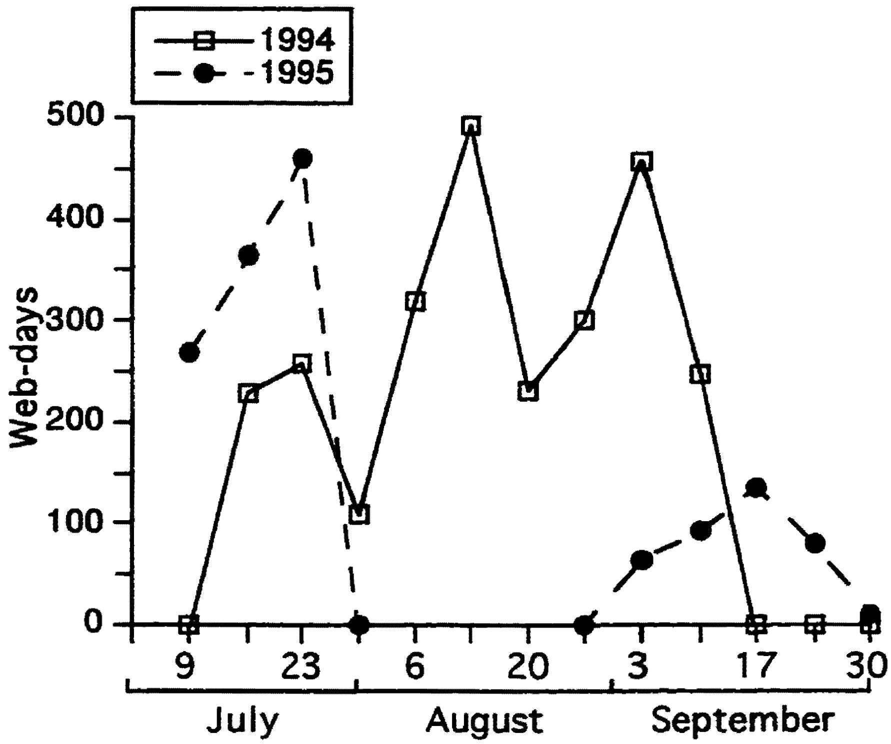


Figure 7.1: Weekly effort in 1994 and 1995. Gap indicates period of fishery closure

Figure 7.2: Spatial distribution of total effort and effort by treatment in web-days in 1994.

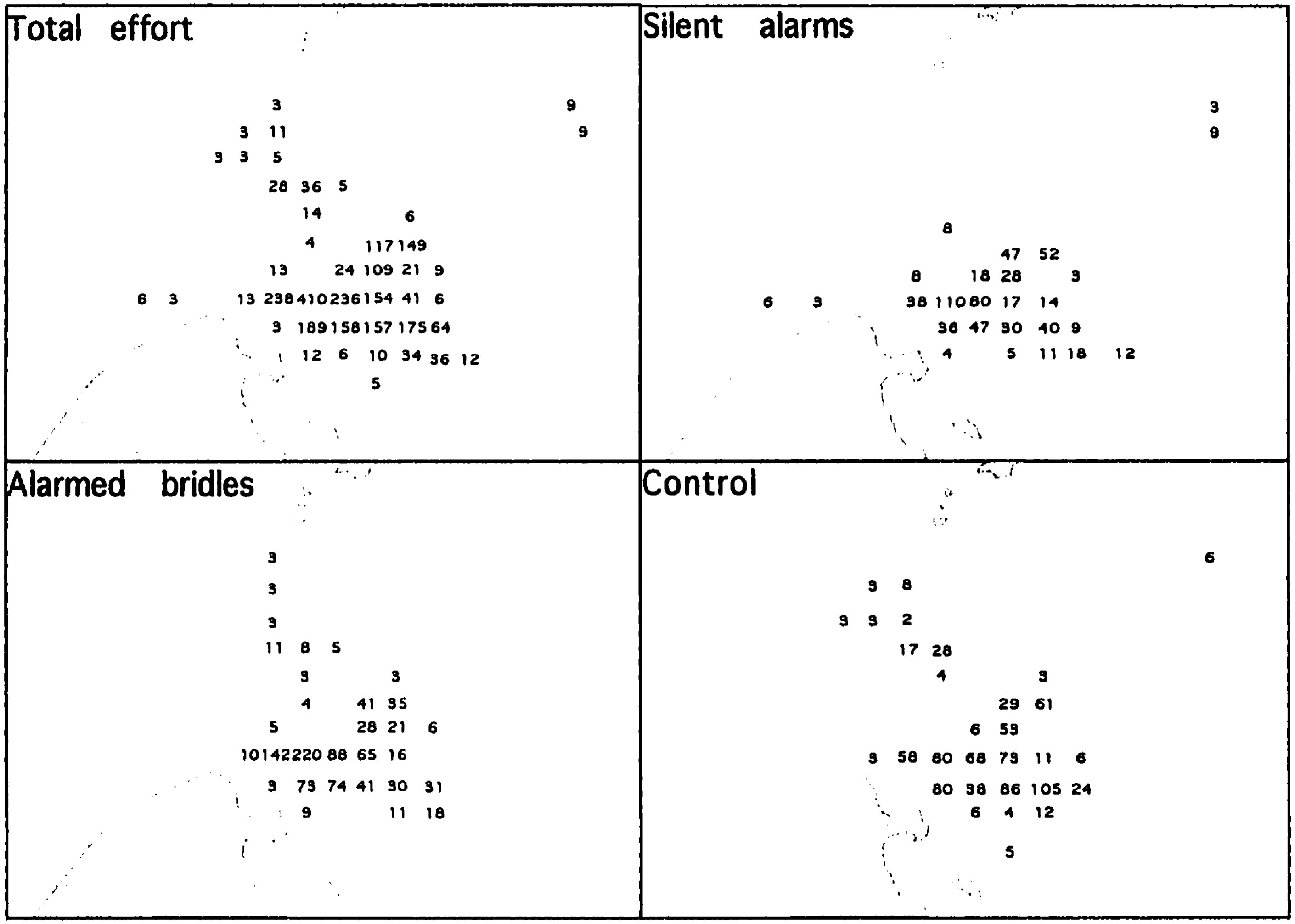
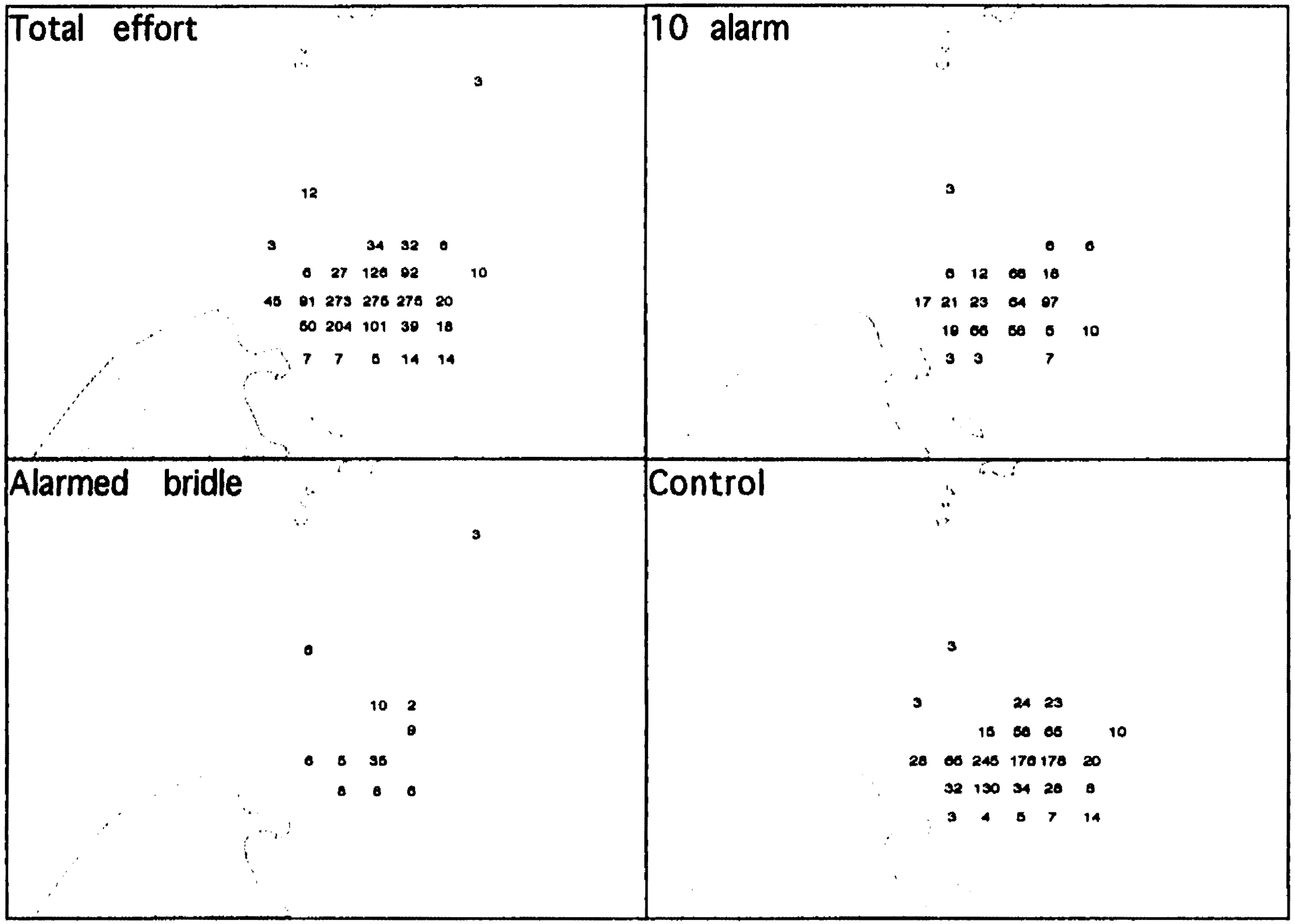

Total effort
3 9
3 11 9
3 3 5
28 36 5
14 6
4 117 149
13 24 109 21 9
6 3 13 238 410 236 154 41 6
3 189 158 157 175 64
12 6 10 34 36 12
5
Silent alarms
3
9
8
47 52
8 18 28 3
6 3 38 110 80 17 14
36 47 30 40 9
4 5 11 18 12
Alarmed bridles
3
3
3
11 8 5
3 3
4 41 35
5 28 21 6
10 142 220 88 65 16
3 73 74 41 30 31
9 11 18
Control
6
3 8
3 3 2
17 28
4 3
29 61
6 53
3 58 80 68 73 11 6
80 38 86 105 24
6 4 12
5

Figure 7.3: Spatial distribution of total effort and effort by treatment in web-days in 1995.


Total effort
3
12
3 34 32 6
6 27 126 92 10
45 91 273 276 276 20
60 204 101 39 18
7 7 5 14 14
10 alarm
3
6 6
6 12 66 18
17 21 23 64 97
19 66 56 5 10
3 3 7
Alarmed bridle
3
6
10 2
9
6 5 35
8 6 6
Control
3
3 24 23
16 56 65 10
28 66 245 176 178 20
32 130 34 26 8
3 4 5 7 14

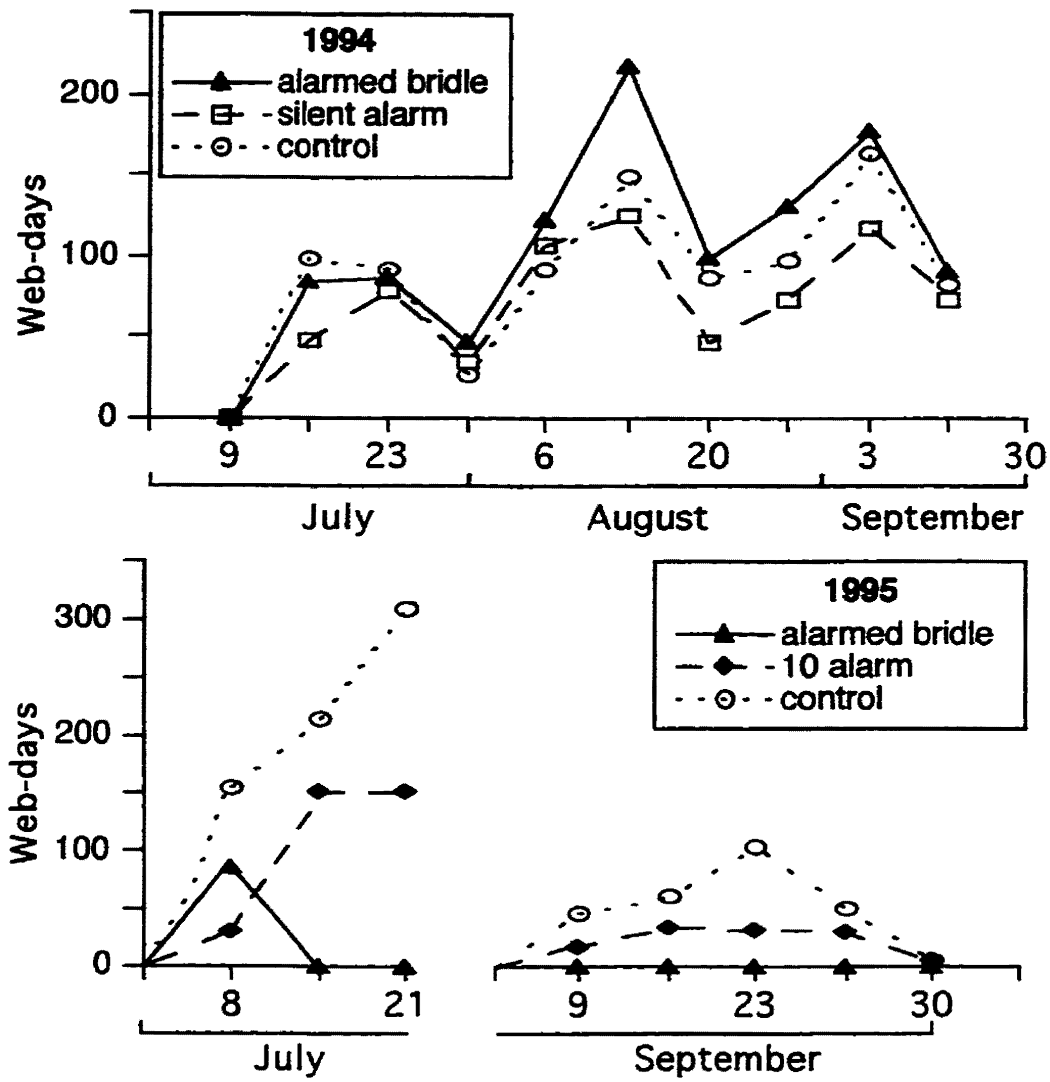


Figure 7.4: Weekly effort by treatment in 1994 and 1995. Gap indicates period of fishery closure.

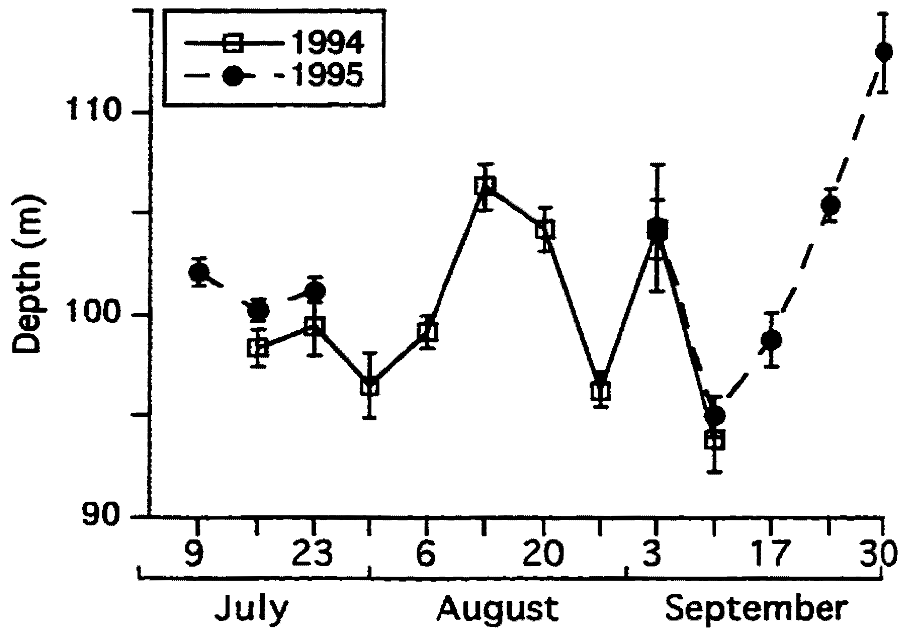


Figure 7.5: Changes in average depth per week in 1994 and 1995. Error bars represent ± 1 S.E.

Table 7.3: Effort according to soak-time and treatment categories in 1994 and 1995.

Year	Treatment	Soak-time category (hrs.)							
		≤ 36		≤ 60		≤ 84		> 84	
		web-days	%	web-days	%	web-days	%	web-days	%
1994	alarmed bridle	552	53	359	34	45	4	98	9
	silent alarm	337	48	229	33	46	7	89	12
	control	411	46	309	35	62	7	107	12
	total	1,299	49	897	34	153	6	293	11
1995	alarmed bridle	60	71	25	29	0	0	0	0
	10 alarm	352	79	81	18	12	3	0	0
	control	685	72	226	24	36	4	0	0
	total	1,097	74	332	23	48	3	0	0

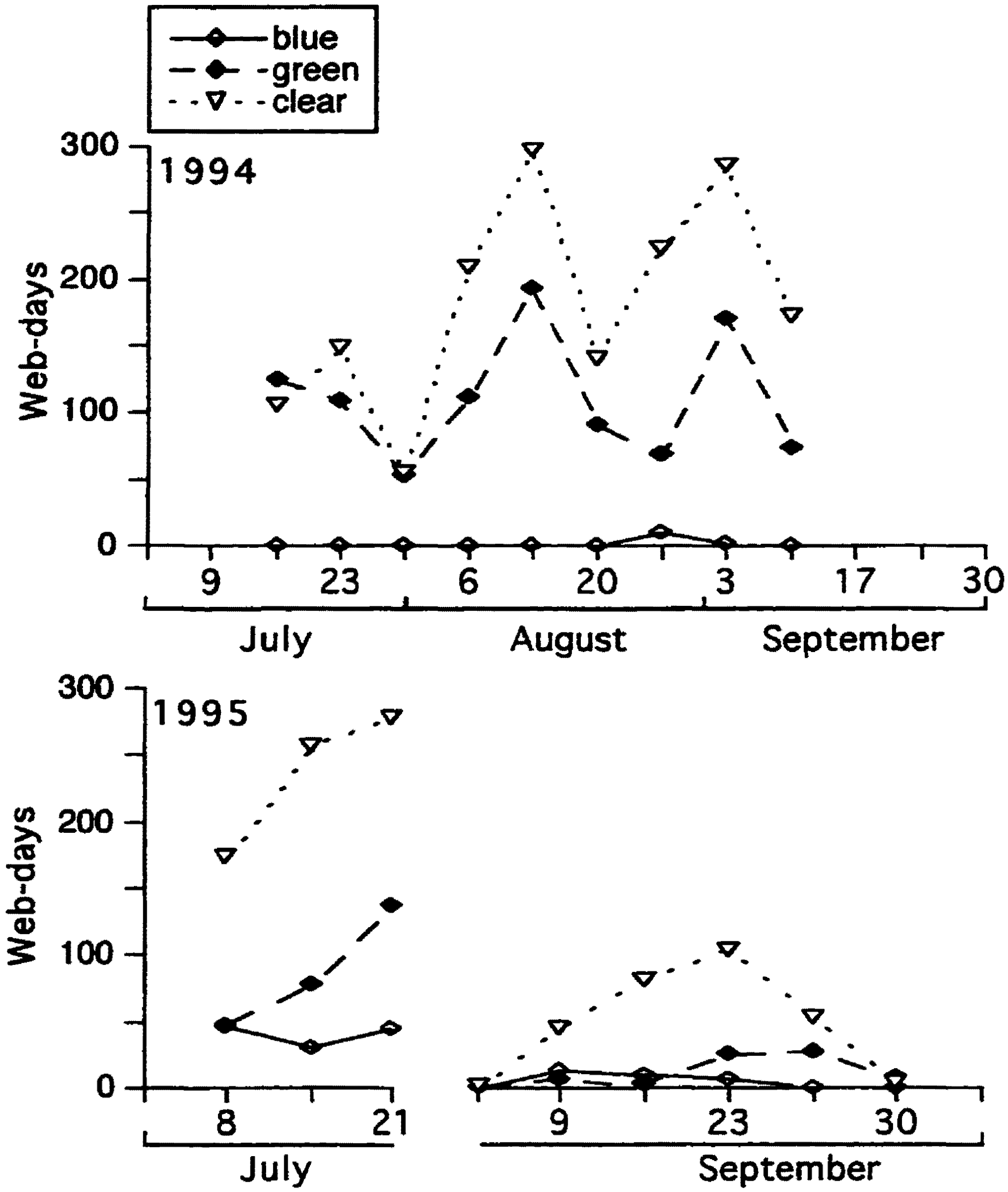


Figure 7.6: Weekly effort by web colour in 1994 and 1995. Gap indicates period of fishery closure.

Table 7.4: Effort according to colour and treatment categories in 1994 and 1995.

Year	Treatment	Web colour					
		blue		green		clear	
		web-days	%	web-days	%	web-days	%
1994	alarmed bridle	3	0.3	504	47.9	546	51.8
	silent alarm	7	1	192	27	502	72
	control	1	0.1	297	33.4	591	66.5
	total	10	0.4	993	37.6	1.639	62
1995	alarmed bridle	12	14	8	9	65	77
	10 alarm	10	2	82	19	352	79
	control	129	14	244	26	574	60
	total	151	10	334	23	991	67

8. APPENDIX C: Assessing uncontrolled factors as management tools

Although it was the purpose of this experiment to evaluate the effectiveness of alarms in reducing harbour porpoise bycatch, other factors relating to gear and setting characteristics were recorded, primarily to control for them in statistical analyses. However, it is worthwhile examining these factors for their usefulness in mitigating porpoise bycatch.

8.1 DATE

Most fish catches varied with date (Figures 8.1 and 8.2). This reflects movements of fish schools in and out of the bay as well as within it, which mirror seasonal changes and, short-term changes in environmental conditions, such as prey availability, water temperature or currents (Steele, 1963; Scott and Scott, 1988; Strong and Hanke, 1995).

Date did not influence catch rates of harbour porpoise, probably due to the low number of porpoise caught. However, catches were highest in August and early September confirming that porpoise move into the Bay early in July and leave the area around late September (Figures 8.1 and 8.2).

Temporal closures are a common practice in fisheries management (Parsons, 1993) and occurred in 1995 to divide quota into monthly allocations. Considering the peak in harbour porpoise bycatch in August and its limited geographic distribution, it seems possible to achieve a reduction in bycatch by closing the fishery during this period in the Swallowtail and Wolves areas. Such a fishery closure reduced bycatch considerably in 1995. However, over 70% of cod and pollock were caught during the same period in 1994. Therefore, closing the fishery to avoid porpoise bycatch is not a suitable solution.

8.2 DEPTH

Catches of all teleost species were affected by web depth during at least one year (Figures 8.3 and 8.4). Depth preferences for these fish are well established (Steele, 1963; Blaxter, 1981b; Scott, 1982; Scott and Scott, 1988). Typically, dogfish do not exhibit pronounced depth preferences (Scott, 1982; Scott and Scott, 1988) and their catches did not vary with depth. Depth was also important for porpoise bycatch in both years. CPUE was highest in webs set deeper than 70 m (Figures 8.3 and 8.4). Kraus *et al.* (1997) reported similar depths for 27 porpoise caught in gillnets in the GoM. Recent findings corroborate reports that harbour porpoise prefer deeper water (Smith and Gaskin, 1983; Watts and Gaskin, 1985). Observations of harbour porpoise diving behaviour using time-depth recorders showed that a large percentage of dives went to depths between 20 – 130 m (Westgate *et* *al*., 1995). Most of the nets monitored off Grand Manan Island were set within this range. Depths of porpoise entanglements examined by Westgate and colleagues fell also in the same range (A. Westgate, pers. comm.).

Thus, depths at which most porpoise are caught overlap with preferred depths for setting gillnets, and depth restrictions are not a suitable management tool to reduce porpoise bycatch.

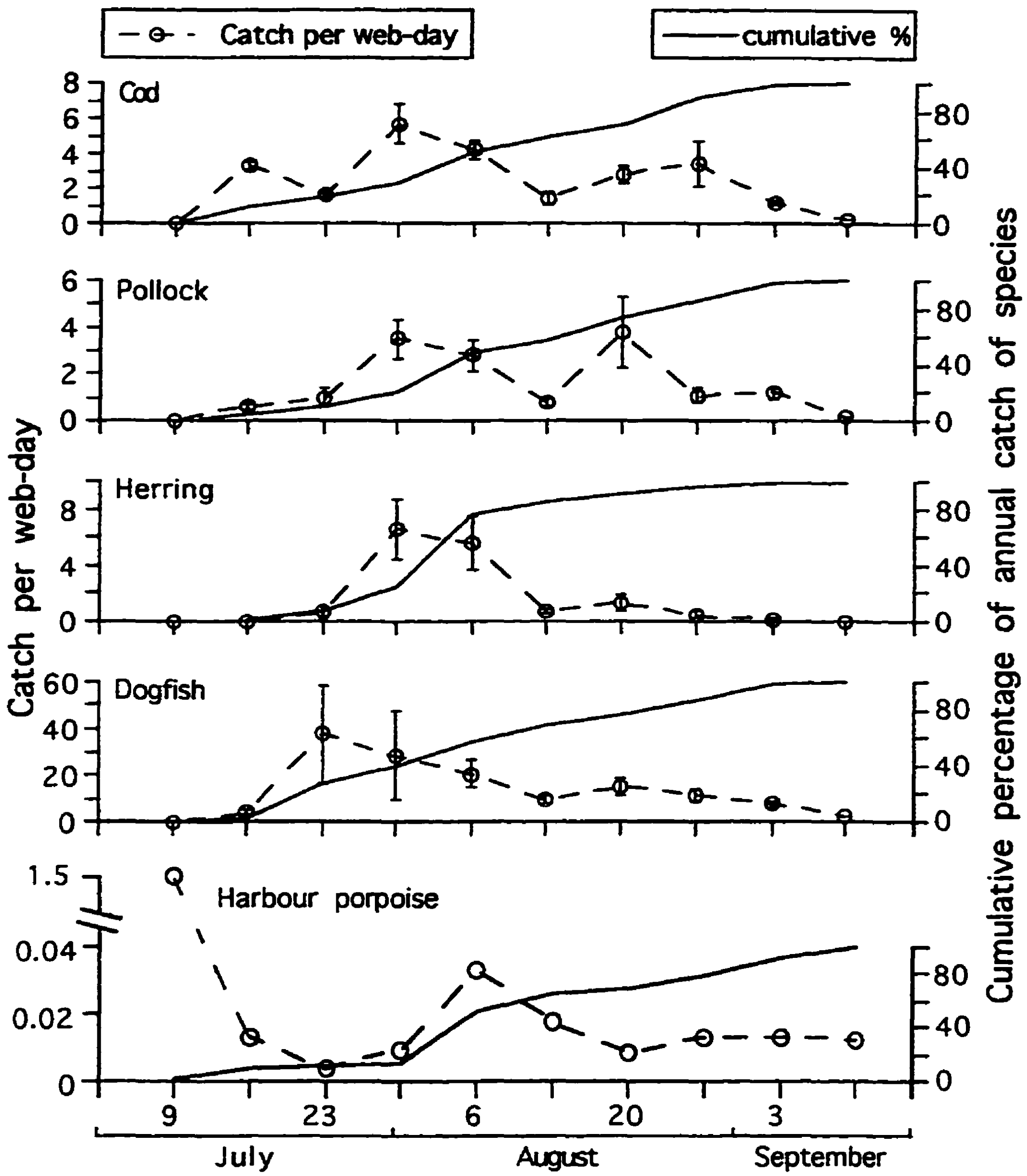


Figure 8.1: Weekly catch rates and proportion of total fish and harbour porpoise catches in 1994. Error bars represent ± 1 S. E.

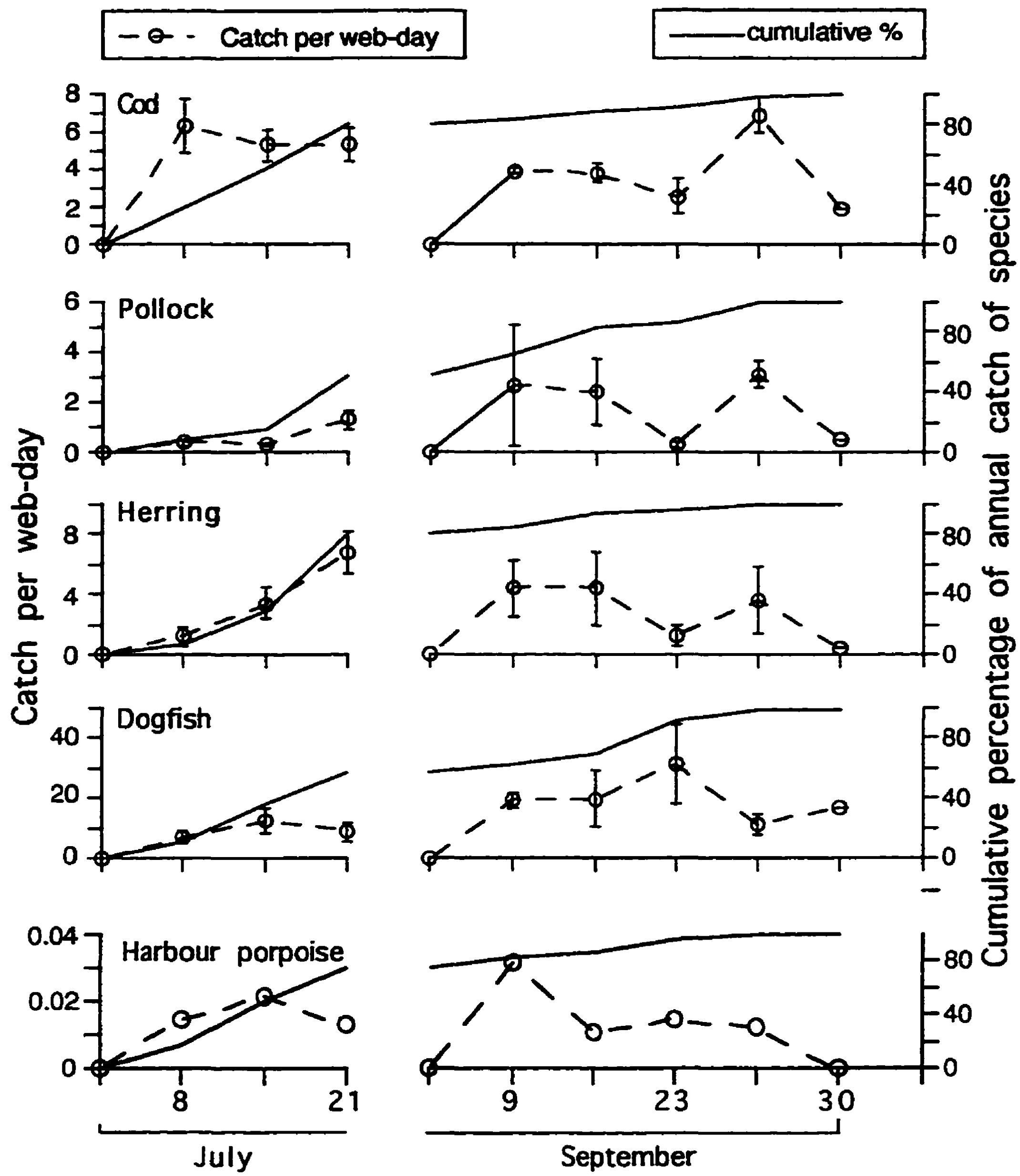


Figure 8.2: Weekly catch rates and proportion of total fish and harbour porpoise catches in 1995. Error bars represent ± 1 S. E. Gap indicates period of fishery closure.

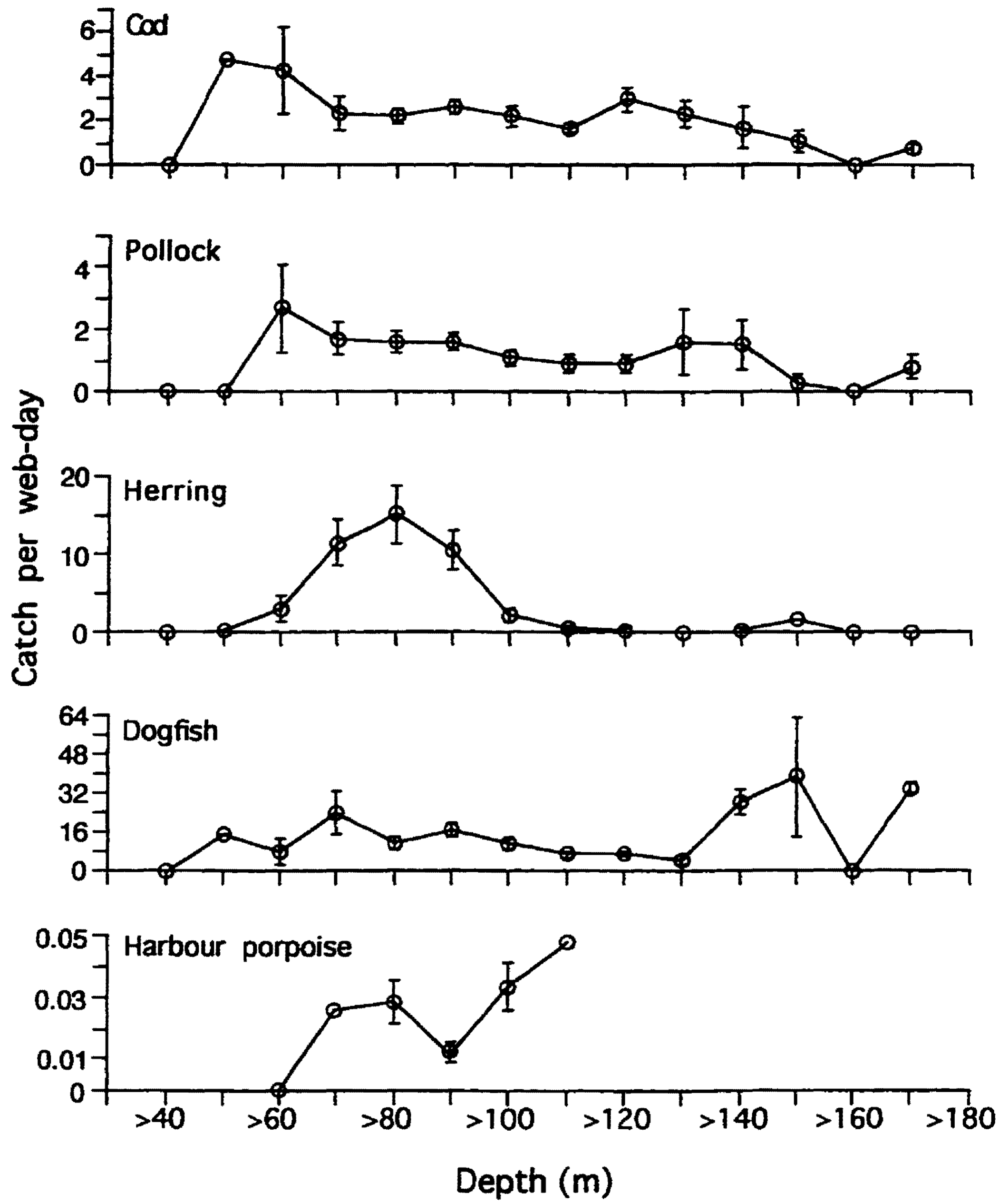


Figure 8.3: Relationship between catch rate (catch per web-day) and depth (m) for fish species and harbour porpoise in 1994. Error bars represent ± 1 S. E.

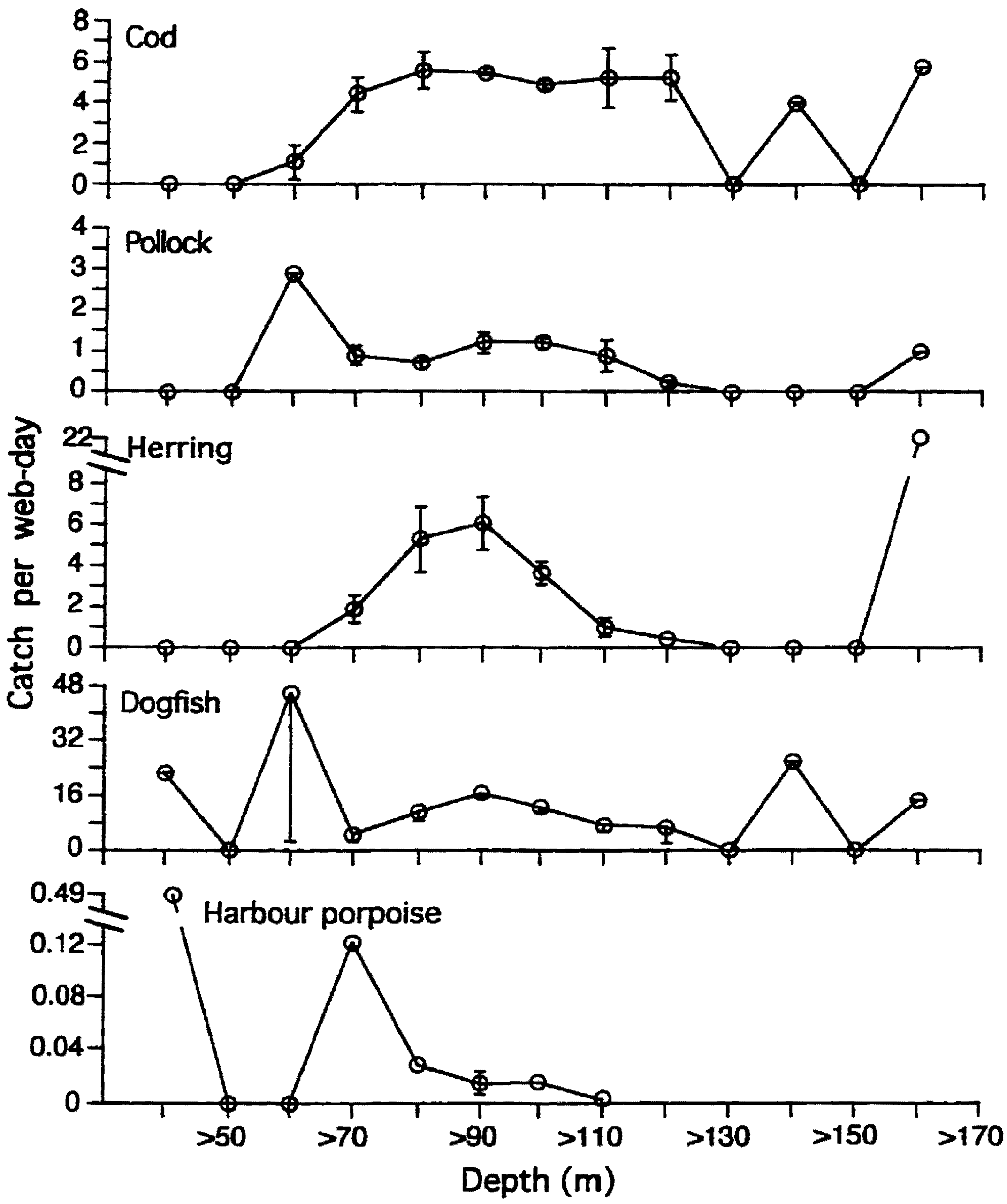


Figure 8.4: Relationship between catch rate (catch per web-day) and depth (m) for fish species and harbour porpoise in 1995. Error bars represent ± 1. S. E., except for dogfish where error bars indicate - 1 S. E. only.

8.3 SOAK-TIME

Soak-time influenced catch rates of fish significantly. The groundfish species as well as dogfish were caught more in webs soaking for up to 84 hours (Table 8.1). Kraus *et al.*(1997) observed a similar reduction in catch rates of cod in webs that remained in the water for > 3 days. Catch rates of harbour porpoise also were lowest in webs with the longest soak-time (Table 8.2). In contrast. Kraus *et al.* (1997) observed an increase in catch rate with longer soak-time.

It seems to be in the best interest of fishers to restrict the time their nets soak to less than 84 hours as fish catches generally decreased in nets soaking longer than 3 days and fish catches in these nets were more often scavenged by hagfish (*Myxine glutinosa*) and thus worthless to the fishers (T. Frost. Seal Cove. Grand Manan. pers. comm.; pers. observation). However. in almost all the cases where nets were left in the water for more than three days. poor weather conditions were the cause. Considering this and the difficulty of monitoring soak-times of nets. soak-time can not be used to reduce bycatch of porpoise.

However, the influence of soak-time on harbour porpoise catch rate points at entanglement at the bottom and not during haul or setting process. In addition. porpoise tagged with time-depth recorders dove deeper during nighttime than during daytime

(Westgate *et al.*, 1995). Deeper dives would bring porpoise closer to gillnets than shallow dives and increase the likelihood of entrapments during night when strings are fishing. In addition, analyses of body temperature and concentrations of various chemical elements in the vitreous humour of incidentally caught harbour porpoise seem to indicate that most porpoise were dead for several hours (Hood, in prep.). Hence, it is unlikely that porpoise were caught while strings were set the day before (more than 20 hours before data collection) or while strings were hauled (less than an hour before data collection).

Table 8.1: Statistical comparison (GLM, Scheffé post-hoc comparisons) of fish catches according to soak-time categories in 1994 and 1995. Numbers in brackets provide web-days. CPUE = Catch per web-day. Matching superscript letters denote significant differences. Level of significance for each pair is provided below table.

Year	Soak-time category	Cod		Pollock		Herring		Dogfish	
		CPUE	1 S. E.	CPUE	1 S. E.	CPUE	1 S. E.	CPUE	1 S. E.
1994	≤ 36 hrs. (1,299)	3.6[a, b]	0.13	2.0[d, e]	0.11	10.9[g, h]	0.80	19.3[j, k]	0.99
	≤ 60 hrs. (897)	1.3[c]	0.06	0.9[d, f]	0.08	6.1[i]	0.50	8.6[j]	0.94
	≤ 84 hrs. (153)	1.1[a]	0.13	0.8	0.13	2.6[g]	0.67	9.6	1.57
	> 84 hrs. (293)	0.3[b, c]	0.035	0.2[e, f]	0.03	2.1[h, i]	0.42	5.2[k]	0.88
1995	≤ 36 hrs. (1,097)	5.7[l]	0.18	1.2	0.08	4.0	0.27	12.4	0.70
	≤ 60 hrs. (332)	3.8[l]	0.29	0.8	0.15	5.2	0.76	9.3	1.20
	≤ 84 hrs. (48)	3.9	0.70	1.8	0.37	0.8	0.24	18.4	2.42

[g, i] $p < 0.05$
[c, e] $p < 0.01$
[a, f, h] $p < 0.005$
[l] $p < 0.001$
[b, d, e, j, k] $p < 0.0001$

Table 8.2: Catches of harbour porpoise according to soak-time categories in 1994 and 1995. Numbers in brackets provide web-days.

Year	Soak-time category	Porpoise catch per web-day	1 S.E.
1994	≤ 36 hrs. (1,300)	0.05	0.033
	≤ 60 hrs. (905)	0.01	0.005
	≤ 84 hrs. (153)	0.01	0.003
	> 84 hrs. (293)	0.0002	0.00020
1995	≤ 36 hrs. (1,097)	0.02	0.005
	≤ 60 hrs. (332)	0.01	0.006
	≤ 84 hrs. (48)	0.005	0.0038

8.4 WEB COLOUR

Catch rates of cod differed consistently between webs of different colour. Dogfish catches varied in 1994 as did pollock catches in 1995 (Table 8.3). It appears that fish must detect and respond to visual properties of nets at least under some conditions. Although gillnets are designed to be almost invisible, certain water and substrate conditions may render them visible to fish.

Experiments with divers as well as with photographs of nylon monofilament lines taken under water demonstrated that colour as well as the orientation of lines in relation to the water surface determined their visibility (Lien, 1980; Dickson, 1989; Wardle *et al.*, 1991). Although effects of web colour on fish catches have not yet been assessed through experiments with fish (Karlsen, 1988), results from these studies are applicable at least to cod, since cod has a comparable colour detection threshold to that of humans (Anthony, 1981). In addition to colour and material, visibility of objects under water depends also on light intensity, water turbidity, cloud cover, angle of incidence of sunlight and contrast (Dickson, 1989; Douglas and Hawryshyn, 1990; Partridge, 1990; Cui *et al.*, 1991; Wardle *et al.*, 1991). The variable catch rates of fish in response to colour in this project was probably due to fluctuations of these factors affecting visibility. Unfortunately, exact local information on these conditions is not available and visibility of different colours can not be predicted.

8.5 THE ALARMS

The housing and weight of alarms may have altered the hydrodynamic characteristics of nets. In preliminary tests in a flow tank, one alarm reduced the height of the floatline by approximately 10 % in currents ranging from 0 - 1.5 knots (C. Richter, unpubl. data) Lowering of the floatline should affect mainly catches of cod and pollock (P. He and J. Foster, pers. comm.). Although such a reduction of catches was not observed in 1995, further tests should be carried out to assess the influence of alarms on net hydrodynamics.

In sum, all factors examined here influence in one way or another porpoise bycatch as well as fish catches. Thus, using any of these factors to control bycatch could influence fishing yields and may not be accepted by the fishing industry.

Table 8.3: Statistical comparison (GLM, Scheffé post-hoc comparisons) of fish catches according to web colour in 1994 and 1995. Numbers in brackets provide web-days. CPUE = Catch per web-day. Matching superscript letters denote significant differences. Level of significance for each pair is provided below table.

Year	Web Colour	Cod		Pollock		Herring		Dogfish	
		CPUE	1 S. E.	CPUE	1 S. E.	CPUE	1 S. E.	CPUE	1 S. E.
1994	blue (10)	4.4	1.2	0.7	0.45	8.5	6.35	15.4	4.56
	green (993)	2.5[a]	0.13	1.7	0.14	9.9	0.98	13.2[b]	1.03
	clear (1,639)	2.8[a]	0.13	1.5	0.09	9.2	0.71	17.7[b]	1.01
1995	blue (151)	5.7[c]	0.37	0.8	0.13	3.6	0.59	8.1	1.01
	green (334)	4.9[c]	0.29	0.8	0.07	3.7	0.48	14.1	1.83
	clear (991)	5.5	0.21	1.3	0.10	4.3	0.33	12.0	0.69

[a, c] $p < 0.05$
[b] $p < 0.001$

9. APPENDIX D: Characteristics of bycaught harbour porpoise

9.1 INTRODUCTION

Bycatch might affect only certain segments of a harbour porpoise population(Read 1987. as cited in Smith *et al*., 1983; Cockcroft and Ross. 1990). For instance, groundfish gillnets may catch predominantly female porpoise since females tend to dive deeper than male porpoise (Westgate *et al*., 1995). Similarly, due to segregation by age, sex or social groupings (Amundin and Amundin. 1974; Smith and Gaskin. 1983; Smith *et al*., 1983), one section of the population may be bycaught more frequently than another. In order to examine if groundfish gillnets in the BoF catch porpoise selectively, several population characteristics of the bycaught porpoise were examined .

9.2 METHODS

The following data were collected from bycaught harbour porpoise immediately after they were retrieved from the net (after Read and Gaskin. 1990a; Read and Hohn, 1995):

1. Sex;
2. Length in cm, as measured from the tip of the rostrum to the notch of the fluke along a straight line, using a measuring tape
3. Girth in cm, as measured anterior to the dorsal fin, using a measuring tape.

9.3 RESULTS

In 1994, information on sex, length and girth was not collected until August. In 10 cases (23%), the porpoise dropped out of the net during the haul, before any information on sex or size could be obtained. Thus, only 29 animals were examined in detail. Sex and size of 18 porpoise (67%) were determined in 1995. Nine animals (33%) fell out of the net during haul before they could be retrieved.

Of the 29 animals whose sex and size were determined in 1994, more than half were female (Tab. 9.1). Most of them were caught in control and silent webs, whereas the majority of males were caught in control and alarmed-bridle webs (Tab. 9.1). In 1995, slightly more male than female porpoise were caught (Table 9.2). Control webs caught the majority of both sexes (Table 9.2).

Females were significantly longer and larger in girth than males (Tab. 9.3). Except for females caught in alarmed bridle webs and control webs in 1994, female and male porpoise caught in different treatments did not differ in length or girth (Tab. 9.3). Females dove deeper than males only in 1994 (Table 9.4). Females in 1994 were caught in webs soaking significantly longer than in 1995 (Table 9.4).

In 1994, two porpoise were caught in the same web in three instances. On August 1, two females of similar size were caught. Two porpoise caught on August 30 both dropped out of the net during hauling before any data could be collected. On September 7, a large female and a small male, possibly a mother and her calf, were caught in the same web. Two porpoise were found entangled in the same net on July 6, 1995. However, one of the porpoise fell out of the net before it could be retrieved. Therefore, no multiple catches per web were recorded for the second year.

Table 9.1: Summary of harbour porpoise bycatch according to sex and treatment categories in 1994.

	Number of porpoise			% of total bycatch: treatment (% of row total)	
Treatment	female	male	sum	female	male
alarmed bridle	2	4	6	33	67
silent alarms	7	3	10	70	30
control	7	6	13	59	41
sum	16	13	29	55	45
% of total bycatch: sex (% of column total)					
alarmed bridle	12	31	21		
silent alarms	44	23	34		
control	44	46	45		

Table 9.2: Summary of harbour porpoise bycatch according to sex and treatment categories in 1995.

	Number of porpoise			% of total bycatch: treatment (% of row total)	
Treatment	female	male	sum	female	male
10 alarm	1	1	2	50	50
control	7	9	16	44	56
sum	8	10	18	44	56
% of total bycatch: sex (% of column total)					
10 alarm	13	10	44		
control	87	90	56		

Table 9.3: Length and girth (cm) of harbour porpoise by treatment in 1994 and 1995. Two-sample t-tests were used to detect differences. Matching superscript letters denote significant differences. Levels of significance for each pair are provided below table.

Year	Sex	Treatment	N	Length (cm)		Girth (cm)	
				mean	1 S.E.	mean	1 S.E.
1994	Female	alarmed bridle	2	134.8 [c]	3.75	87	6
		silent alarms	7	144.8	6.19	90.5	2.85
		control	7	153.1 [c]	4.94	94.8	2.18
		total	16	147.2 [a]	3.68	92 [b]	1.75
	Male	alarmed bridle	4	141.3	3.56	88.7	2.43
		silent alarms	3	136.5	13.34	85.6	5.21
		control	6	127.4	6.73	84.4	1.95
		total	13	133.8 [a]	4.44	86 [b]	1.59
1995	Female	10 alarm	1	154.0	N/A	95.5	N/A
		control	7	152.7	2.39	93.6	2.8
		total	8	152.9 [d]	6.16	93.8 [e]	2.44
	Male	10 alarm	1	155.0	N/A	99.0	N/A
		control	9	130.9	6.35	82.7	3.0
		total	10	133.4 [d]	6.16	84.3 [e]	3.15

[a, b, c, d, e] $p < 0.05$

Table 9.4: Mean depth (m) and soak-time (hrs.) of female and male harbour porpoise bycatch in 1994 and 1995. Two-sample t-tests were used to detect differences. Matching superscript letters denote significant differences. Levels of significance for each pair are provided below table.

Year	Sex	N	Depth (m)		Soak-time (hrs.)	
			mean	1 S. E.	mean	1 S. E.
1994	Female	16	99.6[a]	2.73	42.9[b]	6.66
	Male	13	90.7[a]	2.78	36.5	4.68
1995	Female	8	95.9	3.26	26.5[b]	2.56
	Male	10	95.5	5.56	32.5	5.2

[a, b] $p < 0.05$

9.4 DISCUSSION

Typically, the ratio of females to males in sexually reproducing populations is 1:1 (Krebs and Davies, 1987) and samples of harbour porpoise taken by various means follow this distribution (Gaskin and Blair, 1977; Smith *et al.*, 1983; Read and Gaskin, 1990a; Read and Hohn, 1995). Although females dominated the sample in 1994, gillnets caught more males in 1995, and no skew in the sex of porpoise was obvious in this study .

Male harbour porpoise were significantly smaller than females which is typical for porpoise at any age (Gaskin, 1992). On average, female porpoise in the GoM/BoF were 11 - 17 cm longer than males (Read and Gaskin, 1990a) while the average difference in 1994 and 1995 was 15 cm and 20 cm, respectively. The difference between Read and Gaskin's (1990a) and the present estimate is likely due to limited number of porpoise examined.

Most female harbour porpoise attain physical and sexual maturity at 155 cm and four years of age (Gaskin and Blair, 1977). Based on this criterion, 31 % and 38 % of bycaught female porpoise were mature in 1994 and 1995, respectively. Using a more recent estimate of length at maturity (Read and Gaskin, 1990a), females longer than 143 cm are mature, resulting in 56 % and 100 % of mature, female porpoise in 1994 and 1995, respectively. Male harbour porpoise attain physical and sexual maturity at a length of approximately 145 cm (Gaskin and Blair. 1977), which suggests that 31% and 30% of the males retrieved in 1994 and 1995 were mature. respectively. Compared to published estimates (Read and Gaskin. 1990a; Read and Hohn. 1995), the proportion of mature animals from this study are either lower when using the estimate of length at maturity by Gaskin and Blair (1977), or higher when employing the estimate published by Read and Gaskin (1990a). However. Read and Hohn (Read and Hohn. 1995) recently suggested that porpoise older than 3.36 years are mature. which is almost one year younger than the age used in the estimations above. The proportion of mature porpoise in the present sample could be comparable to the 44 % published by Read and Hohn (1995) if individuals older than 3.36 years are considered. Since no length at maturity was provided. proportion of mature animals in the sample from Grand Manan could not be computed following the criterion of Read and Hohn (1995) . Alternatively, Read and Hohn (1995) detected significant differences in length measurements of the same porpoise taken at sea or on shore. Since all porpoise were measured at sea. length readings in the present study may be biased.

In sum. morphological measures of harbour porpoise in gillnets off Grand Manan Island indicate that this byatch does not affect sections of the population more than others. The length distribution of the porpoise in this sample agrees with published accounts of population parameters of the harbour porpoise in the BoF.

IMAGE EVALUATION TEST TARGET (QA-3)

150mm

6″

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