ASSESSING THE EFFECTS OF INDUSTRIAL ACTIVITY ON CETACEANS IN TRINITY BAY, NEWFOUNDLAND

by

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Abstract

The effects of industrial activity on cetaceans, including humpback whales (*Megaptera novaeangliae*), minke whales (*Balaenoptera acutorostrata*), and harbour porpoise (*Phocoena phocoena*), in Bull Arm, Trinity Bay, Newfoundland during 1992 (Todd *et al.*, 1996), 1994, and 1995 were assessed. Within-year measures of population abundance and distribution, and individual respiration could not detect effects with certainty. These measures were often too variable, too few, or confounded by effects of season and prey distribution.

Tracking individual animals within years provided some evidence of the short-term effects from industrial activity. In 1994, when dredging was the predominant activity, humpback whales were less likely to be resighted near the industrial activity and exhibited movement away from the site; no such changes were observed during blasting in 1992 (Todd *et al.*, 1996) or during vessel activity in 1995. Humpback resightings and residency were comparatively higher in 1995 than in other years. Furthermore, minke whale resightings occurred in an area of heavy vessel activity in 1995. Reactions by individual cetaceans appeared to depend on the type of industrial activity.

Resightings of individually identified animals between years suggested long-term effects of industrial activity on cetaceans. Humpback whales photo-identified in Trinity Bay in 1992 were observed less frequently in Newfoundland in 1993 than were whales

identified in other inshore bays. In addition, a lower proportion of humpback whales identified in Trinity Bay in 1992 were resighted in Newfoundland in 1993 compared with animals identified in an undisturbed area. Individual minke whales were resighted in the industrial area in a subsequent year. Individually identified whales, monitored for several years, were a more sensitive indicator of long-term impacts of anthropogenic activity than abundance, distribution, and respiration measures.

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1. Introduction

1.1. Increased ambient noise levels in the ocean

Noise levels in the marine environment have increased with the increased use of technology (Green *et al.*, 1994). Anthropogenic noise often dominates the underwater sound spectra at low frequencies (<1000 Hz), producing higher energy levels than noise from natural sources such as wind, waves, or precipitation (Wenz, 1962). Although high-frequency sound components (≥1000 Hz) attenuate rapidly in water, low-frequency components can travel with far less loss in energy (Spindel and Worcester, 1990).

Industrial activity, geophysical research, ocean acoustics, and biological oceanography all generate low-frequency sounds (Green *et al.*, 1994). These anthropogenic sounds are often described as either continuous or transient (Greene and Moore, 1995). Marine dredging and construction are examples of continuous noises, usually detectable within only 20-25 km (due to attenuation loss in shallow water); underwater explosions are examples of strong, transient noises sometimes detectable thousands of kilometers away (Greene and Moore, 1995). Thus, anthropogenic sounds are capable of altering the underwater environment at great distances from the sound source (Greene and Moore, 1995).

1.2. The importance of sound to marine mammals

Little is known about the hearing abilities of marine mammals (Herman and Tavolga, 1980), but it is assumed they are sensitive to sounds in the frequency range of their vocalizations (Turl, 1982; Reeves, 1992). Odontocetes (toothed whales) usually emit sounds above 2000 Hz, and not below 500 Hz; whereas mysticetes (baleen whales) mainly produce sounds below 2000 Hz (Payne and Webb, 1971). There are no direct measurements on the auditory sensitivities of mysticetes, but direct measurements on odontocetes indicate they are particularly sensitive to sounds above ~10, 000 Hz (Richardson, 1995c). Studies of ear anatomy provide additional support as to the potential hearing ranges of odontocetes and mysticetes: odontocetes are more sensitive to high-frequency sounds and mysticetes to low-frequency sounds, including infrasonics in some species (Ketten, 1991, 1992).

Audition is probably the most important sensory system for both odontocetes and mysticetes (Fobes and Smock, 1981). Marine mammals apparently use sound for communication, orientation, navigation, and foraging (e.g. Herman and Tavolga, 1980; Watkins and Wartzok, 1985; Clark, 1990a). Ketten (1991, 1992) suggests that differences in odontocete and mysticete ear anatomy and sensitivity are correlated with differences in habitat and feeding. For instance, odontocetes use high-frequency sounds to find prey, while mysticetes may use low-frequency sounds to communicate over longer distances, and infrasonics to map the ocean floor during migrations (Ketten, 1992; see for references). Marine mammals are dependent upon sound so they could be vulnerable to noise disturbance (Reeves, 1992).

Marine mammals evolved in a naturally noisy environment (e.g. noise from wind and waves; Green *et al.*, 1994; Ketten, 1995), and hence could have features that enable them to tolerate changing underwater noise levels (Green *et al.*, 1994; Ketten, 1995; Richardson and Würsig, 1995). Auditory features that prevent barotrauma could lessen impacts from high noise levels (Ketten, 1995). Odontocetes have been shown to alter the frequency or sound level of their vocalizations in response to changing ambient noise conditions (Richardson, 1995c). In addition, acoustic signals of baleen whales may have evolved to occur below the frequencies generated by wind noise (Payne and Webb, 1971). However, anthropogenic noise such as motorized shipping has only been present in the ocean since the early 1800's (Payne and Webb, 1971). Marine mammal hearing may be less well suited for some modern day noise levels (Ketten, 1995).

1.3. Potential impacts

The impact of increased levels of low-frequency sounds on marine mammals is of concern, but is poorly understood at present (Cowles and Imm, 1988; Clark, 1990b; Reeves, 1992; Green *et al.*, 1994). Effects could be short-term such as behavioural reactions, stress, disorientation, disruption in communication by masking, or long-term such as physiological problems, displacement from important habitats, or population decline (Norris and Reeves, 1978; Geraci and St. Aubin, 1980; Turl, 1982; Myrberg, 1990; Lien *et al.*, 1995).

Temporary hearing damage resulting from short-term exposure to high noise levels could lead to a decreased ability to navigate, or find prey and conspecific whales (Richardson and Malme, 1995). Continued exposure to high noise levels, or short-term exposure to extremely high sound levels, could cause death or permanent hearing damage (Richardson and Malme, 1995). Marine mammal fatalities associated with underwater explosions have been documented (e.g. Fitch and Young, 1948). In addition, marine mammals have shown signs of auditory damage when exposed to underwater blasts (Ketten *et al.*, 1993; Ketten, 1995). Given the potential negative effects of anthropogenic sounds on marine mammals, it is important that they are adequately investigated (Green *et al.*, 1994).

1.4. Investigations of effects of low-frequency sounds on cetaceans

1.4.1. Short-term effects

Most studies on the effects of anthropogenic low-frequency sound on cetaceans have investigated short-term behavioural responses (Richardson, 1995b). Although many are concerned with impacts of low-frequency noise on baleen whales, studies have found that odontocetes may also respond if the anthropogenic activity occurs at high noise levels or contains high-frequency components (Richardson, 1995b). Short-term responses are usually assessed using changes in measures such as abundance, distribution, respiration, and orientation (e.g. Richardson *et al.*, 1986; Richardson *et al.*, 1987; Cosens and Dueck, 1988; Ljungblad *et al.,* 1988; Malme *et al.*, 1988; Bauer *et al.*, 1993; Tyack, 1993; Mate *et al.*, 1994; Richardson *et al.,* 1995).

Malme *et al.* (1983) studied behaviour of migrating gray whales (*Eschrichtius robustus*) off the coast of California, and found that whales changed direction of travel in response to playbacks of a drilling platform at distances of 2-3 km. Migrating bowhead whales (*Balaena mysticetus*) in the Beaufort Sea avoided drillships and their support vessels by distances of 9.5 km (LGL and Greeneridge, 1987). In addition, Richardson *et al.* (1985a) found that bowhead whales in the Beaufort Sea moved away from vessels approaching within 1-4 km, and changed their respiration and dive patterns. Belugas (*Delphinapterus leucas*) and narwhals (*Monodon monoceros*) exhibited a change in distribution in response to vessel activity (Finley *et al.*, 1990). Bowles *et al.* (1994) discovered that sperm whales (*Physeter macrocephalus*) ceased vocalizing when exposed to high energy, low-frequency sound. Although short-term behavioural responses to anthropogenic noise are sometimes detected in such studies, these impacts are of less concern than long-term impacts (Richardson, 1995a).

1.4.2. Long-term effects

Few studies have been able to assess the long-term effects of anthropogenic activity on marine mammals (Richardson, 1995b). It has been suggested that gray whales abandoned a winter breeding ground during a period of increased vessel activity, but reoccupied the area when the activity stopped (Gard, 1974; see Reeves, 1977 for additional references). Biggs (1991, *in* Reeves, 1992) proposed that killer whales (*Orcinus orca*) abandoned a beach area due to increased human activity. Increased entrapment of humpback whales (*Megaptera novaeangliae*) in fishing gear, due possibly to loss of orientation, was suggested as a long-term effect of underwater blasting (Todd *et al.*, 1996). Reported effects of anthropogenic activity are sometimes anecdotal (Malme *et al.*, 1983; Green *et al.*, 1994; Richardson, 1995b); studies that can adequately assess potential long-term effects are needed (Richardson, 1995a).

Short-term responses to anthropogenic sounds do not necessarily indicate long-term impacts (Richardson *et al.*, 1985a; Richardson *et al.*, 1987; Reeves, 1992; Richardson and Würsig, 1995). For example, bowhead whales ceased feeding and moved away from an area during dredging-sound playbacks (Richardson *et al.*, 1990), but long-term consequences to individuals were unknown. Humpback whales have been shown to alter their songs on the mating grounds in response to vessel traffic (Norris, 1994). The reproductive success of individuals affected (Richardson and Würsig, 1995), is unknown (Norris, 1994). Richardson *et al.* (1985b) suggest that, compared to migration costs, short interruptions of feeding or short displacement probably do not result in significant impacts, unless there is repeated disturbance to the same individuals. Long-term studies are needed to determine the consequences of the repetitive short-term changes observed in many studies (Richardson and Würsig, 1995).

1.4.3. Lack of demonstrated effects

Not all studies have detected behavioural responses by cetaceans to anthropogenic activity. Fraker *et al.* (1981, *in* Malme *et al.*, 1983) found feeding bowhead whales close to a site with dredge, barge, and tug activity. In addition, Fitch and Young (1948) reported that gray whales did not abandon an area during underwater explosions. Although migrating bowheads in the Beaufort Sea respond to drilling activity, they were reported less than 1 km from a dredge and 4 km from drillships (Richardson *et al.*, 1985a). Richardson *et al.* (1987) noted that bowheads continued to occupy an area with anthropogenic activity over a number of years. Such results indicate tolerance of, or habituation to, anthropogenic noise by marine mammals (Richardson, 1995b). Alternatively, these results may indicate that measurements have not been sensitive enough to detect effects.

1.5. Difficulties in interpreting such studies

There are many factors that could make detecting impacts difficult. For instance, behavioural responses vary between individual whales, and may depend on the type of noise source, ongoing activity of the whale, and the animal's previous experience (Myrberg, 1990; Richardson and Greene, 1993; Richardson and Malme, 1995). Whales could exhibit a lesser response to anthropogenic activity on their feeding grounds, due to habituation, than on their migration routes (Richardson *et al.*, 1990). Specific sound qualities could be important; continuous sounds may produce greater reactions than transient sounds at similar pressure levels (Green *et al.*, 1994). In addition, whales may respond more to rapidly changing sounds compared with constant sounds (Richardson *et al.*, 1985a, b; Richardson, 1995b). Thus, a lack of demonstrated short-term behavioural change does not necessarily indicate that there are no effects (Richardson and Würsig, 1995; Todd *et al.*, 1996).

Studies that have not detected effects of anthropogenic noise on marine mammals should be treated with some degree of caution. A study on the distribution of humpbacks in response to playbacks of industrial activity in Alaska did not report significant changes in local populations, but individual animals were not tracked (Malme *et al.*, 1985). Todd *et al.* (1996) reported that individual humpback whales showed no short-term behavioural changes in response to industrial activity, but habituation and shifts in hearing thresholds were suggested as contributing factors. Brodie (1981) suggested that marine mammals may remain in an area with increased noise levels if they need to be in the area due to food or habitat requirements. Even if no behavioural changes are observed in animals within a few kilometers of the anthropogenic sound source, long-term effects could still occur (Richardson *et al.*, 1985a).

It is often difficult to distinguish effects of anthropogenic activity from natural variation in whale behaviour (Richardson *et al.*, 1995). For example, a study in the Beaufort Sea considered food availability as a potential explanation for the decreased number of bowheads in the main industrial area over subsequent years (Richardson *et al.*, 1987). Variability in respiration also makes it difficult to attribute changes solely to anthropogenic activity (Watkins, 1985; Dorsey *et al.*, 1989); respiration patterns can vary between individuals and different times of the day (Winn *et al.*, 1995). In addition, Cosens and Dueck (1988) mentioned factors such as seasonal variation, which could contribute to variation in monitoring results.

Many reviews on the impacts of anthropogenic activity on marine mammals have identified the need for control studies so impacts can be properly assessed (Turl, 1982; Reeves *et al.*, 1984; Green *et al.*, 1994; Richardson *et al.*, 1995; Richardson and Würsig, 1995). However, the interpretation of results can be difficult. One study found that abundance of bowhead whales changed in both the industrial and non-industrial area, so causation could not be attributed (Richardson *et al.*, 1987). In another case, the control and experimental periods were separated by one year (Sorensen *et al.*, 1984); temporal differences between control and experimental periods could affect results (Cosens and Dueck, 1988). When humpback whale movement varied both during the control and experimental conditions, it could not be concluded that there was a response to the noise source (Malme *et al.*, 1985). Malme *et al.* (1983) urged further control studies to assess long-term effects, and to make certain that the results were not dependent on the particular area or event. Thus, control designs may not be the most appropriate design to study the effects of anthropogenic noise.

1.6. Tracking recommended for impact assessment

Appropriate indicators are needed to assess impacts to the individual, and the population. For example, long-term tracking of individually identified animals will help determine the true impacts of anthropogenic noise (Richardson *et al.*, 1985b; Reeves, 1992; Green *et al.*, 1994; Richardson and Würsig, 1995). According to Richardson and Würsig (1995: 402), research is needed on "site tenacity, well-being, and reproductive success of known individuals, including some that remain in preferred undisturbed ('control') locations and others that are displaced." Thus, comparing resighting, residency, and return rates of individually identified whales over many years may assist in determining impacts of disturbance (e.g. Davis *et al.*, 1986; Weinrich *et al.*, 1991; von Ziegesar *et al.*, 1994).

Some studies have used individually identified animals to assess the effects of anthropogenic activity. For example, Baker *et al.* (1983) found that humpback whales exhibited short-term behavioural responses to vessel traffic, but four individually identified whales were resighted in the area of disturbance over a long time period; some identified whales returned in subsequent years (Baker *et al.*, 1988). Another study noted changes in resightings and residency of humpbacks among years, and suggested that they were due to increased vessel traffic (Jurasz and Palmer, 1981); other studies contend that changes were due to prey abundance (see Richardson, 1995b). Aerial photo-identification of bowheads showed that three were resighted over an interval of 9-14 days in an area with vessel traffic (Richardson *et al.*, 1987, *in* Koski *et al.*, 1988). A radio-tracked bowhead whale exhibited changes in its respiration rate during approaches from vessels on various days, but remained in the area (Wartzok *et al.*, 1989, *in* Richardson, 1995b). Tracking individual animals appears useful to evaluate the effects of anthropogenic noise. To date there have been few long-term studies using tracked animals.

1.7. Need for research

The United States National Research Council's report on the effects of noise on marine mammals expresses an urgent need for further research on the effects of low-frequency sounds (Green *et al.*, 1994). Currently there is inadequate information for industry to develop and evaluate management plans in areas where cetaceans occur

(Geraci and St. Aubin, 1980; Lien *et al.*, 1995), or for scientists and managers to develop regulations on the use of low-frequency sounds in the ocean (Green *et al.*, 1994). This lack of information has recently been highlighted in emotional responses to the proposed ATOC (The Acoustic Thermometry of Ocean Climate) study that will use low-frequency sounds to determine the extent of oceanic and global warming (Green *et al.*, 1994). A criterion used by the United States National Marine Fisheries Service, which considers noise levels harmful to marine mammals to be above 120 dB (referenced to 1μPa at 1 m), has also caused debate since there is little evidence to support this conclusion (Green *et al.*, 1994). To date there is insufficient information to ascertain or predict potential effects of anthropogenic sounds on any marine species (Green *et al.*, 1994).

1.8. Statement of purpose

Increased numbers of collisions with fishing gear by humpback whales in Trinity Bay, Newfoundland were reported by fisherpersons to be associated with underwater explosions. Consequently, in 1992, the Whale Research Group of Memorial University of Newfoundland began a monitoring program to assess impacts of this industrial activity on marine mammals in the bay (Todd *et al.*, 1996). Trinity Bay is an important habitat for both mysticetes (Fig. 1) and odontocetes so monitoring continued during periods of heavy industrial activity through 1995. Observable behaviours were measured to test for the effects of noise. In addition, photo-identification of individual animals enabled long-term

A.

B.

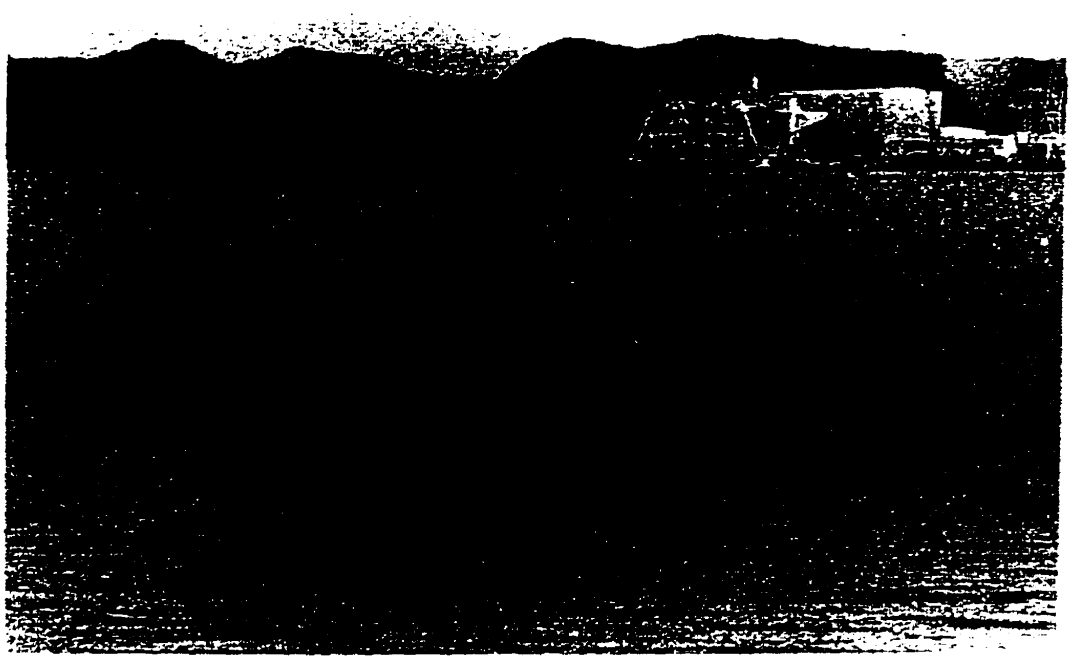


Figure 1.
Humpback (*Megaptera novaeangliae*) (A) and minke (*Balaenoptera acutorostrata*) (B) whales in Bull Arm, Trinity Bay.

impacts of industrial activity to be assessed. Results from some of this monitoring have been presented previously (Ketten *et al.*, 1993; Lien *et al.*, 1993; Borggaard and Lien, 1995; Borggaard *et al.*, 1995; Lien *et al.*, 1995; Todd *et al.*, 1996).

2. Project description

2.1. Industrial activity

2.1.1. 1991 and 1992

In 1990, Hibernia Management and Development Company Ltd. began infrastructure development for construction of an offshore-oil-support platform in Great Mosquito Cove, Bull Arm, Trinity Bay, Newfoundland (47°48.65' N, 53°53.30' W; Fig. 2). On 3 July 1991 the first phase of underwater blasting and drilling began in Great Mosquito Cove for further infrastructure development and to allow a Gravity Base Structure (GBS), the support for the platform, to be moved outside the cove for further construction (Fig. 3). From 1991-1992, blasting and drilling constituted the predominant underwater activity (Appendix A), with periodic clamshell dredging and vessel traffic (Table 1).

During 1992, blast charges (Tovex™) occurred from one per day to one per seven days; sizes varied between 30-5500 kg, and averaged 1055 kg (Todd *et al.,* 1996). The sound energies of these charges varied, but were typically between 140-150 dB (referenced to 1 μPa at 1 m) near 400 Hz, measured at a distance of 1 km (Todd *et al.*, 1996). The maximum charge size of 5500 kg had a peak source level of 153 dB (Todd *et al.,* 1996). In addition, dredging operations in Great Mosquito Cove dumped a total 118,152 m^3 blasted rock and 6218 m^3 till. Seven vessels arrived and departed from the cove, including supply ships and tugs with barges (Table 1).

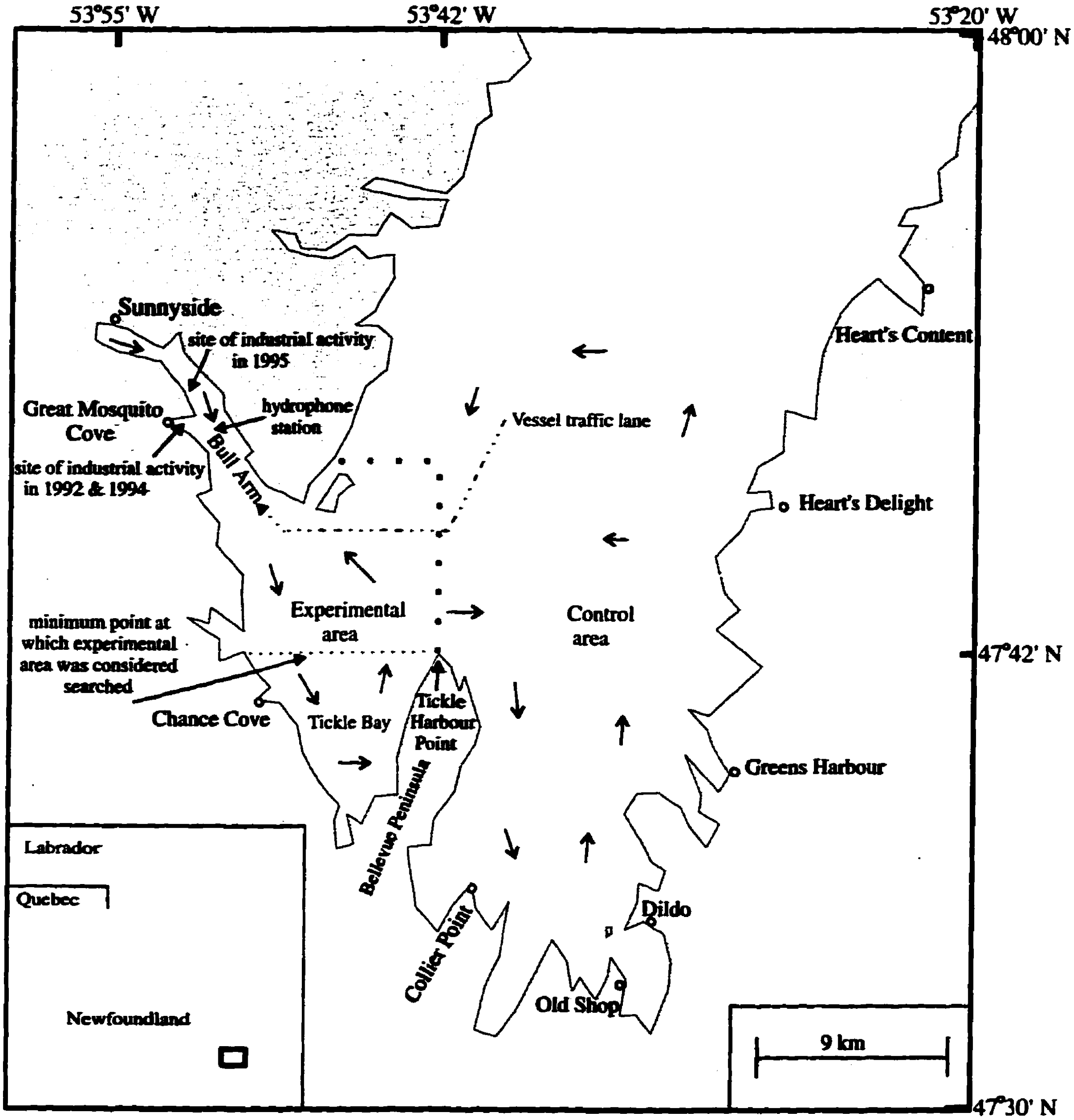


Figure 2.

Southern Trinity Bay, Newfoundland study area including experimental and control areas (divided by 53°42' W), vessel traffic lane, hydrophone station, and transect routes (⟶).

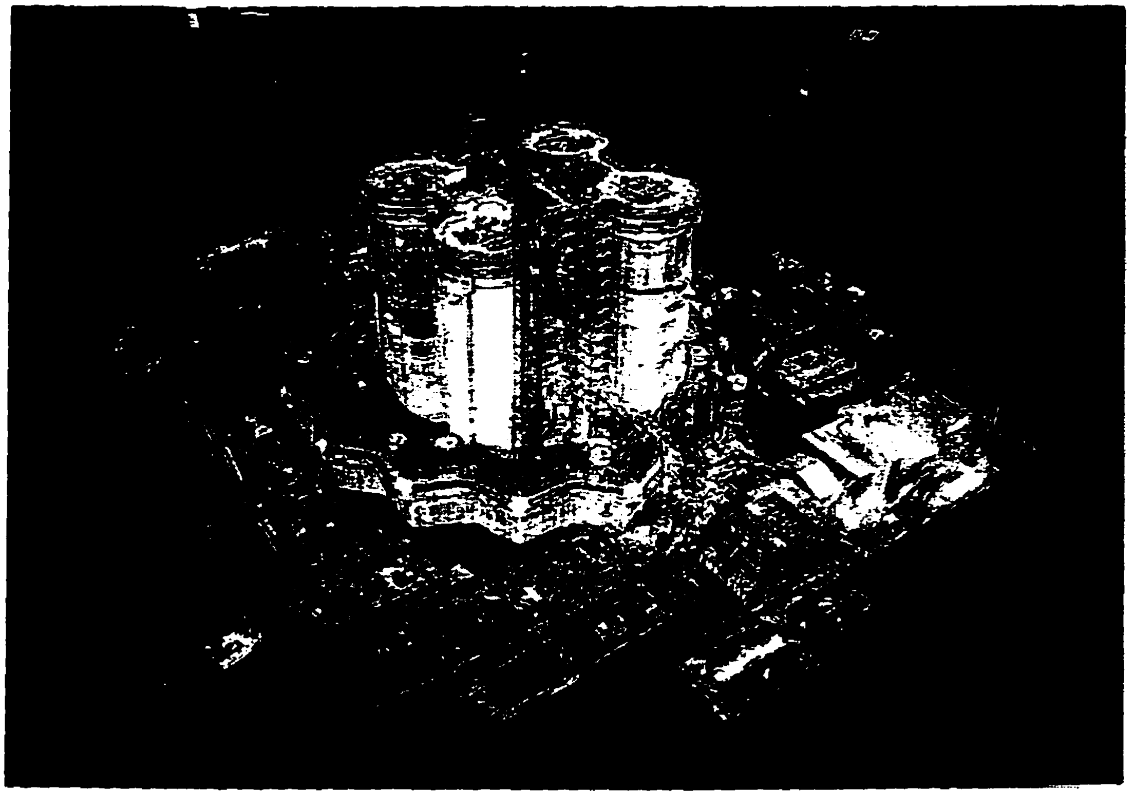


Figure 3.

The Gravity Based System (GBS), support for the oil production platform, located in Bull Arm, Trinity Bay (courtesy of Hibernia Management and Development Company Ltd., 1995).

Table 1. Industrial activities in Bull Arm, Trinity Bay, 1991-1995. Averages are reported from June - September for all years unless otherwise noted. The 1991 and 1992 values are based on available charge sizes (from Todd *et al.*, 1996; see Appendix A).

Year	Dredging		Blasting		Vessel activity			
	Total m^3/yr	Average m^3/mo	Total no./yr (average size)	Average no./mo (average size)	Total no. arrivals/yr	Average no. arrivals/mo	Average no. arrivals and departures/mo	Average no./day on site
1991	106,480	16,464[a]	115 (884 kg)	24.3[b] (832 kg)	similar to 1992	-	-	-
1992	124,370	2,239	55 (1055 kg)	5.5 (1254 kg)	7	0.7[b]	1.3[b]	0.07[b]
1993	none	-	none	-	15	1.8	3.0	2.1
1994	502,886	128,449[b]	90 (701 kg)	32.5[a] (690 kg)	71	8.3	14.3	7.7
1995	none	-	none	-	84	5.0	9.8	15.4

- not applicable
[a] August - September
[b] July - September

2.1.2. 1993

In 1993, the industrial activity in Great Mosquito Cove occurred in an area similar to previous years. There was no blasting or dredging. There was some vessel traffic: fifteen vessels arrived, but not all departed (Table 1).

2.1.3. 1994

In 1994, dredging, blasting, drilling and vessel activity occurred in Great Mosquito Cove (47°48.500' N, 53°53.500' W) for berm removal and to deepen the tow-out channel for the GBS (Fig. 2). Further construction of the platform and its Topsides production facilities increased vessel traffic to the site relative to previous years (Table 1):

Dredging. Clamshell dredging occurred in water 14-24 m deep; the loads of rock and till removed and dumped reached a maximum of 9/day. Dredging operations (24 hr) increased in frequency with time. During the first phase of dredging (5 July - 23 September) the amount of material removed and dumped totaled 239,581 m^3 blasted rock and 145,765 m^3 till (Table 1); the second phase (12 October - 17 November) totaled 88,455 m^3 blasted rock and 29,065 m^3 till.

Blasting and Drilling. Charges (POURVEX® EXTRA®/DETALINE® Delay System) were placed in 4-9 m bore holes, and 10-15 m of water (Appendix A). Two small charges of Fishing Salutes (~38 g each) were detonated before blasts to scare fish from the area. During the first set of blasts (9 August - 17 September), charges ranged from 1-3 per day, with a maximum break in activity of two days; sizes varied between 52-1705 kg, and averaged 690 kg (Table 1). During the second set of blasts (9 October - 2 November) charges ranged from 1-5 per day, with a maximum break in activity of fourteen days; sizes varied between 191-1697 kg, and averaged 730 kg.

Vessel Traffic. Seventy-one vessels arrived at Great Mosquito Cove; not all departed (Table 1). Activities such as laying of chain for the support platform from 24 July - 10 August, and resuming from 16 September - 1 November, resulted in continuous vessel traffic within Bull Arm. Dredging operations required tugs to move barges to dump sites. In addition, the GBS was towed into a deeper area of Bull Arm for further construction on 11 November.

2.1.4. 1995

In 1995, vessel activity was the only industrial disturbance at the Bull Arm construction site (47°49.390' N, 53°52.218' W) (Fig. 2). Eighty-four vessels arrived in Great Mosquito Cove, with an increased number of vessels remaining on site as compared to previous years (Table 1). Continuous vessel activity included two ferries traveling between the GBS and land throughout the day, as well as tug and boat transport activities.

2.2. Monitoring

2.2.1. 1992

In 1992, a monitoring program began in Trinity Bay, Newfoundland to assess possible impacts of industrial activity in Bull Arm on cetaceans in the area. For 9 days between 6 - 25 June (with some effort on 2 June), two boats monitored the occurrence of humpback whales (Todd *et al.,* 1996). Photographs of the underside of the fluke were used to track individual humpback whales (see Katona *et al.*, 1979). The total number of species sighted in 1992 are listed in Table 2. During 1992, humpback whales were also individually identified during surveys throughout Newfoundland and Labrador, but primarily along the eastern coastline of Newfoundland, until 17 September, as part of YoNAH, Years of the North Atlantic Humpback Whale (Smith *et al.*, 1997).

Results showed that when blasting and drilling occurred in 1991 and 1992, entrapments of humpback whales in fishing gear occurred significantly closer to Bull Arm, and in greater number throughout Trinity Bay compared with previous years (Todd *et al.*, 1996). In addition, two humpback whales that died in fishing gear near the blasting and drilling activity were autopsied, and exhibited ear damage indicative of trauma from underwater blasting as compared with two control animals (Ketten *et al.*, 1993).

Table 2. Minimum number of marine mammal sightings during the 1992 study in Trinity Bay, Newfoundland, without standardizing by effort (data from Todd *et al.*, 1996). Some animals may be present on more than one day. Seals were sighted but totals could not be calculated.

Humpback (*Megaptera novaeangliae*)	Finback (*Balaenoptera physalus*)	Minke (*Balaenoptera acutorostrata*)	Blue (*Balaenoptera musculus*)	Harbour Porpoise (*Phocoena phocoena*)
187	6	18	1	5

However, changes in the distribution, resighting, residency, and overall behaviour of humpback whales feeding in the area were not detected (Todd *et al.*, 1996).

2.2.2. 1993

In 1993, YoNAH surveys were again conducted throughout Newfoundland and Labrador, but primarily along the eastern coastline of Newfoundland, including northern Trinity Bay. From 15 June - 29 August two boats conducted photo-identification of humpback whales. No special monitoring surveys occurred in the Bull Arm area.

2.2.3. 1994 and 1995

Monitoring occurred in southern Trinity Bay from 5 July - 14 November 1994, and 17 June - 8 August 1995. Coastal surveys, following YoNAH sampling protocols (Smith *et al.*, 1997), were conducted in 1994 primarily along the eastern coastline of Newfoundland from 16 June - 17 September. No coastal surveys were conducted in 1995. Blasting, drilling, dredging, and vessel activity occurred in 1994; only vessel activity occurred in 1995 (Table 1).

2.3. Objective of present study

The present study, conducted from 1994-1995, was part of the ongoing monitoring program. The objective was to assess the effects of a variety of industrial activities on marine mammals in Trinity Bay, Newfoundland. To accomplish this marine mammal abundance, distribution, and respiration were measured, and the behaviour of individually identified humpback and minke whales was observed. Additionally, resighting information on individually identified humpbacks from 1992-1995 was used to examine long-term effects.

3. Methods

3.1. Study area

The study area in Trinity Bay occurred below 48° N (i.e. southern Trinity Bay) (Fig. 2). The longitudinal line of 53°42' W, at the Bellevue Peninsula, divided southern Trinity Bay into a control area, and an experimental area, including Bull Arm. This arbitrary division attempts to separate impact from control area based on the attenuation of sound from Bull Arm due to distance, and the presence of a land boundary. The experimental area was considered monitored by surveys that reached a minimum point of 47°42' N; this line represents an area outside the protection of Bull Arm.

3.2. Study periods

For 49 days between 5 July - 14 November 1994, one 6-m boat monitored southern Trinity Bay (Table 3). Logistic problems and sighting few whales on a preliminary survey (26 June) resulted in the study period beginning in early July. The main observation period occurred between 5 July - 10 September; effort decreased after 10 September following a period when few whales were found. Monitoring occurred at the onset of 24-hr dredging operations (Fig. 4); before, during, and after the two blast periods (first period in Fig. 5); and during vessel activity (Fig. 6).

Preliminary boat surveys in 1995 indicated that whales were abundant and the study was started earlier than the previous year. Southern Trinity Bay was monitored by

Table 3. Survey dates with area searched (Bull Arm, experimental, and control) from the 1994 and 1995 study. Bull Arm is listed separately to indicate days when the entire experimental area was not searched due to poor weather conditions. Dates from 1995 when only opportunistic sightings were made (i.e. without searching effort) are not included.

Date	1994 Survey area			Date	1995 Survey area		
	Bull Arm	Experimental	Control		Bull Arm	Experimental	Control
26 Jun	√	√	√	17 Jun	√		
5 Jul	√	√	√	18 Jun	√	√	√
8 Jul	√	√	√	20 Jun	√		
9 Jul	√	√		21 Jun	√		
10 Jul	√	√	√	22 Jun	√	√	√
12 Jul	√			23 Jun	√	√	
13 Jul	√	√	√	24 Jun	√	√	√
14 Jul	√	√		25 Jun	√	√	√
15 Jul	√	√	√	27 Jun	√		
19 Jul	√	√	√	29 Jun	√	√	√
21 Jul	√	√	√	30 Jun	√	√	
23 Jul	√	√	√	1 Jul	√		
24 Jul	√			2 Jul	√	√	
25 Jul	√	√	√	4 Jul	√	√	√
26 Jul	√	√		5 Jul	√	√	√
29 Jul	√	√		6 Jul	√		
30 Jul	√	√		7 Jul	√		
31 Jul	√	√		8 Jul	√		
1 Aug	√	√		9 Jul	√	√	
2 Aug	√			11 Jul	√	√	
3 Aug	√	√	√	12 Jul	√	√	√
4 Aug	√	√		13 Jul	√	√	
5 Aug	√			15 Jul	√	√	√
6 Aug	√			16 Jul			√
7 Aug	√	√		18 Jul			√
8 Aug	√			19 Jul			√
9 Aug	√	√		20 Jul	√		

Table 3. (continued)

Date	1994 Survey area: Bull Arm	1994 Survey area: Experimental	1994 Survey area: Control	Date	1995 Survey area: Bull Arm	1995 Survey area: Experimental	1995 Survey area: Control
10 Aug	√	√	√	21 Jul	√	√	
11 Aug	√	√	√	23 Jul	√	√	
12 Aug	√	√		25 Jul	√		
13 Aug	√	√	√	26 Jul	√		
14 Aug	√	√		29 Jul	√		
16 Aug	√	√		1 Aug	√	√	√
19 Aug	√	√		2 Aug	√	√	√
23 Aug	√	√	√	4 Aug	√	√	√
24 Aug	√	√	√	8 Aug	√	√	
25 Aug	√	√					
26 Aug	√	√					
27 Aug	√	√					
28 Aug	√	√					
29 Aug	√						
30 Aug	√						
5 Sep	√	√					
10 Sep	√	√	√				
22 Sep	√						
29 Sep	√	√					
6 Oct	√	√					
22 Oct	√	√					
29 Oct	√	√					
14 Nov	√	√					

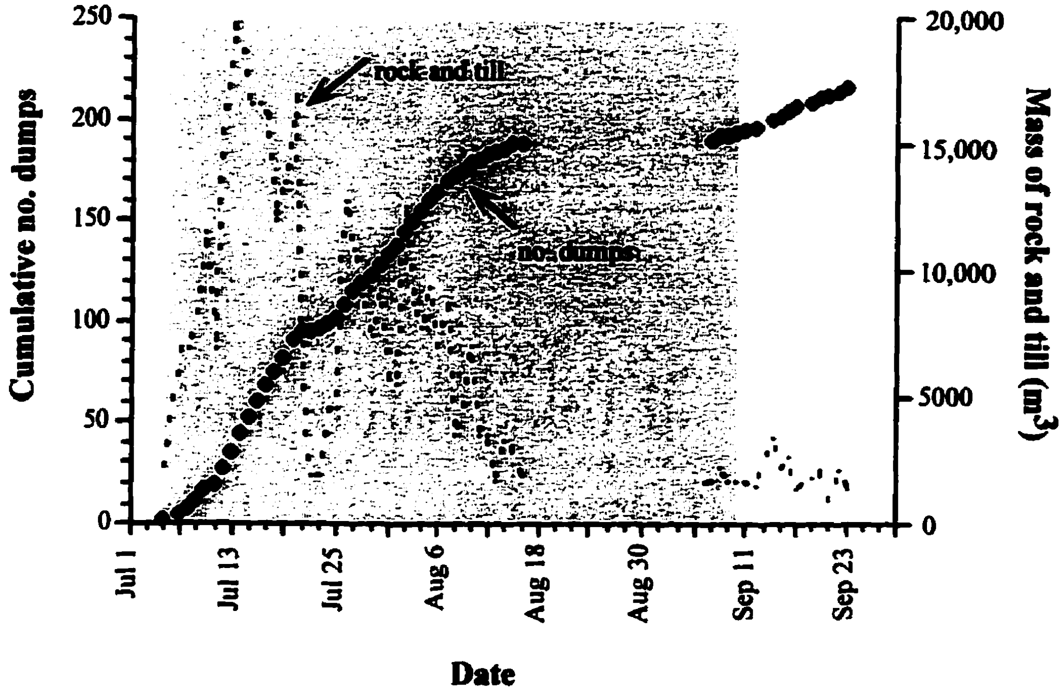


Figure 4.

First phase of clamshell dredging activity in Great Mosquito Cove in 1994. Cumulative number of dumps with the corresponding amount of rock and till removed are depicted. No dredging occurred between 16 August and 7 September. Shaded area indicates the main observation period.

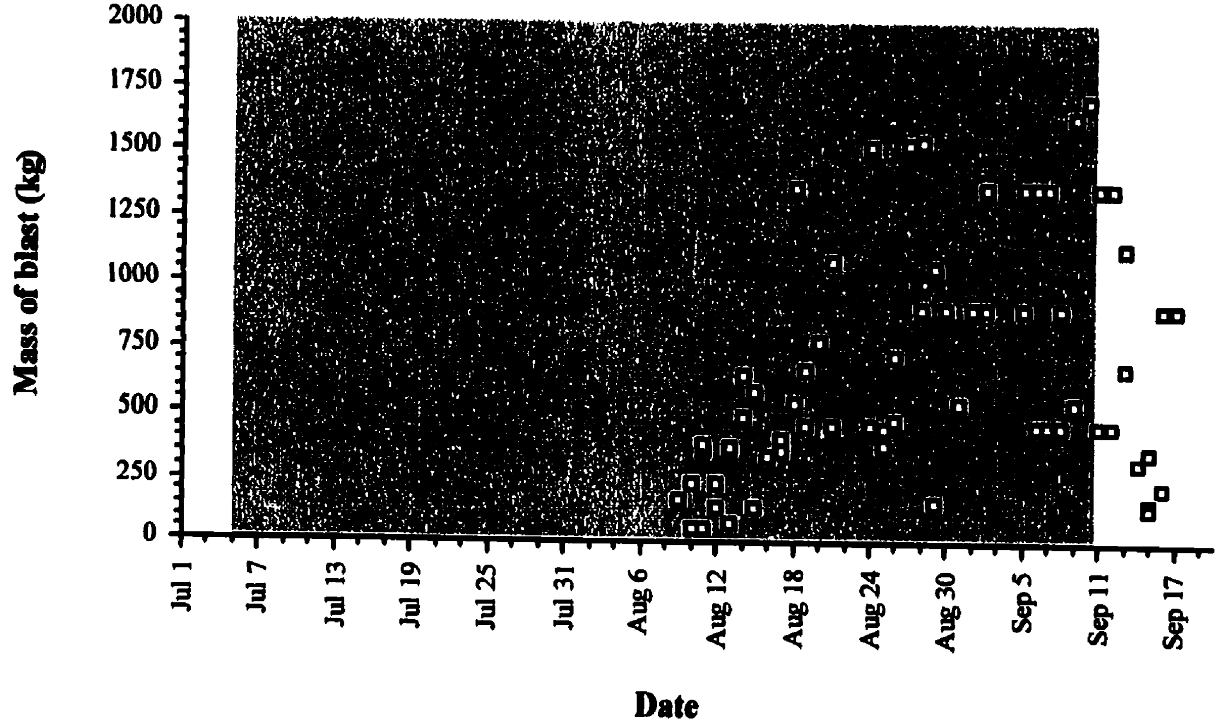


Figure 5.

Mass of each blast (kg) during the first period of blasting in 1994. Shaded area indicates the main observation period.

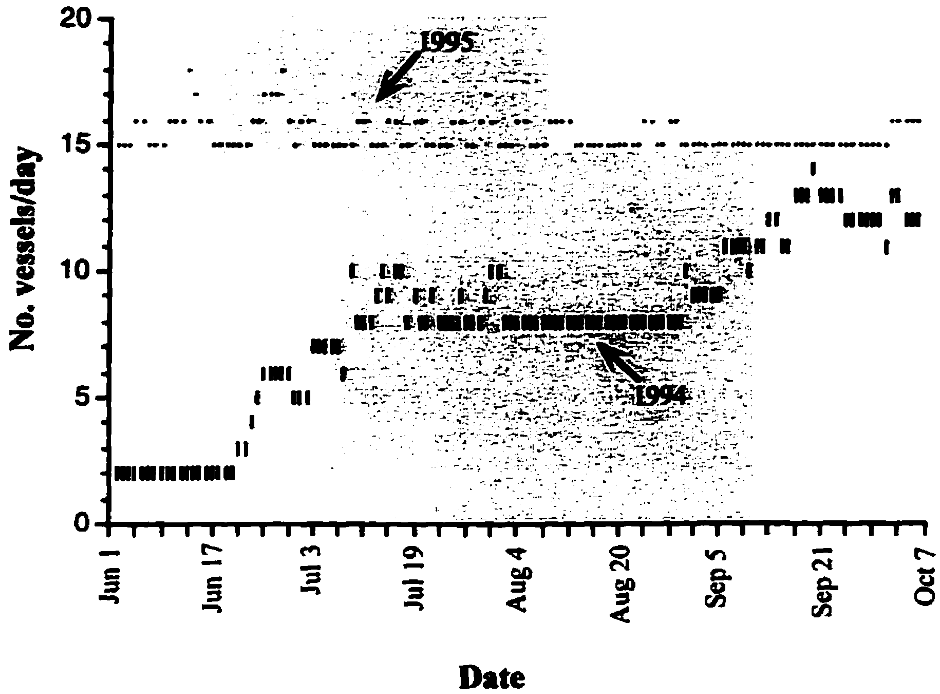


Figure 6.

Number of vessels per day at Great Mosquito Cove in 1994 (|) and 1995 (•); shaded area indicates the main observation period. In 1994, anchor chain for the oil support platform was layed from 24 July - 10 August, and resumed on 16 September; this activity created continuous vessel activity.

daily boat transects on 36 days between 17 June - 8 August 1995 (i.e. the main observation period). Although equipment problems prevented further surveys, the 1995 survey period coincided with peak whale abundance in southern Trinity Bay.

Coastal surveys, following YoNAH sampling protocols (Smith *et al.*, 1997), occurred primarily along the east coast of Newfoundland from 16 June - 17 September 1994. Although times were comparable to the YoNAH surveys from 1992-1993, survey effort was not as high (see sections 2.2.1. and 2.2.2.). There were no coastal surveys along the east coast of Newfoundland in 1995.

3.3. Survey transects

Surveys departed from Sunnyside, located near Great Mosquito Cove, with two to three observers aboard the boat. The departure point ensured monitoring of the area closest to the industrial site. In the experimental area transects were conducted from Bull Arm to Tickle Bay then to Tickle Harbour Point. In the control area transects began southward from Tickle Harbour Point off the coast and then headed northward and back into the experimental area (Fig. 2). The portion of the control area most frequently monitored was south of the traffic lane. Boat speed usually ranged from 10-12 knots along the survey route which was adequate to survey the entire study area. Transect completion depended on weather, time, and number of sightings.

In 1994, intensive monitoring of the control area occurred before blasting began. However, poor weather conditions resulted in less effort in the control area during blasting. In 1995, stormy weather conditions prevented regular monitoring of the control area. One report of high whale abundance in the control area, outside of the usual transect route, was received during this year (D. Pinsent, Biology, Memorial University of Newfoundland, NF, pers. comm.). Therefore, some trips began from Old Shop after 13 July (Fig. 2). In 1995, the occurrence of whales off Sunnyside allowed land-based sightings when weather prevented boat surveys; these sightings were considered opportunistic as they occurred without searching effort.

3.4. Data

3.4.1. Acoustic recordings

To determine relative sound levels, industrial activity and ambient noise recordings were made between 9 August - 22 October 1994, and 12 - 21 July 1995. A hydrophone station located within the experimental area (47°48.378' N, 53°51.166' W) was used for most recordings (Fig. 7). This position was approximately 2.9 km from the industrial site in 1994 and 2.3 km in 1995. Acoustic recordings were also made at oceanographic stations in both years (see section 3.4.3.). In 1994, a recording was made in the control area during blasting activity so sound levels could be compared to the experimental area (Appendix

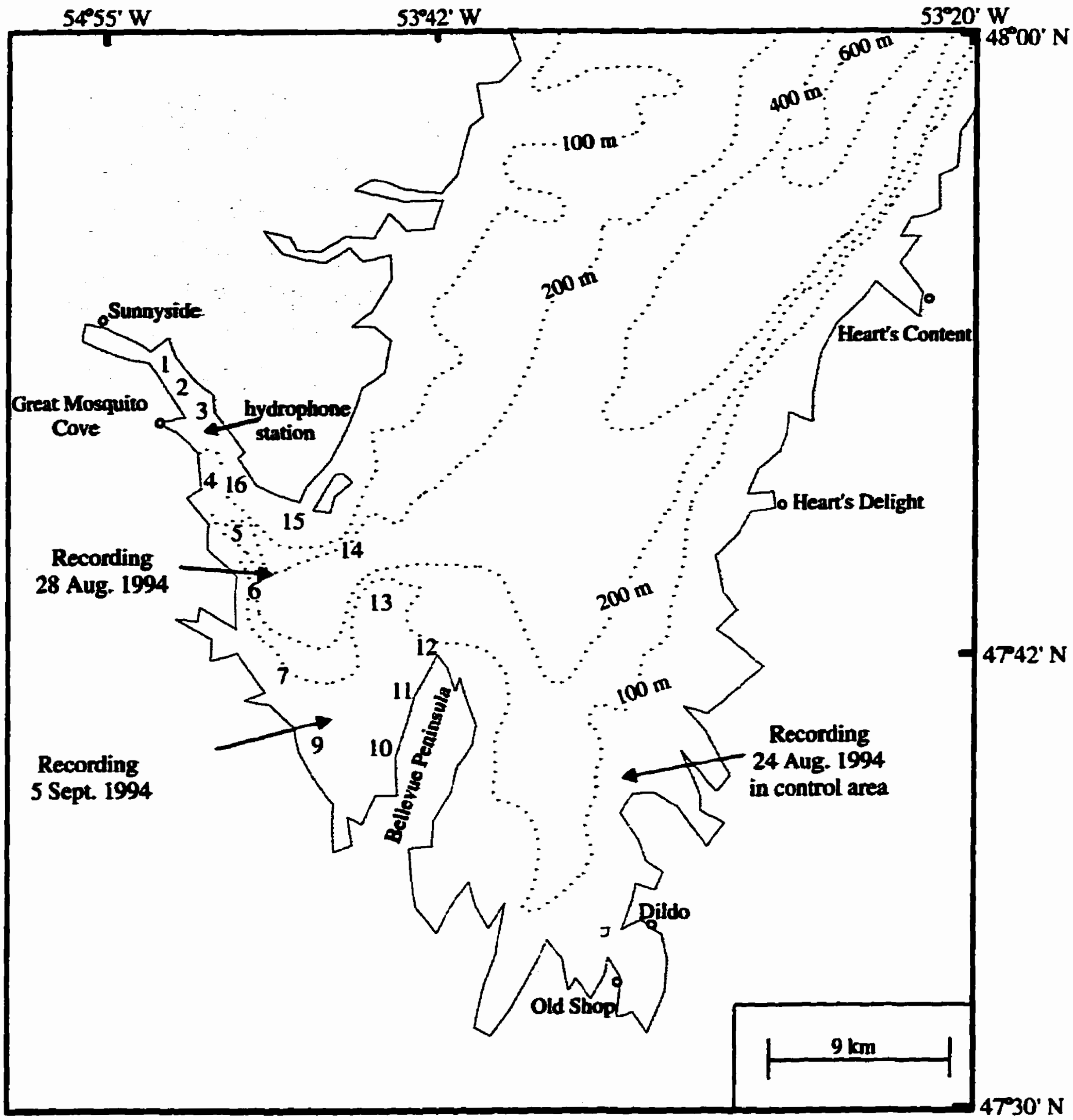


Figure 7.

Oceanographic stations used during 1994 (no. 1-16) and 1995 (no.1, 9, and 13), and the hydrophone station used for recordings. Three additional accustic recording stations are indicated.

B). Recordings were made by an additional vessel during the first set of blasts in 1994, and by the survey boat for all other recordings made in 1994 and 1995.

A Sony DAT TCD-D10 Pro II system with a flat (±1 dB) response of 20 Hz - 22 kHz (Sony Corporation, Tokyo, Japan) and two hydrophones with a flat (±3 dB) response of 20 Hz - 19 kHz (constructed by Technical Services, Memorial University of Newfoundland, St. John's, NF, Canada) each with a 15 Hz - 25 kHz bandwidth filter (constructed by Technical Services, Memorial University of Newfoundland, St. John's, NF, Canada) were used for recordings. Hydrophones were placed at depths of 5 and 30 m. Time, weather (including wind speed and Beaufort scale), depth, and ocean temperature profiles were collected for each recording.

3.4.2. Prey

Presence or absence of prey were assessed on a fine scale using the results of a colour Raystar V-820 echosounder (Raytheon Marine, Manchester, NH, USA) in 1994, and a Si-Tex Fishfinder (Model HE30B, Smiths Industries Inc., St. Petersburg, FL, USA) in 1995. Recordings were dependent on equipment; on some occasions observations could not be made due to malfunctions. Observations of feeding birds or feeding whales (section 3.4.4.) were also used to indicate the occurrence of prey in the area. In addition, in 1994, the Hibernia Environment Department provided a list of fish species killed during blasting activity; capelin (*Mallotus villosus*) and herring (*Clupea harengus*) were used as indicators of prey presence. Fisherpersons in Sunnyside were also consulted regarding prey presence.

Capelin presence was used to construct a comparable time frame between 1994 and 1995. Daily observations that began on 1 June at Chance Cove were used to assess the time when capelin was present in the area each year (Fig. 8; Nakashima, DFO, St. John's, NF, unpubl. data). In addition, measurements of the relative abundance of capelin schools, obtained from aerial surveys in the control and experimental area, were used to indicate periods of peak abundance for each year (Fig. 9; see Nakashima, 1996).

Indications of capelin in Chance Cove occurred on 5 July 1994, and 4 July 1995; and the peak in capelin abundance from aerial surveys occurred on 15 July in both years. Based on these findings there were no seasonal adjustments made when the two years were compared. Thus, the time period at the onset of dredging activity, but before blasting in 1994 (5 July - August 9), was compared with the 1995 study (5 July - August 8).

3.4.3. Oceanographic conditions

Oceanographic conditions were sampled with a Seabird SBE-19 Conductivity, Temperature, and Depth recorder (CTD; Seabird Electronics, Inc., Bellevue, WA, USA), or SEALOG-TD temperature/depth probe (VEMCO Ltd., Halifax County, Nova Scotia, Canada) at predetermined stations in the experimental area (Fig. 7). The CTD measures

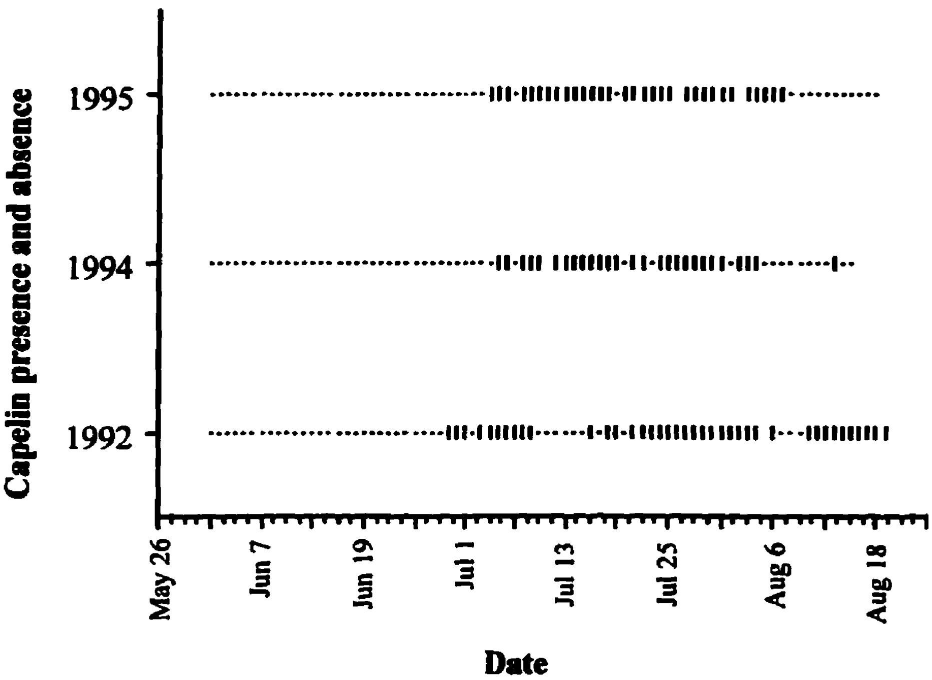


Figure 8.

Presence (|) and absence (•) of capelin (*Mallotus villosus*) in 1992, 1994, and 1995. Results based on daily observations made at Chance Cove in the experimental area (Nakashima, DFO, St. John's, NF, unpubl. data).

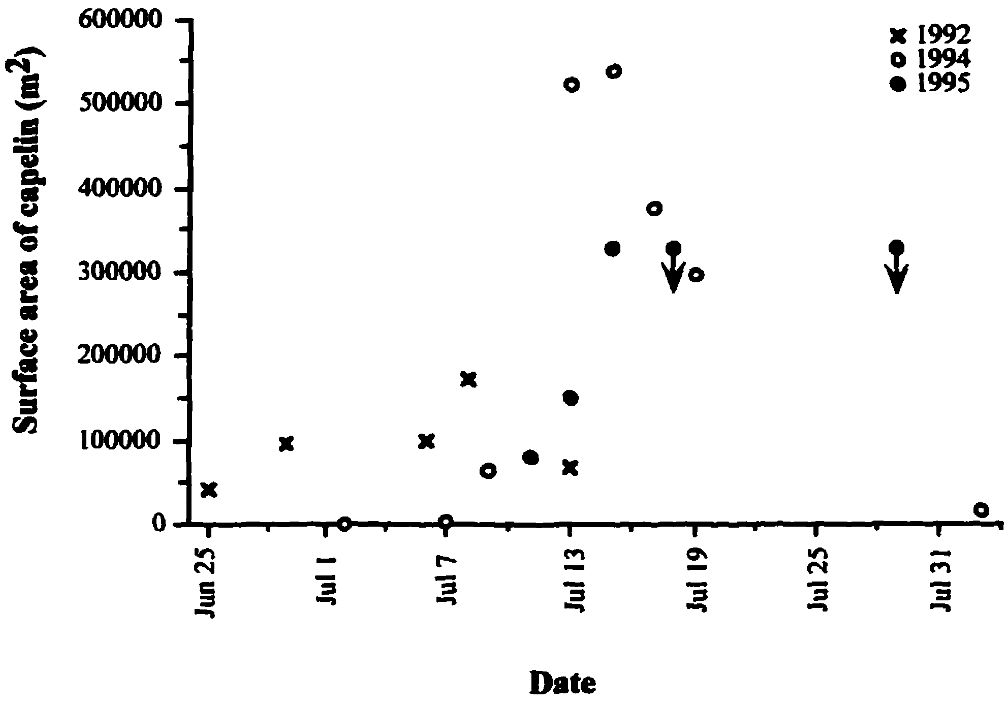


Figure 9.

Surface area (m^2) of capelin (*Mallotus villosus*) schools in southern Trinity Bay in 1992, 1994, and 1995 (from Nakashima, 1996). Points with arrows indicate days for which data have not been processed for 1995, but the number of capelin schools present suggests a lower abundance than 15 July.

temperature with 0.001°C resolution and 0.01°C accuracy; the SEALOG-TD measures temperature with 0.1° resolution and ±0.3°C accuracy, and depth with 1 m resolution and ±5 m accuracy. Both CTD and SEALOG-TD probe were calibrated, and within manufacture specifications. The probe took measurements every 30 seconds, and was lowered slowly in order to obtain readings at ~1 m intervals. It was not possible to sample each station every day. Oceanographic data are available in Borggaard (1996).

CTD and SEALOG-TD data were edited such that only the downward casts, and initial measurement for each meter (to eliminate slow readings) were used. Probe casts were not used if the entire vertical temperature profile was not obtained (due to lowering the probe too fast). Stations 1, 9, and 13 were common between years and used for analyses.

Comparisons were made among stations and between years as an indicator of seasonal change. Measurements from the upper 35 m (depth of the shallowest station) were averaged for each day a station was sampled. In addition, daily temperature averages at 10 m in Chance Cove were calculated for the years 1992, 1994, and 1995 (Nakashima, DFO, St. John's, NF, unpubl. data).

3.4.4. Effort and sightings

Observation effort summaries were produced for each day. Summaries included times and positions for the start and finish of each trip; changes in the vessel's speed, direction, or activity; changes in weather condition (e.g. visibility, Beaufort scale, or wind speed); and each whale sighting. A Global Positioning System (GPS NAV 5000DX™, Magellan System Corp., San Dimas, CA, USA, or EnsignXL GPS, Trimble Navigation, Austin, TX, USA) was used to determine sighting locations with accuracy ranging from 2-32 m.

For each cetacean sighting (i.e. group) the species, minimum/maximum number, and behaviour were also recorded. If an animal could not be positively identified, the species was considered "unknown." A group of humpbacks was considered one sighting if two or more animals were side by side, and appeared to coordinate their speed, direction of movement, and surfacing and diving behaviour (Mattila *et al.*, 1990). A group of minke whales (*Balaenoptera acutorostrata*) was considered one sighting if the whales appeared to be feeding cooperatively, or coordinating surfacings (Dorsey *et al.*, 1990). For all species, each sighting was counted unless it was positively determined to be a resighting for that day either in the field, or later by photographic matching. Sighting data are available in Borggaard (1996).

General activities were categorized as feeding, resting, traveling, or milling. Animals were considered to be feeding if they surfaced with the mouth open, or prey was present and the animals remained in the area, changing directions often. Animals were considered milling if they were rapidly changing directions over a large area. Resting was defined as animals remaining at the surface in one location, with long time intervals between breaths. Animals were considered traveling if they kept the same course and speed. An "unknown" category was used for animals which were probably feeding, but indicators of prey presence could not be detected (e.g. due to equipment malfunctions).

Twenty minutes of observation were collected before photographing the animal, but was dependent on time, weather, and behaviour of the animal. In 1994, an attempt was made to follow animals for longer periods of time (~2 hr) during blasting activity. Respiration times were recorded each time the animal surfaced; dives were considered to occur when the animal arched its tail stalk, or raised its flukes in the air. Behaviours such as breaching, lob-tailing, and flipper slapping were also noted (see Winn and Reichley, 1985). Depending on the activity of the whale(s), boat speed ranged from 0-3 knots and the distance away ranged from 50-100 m. Animals were followed from behind with no rapid change in speed. A note was made if changes in direction, speed, or dive pattern occurred that could have been attributed to the research boat. Identification by dorsal fin or fluke patterns ensured observations were conducted on the same animal.

Time for various activities varied within and between years so whale counts were standardized. The relative abundance (RA) of each species was calculated as the total number of whales seen each day per searching effort (whales/hr). Searching effort was defined as time (hr) on the water actively looking for whales; time taken for photographs or behavioural observations, oceanographic measurements, and acoustic measurements was not included. Minimum species numbers were used rather than maximum since they provided a more conservative estimate. Whales were not included if seen when oceanographic or acoustic measurements were taken since searching was not as effective if the survey boat was stationary; few whales were sighted during these times. Relative occurrence of whales (RO= whales/hr), the RA only for days when observations were made, measured how days when no whales were observed affected the results of abundance analyses. Results of analyses with RO are reported in tables, but are not discussed unless different from those with RA.

Global Positioning System (GPS) positions were used to calculate distances (D= km) between sightings and the industrial activity in Bull Arm. The following formula calculates great circle distance in nautical miles:

$$\text{distance} = \arccos[\sin(\text{latitude}1)\sin(\text{latitude }2) + \cos(\text{latitude}1)\cos(\text{latitude}2)\cos((\text{longitude}2 - \text{longitude}1)] * 60$$

where latitude and longitude 1 correspond to the initial sighting position, and latitude and longitude 2 correspond to the industrial site; values were subsequently converted into km. All distances were calculated as straight lines, and do not compensate for the presence of Bellevue Peninsula or any other land boundary (similar to Todd *et al.*, 1996).

3.4.5. Photo-identification

Humpback and minke whales sighted were individually identified by photographs. Humpback whales can be identified by the pigmentation patterns on the underside of their flukes (Fig. 10; Katona *et al.*, 1979); minke whales by pigmentation on the lateral side of the body, scars, and dorsal fin shape (Fig. 11; Dorsey, 1983). Success in photographing these traits was dependent on the whale's behaviour, as well as weather and time.

Humpbacks were the main focus for both photo-identification and behavioural observation similar to the 1992 study. In 1994, there was greater concentration on minke whales as humpbacks were not present throughout the main observation period. In 1995, photographic effort for minkes was greater than in 1994. During 1995, three of four humpback whales which remained at the Hibernia site for an extended period of time became easily identifiable in the field; therefore, on a few occasions photographs were not taken. The 1995 animals which were opportunistic sightings, or observed in the control area after the personal communication (section 3.3.), were used only for photo-identification analyses.

3.5. Data analysis

3.5.1. Acoustic recordings

Although absolute sound pressure levels could not be obtained due to lack of calibrated equipment, relative sound pressure levels and frequencies were compared for recordings made at similar gain settings at 30 m depth (due to additional noise sources heard at 5 m), and under similar weather conditions to control for ambient noise influences

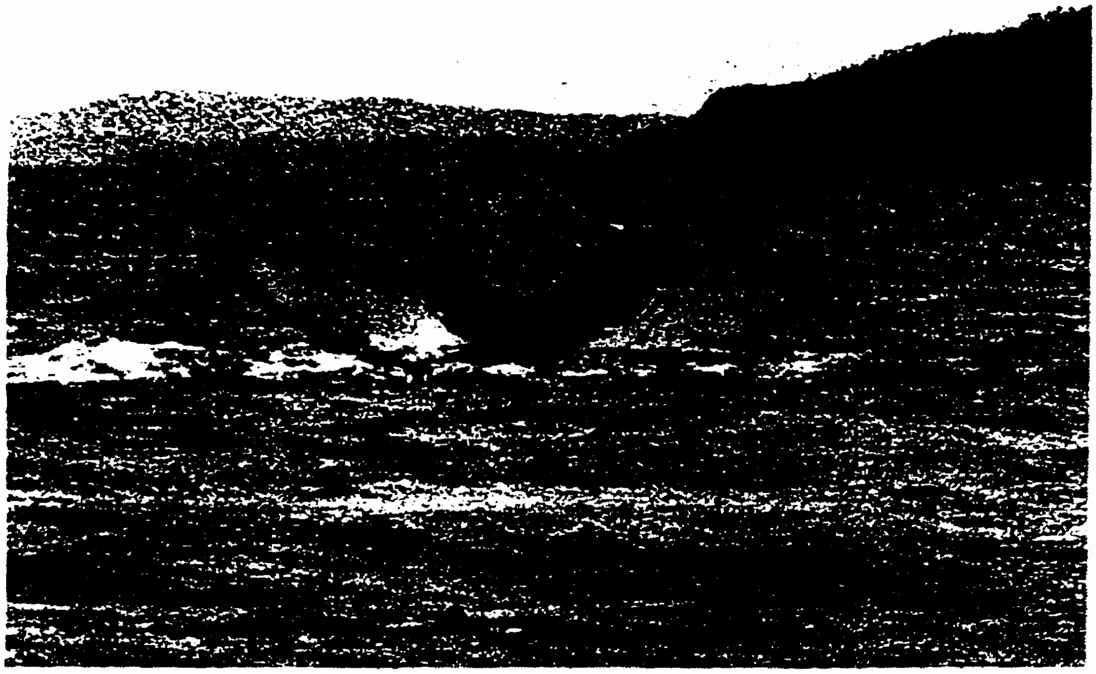


Figure 10.

View of the underside of a humpback whale (*Megaptera novaeangliae*) fluke as used for identification.

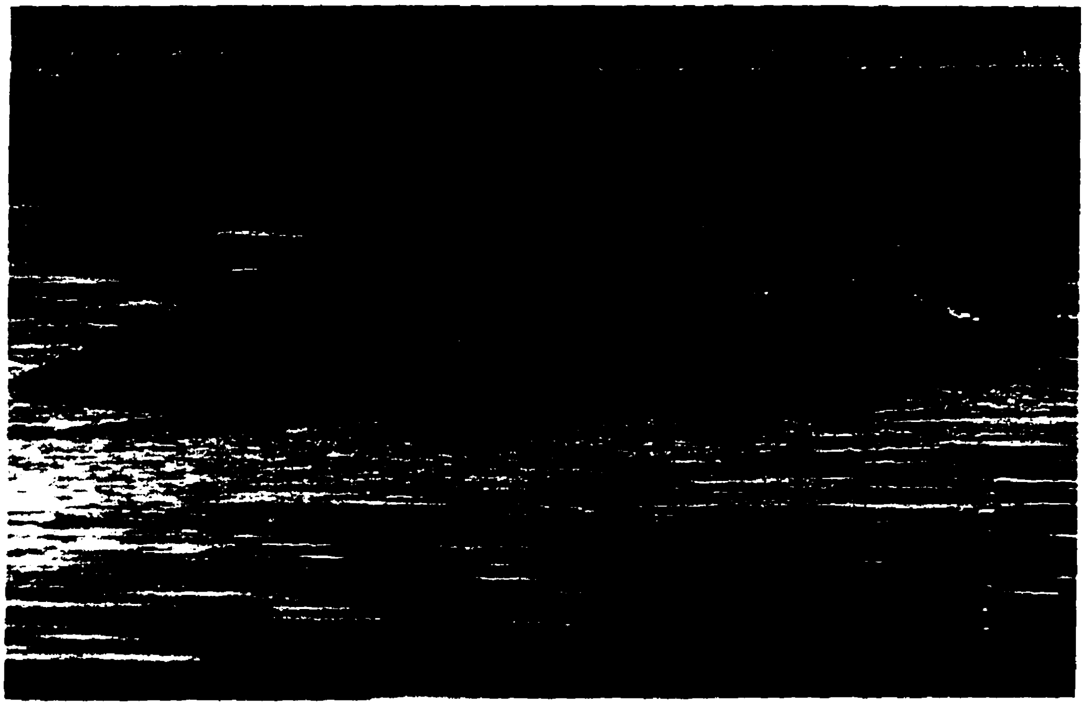


Figure 11.

View of the lateral side of a minke whale (*Balaenoptera acutorostrata*) as used for identification.

(see Wenz, 1962) and masking effects (see Greene, 1995). Sound recordings were analyzed using a Macintosh sound analysis program (Canary Version 1.2, Cornell Bioacoustics Workstation, Ithaca, NY, USA). Analyses were performed at a sampling rate of 22.3 kHz with a filter bandwidth of 88.24 Hz. In addition, a Hamming window function with a 5.572 ms, 21.73 Hz, and 1024 point FFT (fast Fourier transform) resolution grid was used.

A 6 second non-random recording sample (gain setting of 1; wind speed of 5-10 knots) of blast (491 kg; 14 August 1994), dredge (22 October 1994), and vessel activity (13 July 1995) taken at the hydrophone station were compared qualitatively (Fig. 7). In addition, a recording sample (gain setting of 1; wind speed 10-15 knots) of a blast (1545 kg; 28 August 1994) taken near station 6 (47°44.426' N, 53°49.117' W); and recording sample (gain setting of 2.5; wind speed 0 knot) of a blast (904 kg; 5 September 1994) taken near station 9 (47°40.693' N, 53°45.680' W) were analyzed. The recording sample (gain setting of 2; wind speed 2 knots) taken at the time of a blast (1524 kg; 24 August 1994) in the control area (47°38.366' N, 53°34.791' W) was examined; however, no analysis was performed as the blast signal could not be discerned from ambient noise (which included boat noise).

3.5.2. Statistical analysis

Initially, statistical analyses involved an exploratory approach, but once models were formed a confirmatory approach was taken. Analyses were performed on SAS (SAS Institute Inc., Cary, NC, USA) and Minitab (Minitab Statistical Software, State College, PA., USA). General Linear Models (GLM) were used with distance (D= km), relative abundance (RA= whales/hr), and relative occurrence (RO= whales/hr) as the response variables. Interactions terms were included in models except for those in which day of the year acted as a statistical control for season. G-tests were used for comparisons of the number of humpback whales identified between years. The degrees of freedom for all statistics are noted in subscripts. A change (two-tailed) rather than a predicted direction of change (one-tailed) was tested because it could not be predicted how the industrial activity would affect marine mammals. The significance level (α) was set at <0.05; however, repeated tests with RO used a significance level set at <0.025 (see Bonferroni technique in Sokal and Rohlf, 1995).

Data that produced residuals which appeared associated with the statistical model were transformed (removing any association) for the purpose of parametric statistical analysis. Transformations are noted as L for natural logarithm, SQ for the square, INV for the inverse value, SR for the square-root, and Pn for variables taken to a power (n) greater than two (e.g. P3). If the response variable contained zeros the value of 1 was added to all observations before taking the logarithm, and the value .5 was added before any other transformation (Sokal and Rohlf, 1995). However, graphs use untransformed data. Data for tests with non-normal residuals were randomized 1000 times (see Crowley, 1992) to obtain probability values based on the distribution of the statistic, given the data (p_r), rather than a theoretical distribution of the statistic (p_F). The average distance ($\overline{D}$ = km) and relative abundance ($\overline{RA}$ = whales/hr) are reported ± the standard error (se).

3.5.3. Environmental conditions

Effects of wind (Beaufort scale) and visibility on the sightability of each species in 1994 and 1995 were tested separately. The number of sightings per searching hr in each Beaufort and visibility condition (0-20, 21-40, 41-60 km) per day were considered. Beaufort 0, 1, 2, and 3 were used; sightings and effort were combined for Beaufort equal to or greater than 3 since these occurrences were rare.

Analyses controlled for day of the year. Days used ranged from the first day a species was sighted until the last for the entire study period, and only if the entire experimental area was searched. This removed potential bias toward conditions when searching occurred only in Bull Arm, due to deteriorating weather conditions outside. Sightings were not used for this analysis if made during oceanographic sampling, or during conditions in which searching effort did not occur.

3.5.4. Survey distance from the industrial site

Searching effort at various distances from the industrial site in the entire experimental area (0-10 and 11-20 km) was used to determine if monitoring was comparable within each year and between years. The daily activity logs were used to determine the effort with the corresponding distance for each day. Only days when the experimental area was searched were used.

3.5.5. Abundance

Changes in the RA and RO of whales were tested using days during the main observation period, as well as during dredging (but before blasting), blasting, and before and during blasting where appropriate. To remove any bias towards Bull Arm, only days when the experimental area was searched were considered. Comparisons between the experimental and control areas were done for days when effort occurred in both, and controlled for day of the year; the number of whales per searching effort was calculated for each area. When this analysis was run for 1995, abundance of humpbacks in the control area after 13 July was not considered since these numbers were potentially biased by a personal communication (see section 3.3.).

To enable comparisons in the experimental and control areas to 1992, relative abundance was calculated by standardizing the number of humpback whales by the total time the monitoring boat was on the water (including photographic time). In 1994 and

1995, time taken for respiration, oceanographic, and acoustic measurements were deducted since these activities did not occur on days used for 1992.

3.5.6. Distribution

Changes in the distance of whales from the industrial site were tested using days during the main observation period, as well as during dredging (but before blasting), blasting, and before and during blasting where appropriate. To remove any bias towards Bull Arm, only days when the experimental area was searched were considered (see Appendix C for additional sightings). Positions for each sighting were used including those in which no photographs were obtained, and those observed during oceanographic or acoustic measurements. Positions were used even if the boat was stationary since distribution rather than abundance was considered. Only initial sighting positions per day were used for each animal, although they may have been sighted on multiple days.

3.5.7. Behavioural data

All 20-minute observation trials on individually identified humpback whales were separated based on whether they were observed in the control or experimental area. Only respiration of animals with similar behaviours (e.g. feeding vs. traveling) and group sizes (e.g. single vs. group) were compared (see Dorsey *et al*., 1989). Activities classified as unknown were included in the feeding category since it was believed to be likely that the whales were feeding. In addition, observations were not used if the whales were surface active, or if it appeared that the boat might have caused any disturbance in behaviour. The following terms and definitions were taken from Baker *et al.* (1982):

trial: 20 minutes

blow interval: average blow interval measured during an observation trial.

blow rate: number of blows in a trial divided by the duration of the trial.

maximum dive interval: longest submergence recorded in an observational trial.

total dive time: total of the submergence time following all fluke-up or fluke-down dives in an observational trial and expressed as a percentage of the total length of the observation trial.

Analyses were not performed because few animals could be compared, and respiration were highly variable (see Appendix D).

3.6. Photo-identification

3.6.1 Humpback whales

3.6.1.1. Resightings across years

Only photographs that were clear and had enough detail to enable positive matchings were used for resighting analyses. Photographs from 1994 and 1995 were catalogued and matches found within years; a second person provided verification if there were any uncertainties about a match. Southern Trinity Bay humpbacks in 1992, 1994, and 1995 were compared between years to determine resightings. Location histories of

YoNAH whales sighted in this area were obtained at College of the Atlantic, Bar Harbor, ME, USA, curator of the photographic catalogue on North Atlantic humpback whales.

The YoNAH photographic archive was used to compare the numbers of individually identified whales sighted inside southern Trinity Bay (n= 67) and outside in 1992 (n= 225), returning to eastern Canada (n= 629) and Newfoundland (n= 359) in 1993. Individually identified humpback whales in southern Trinity Bay in 1992 were also compared with those from eastern Newfoundland in 1994 (n= 162). Due to time constraints it was not possible to compare humpbacks sighted in Newfoundland and eastern Canada in 1992 and 1993, to those sighted in 1994 and 1995. These data will eventually be analyzed in the annual cataloguing process at College of the Atlantic. In addition, few 1992 YoNAH humpbacks from southern Trinity Bay, and eastern Canada and Newfoundland, were resighted in the West Indies to allow adequate comparisons of return proportions to the wintering grounds (P. Stevick, Allied Whale, College of the Atlantic, Bar Harbor, ME, USA, pers. comm.). However, comparisons were made between the number of YoNAH humpback whales sighted along the southeast shore (n= 64) (Cape Spear to Cape Race) and Bonavista Bay (n= 20) (Cape Bonavista to Cape Freels) in 1992, resighted in eastern Newfoundland in 1993 and 1994 (Fig. 12).

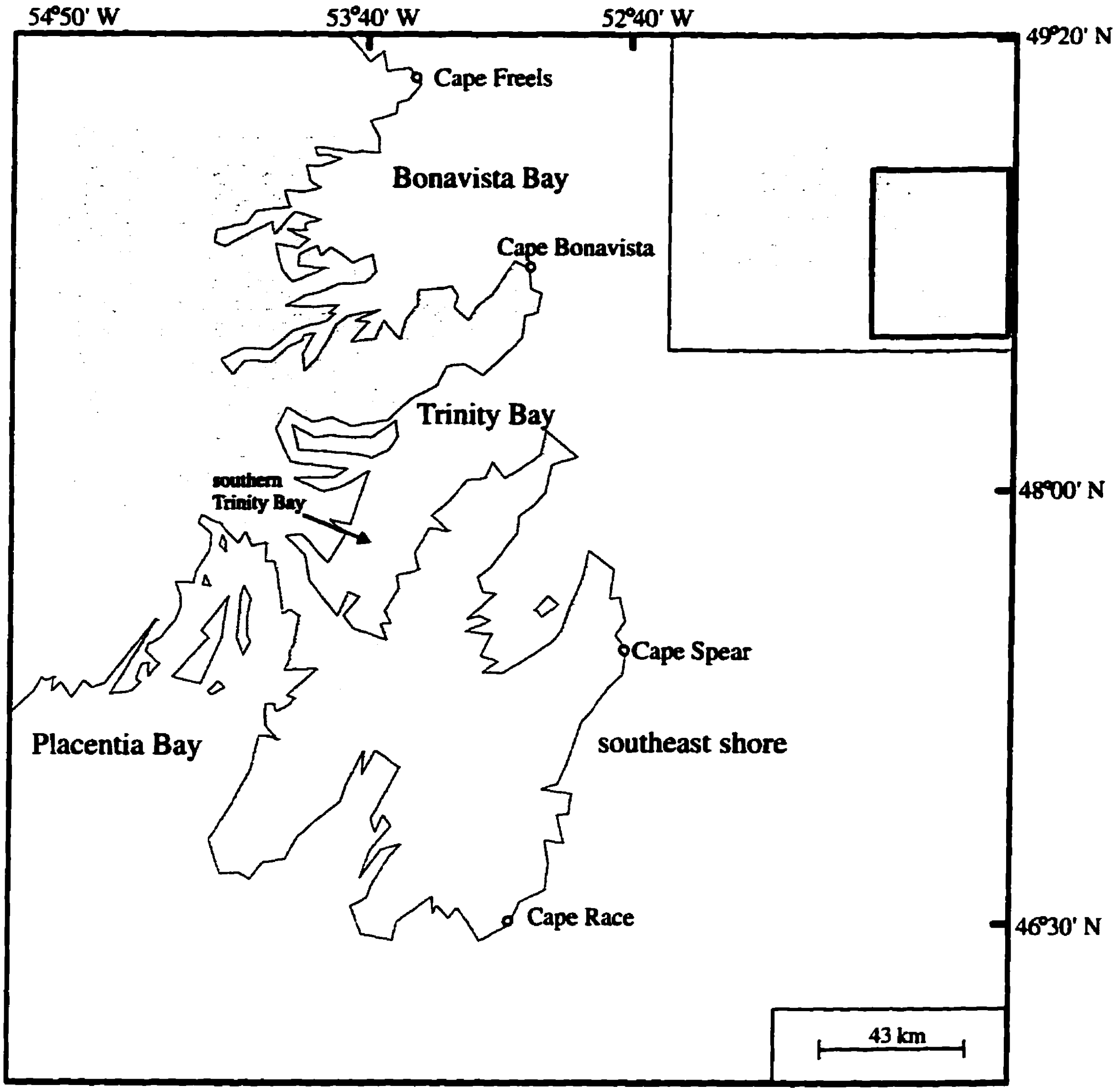


Figure 12.

Bonavista Bay, Trinity Bay, Placentia Bay, and the southeast shore study areas used for between year comparisons.

3.6.1.2. Resightings and residency among years

The percentage of whales moving closer to or further from the industrial site was determined by comparing the daily maximum distance from the industrial site of subsequent sightings of individually identified whales (Todd *et al.*, 1996). In addition, the daily maximum distance from the industrial site for each photographed whale was averaged and the result categorized (< 10, 10-20, and > 20 km); the average number of days animals were resighted was subsequently calculated by averaging the days animals were sighted for each category (Todd *et al.*, 1996). Resightings are defined as the number of days an animal was identified, and residency is defined as the time interval between the first and last sighting. Some results from 1992 (data from Todd *et al.*, 1996) were recalculated to standardize the limits of the study area in each year.

The 1992 study was shorter than 1994 and 1995, and it appears that capelin were present earlier (Figs. 8, 9). To test whether any differences in resightings and residency were due to different time periods, the 1995 study period was divided into two periods. The period from 17 June - 4 July 1995 was compared to the 1992 study (6 June - 25 June); the period from 5 July - 8 August 1995 was compared to the 1994 study (5 July - 29 July). To test that resightings and residency were not affected by the study intervals, opportunistic sightings from Sunnyside (whales exhibiting high residency in Bull Arm in 1995 were sighted during this time), and sightings made when only the control area was monitored (3 days) were removed. Humpback resightings and residency from Placentia

Bay during 1993 and 1994 (data from Marques, 1996) were also calculated for additional comparisons (Fig. 12).

3.6.2. Minke whales

There was no established catalogue of photo-identified minkes; matching was conducted between photographs obtained during the 1994 and 1995 surveys. Only photographs that were clear and had enough detail to enable positive matchings were used. Two main matchers (author included) conducted blind matches of all good minke whale photographs within and between 1994 and 1995; a third matcher provided additional confirmation for all potential resightings. If resightings could not be confirmed by all the matchers, they were not used. Matches were not based on dorsal shape alone unless the shape was unique or notches were present (Fig. 13). Minke whale photographs showing the left side of the body were used when reporting the number of whales photographed. Photographs of animals in which only the right side of the body was obtained were used for resightings and counts if they had unique dorsal fin shapes (Fig. 14).

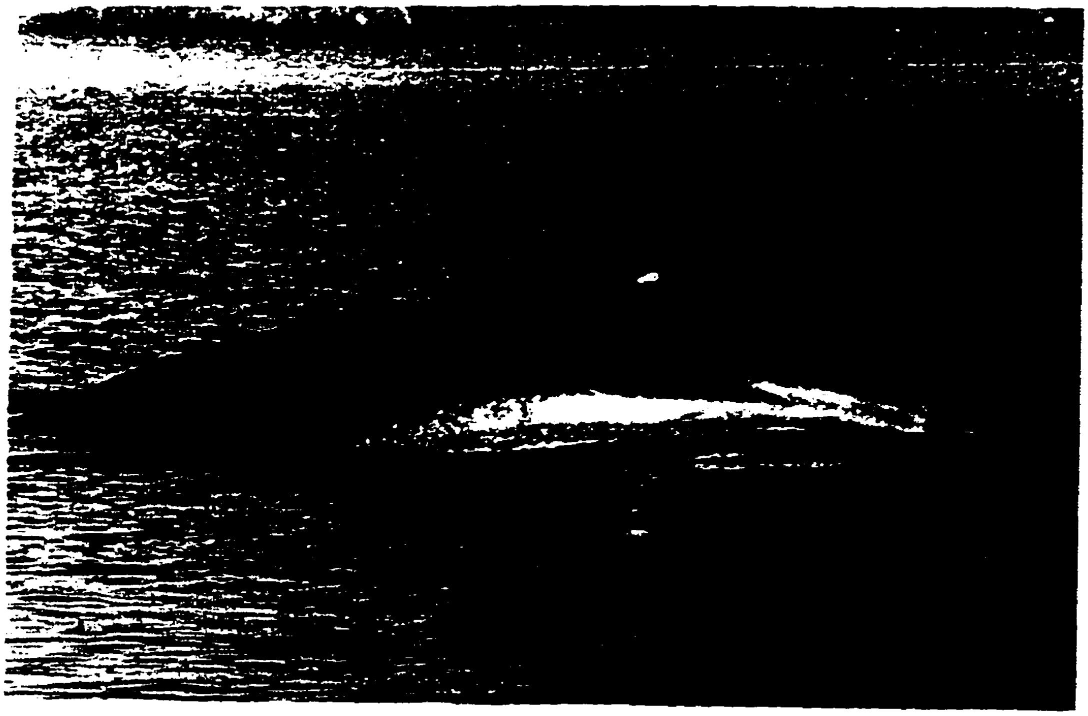


Figure 13.

Example of the left side of a minke whale (*Balaenoptera acutorostrata*) showing a unique dorsal fin shape, scars, and pigmentation patterns.

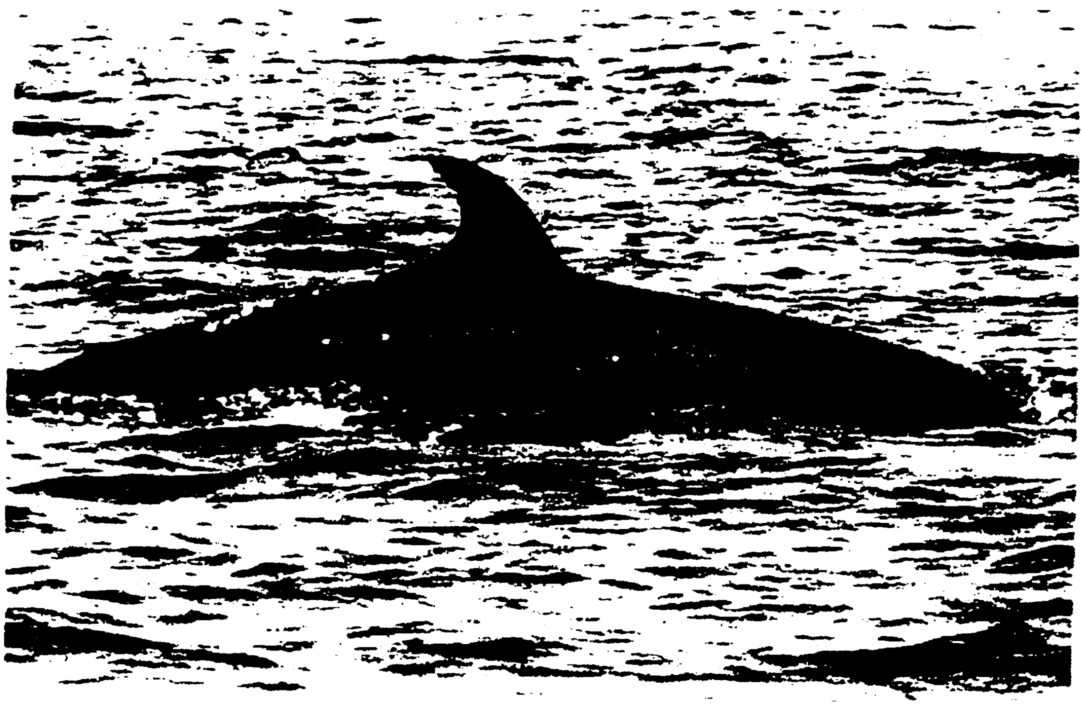


Figure 14.

Example of a minke whale (*Balaenoptera acutorostrata*) in which only the right side was photographed; however, the unique dorsal fin shape enables its use for identification.

4. Results

4.1. Acoustics

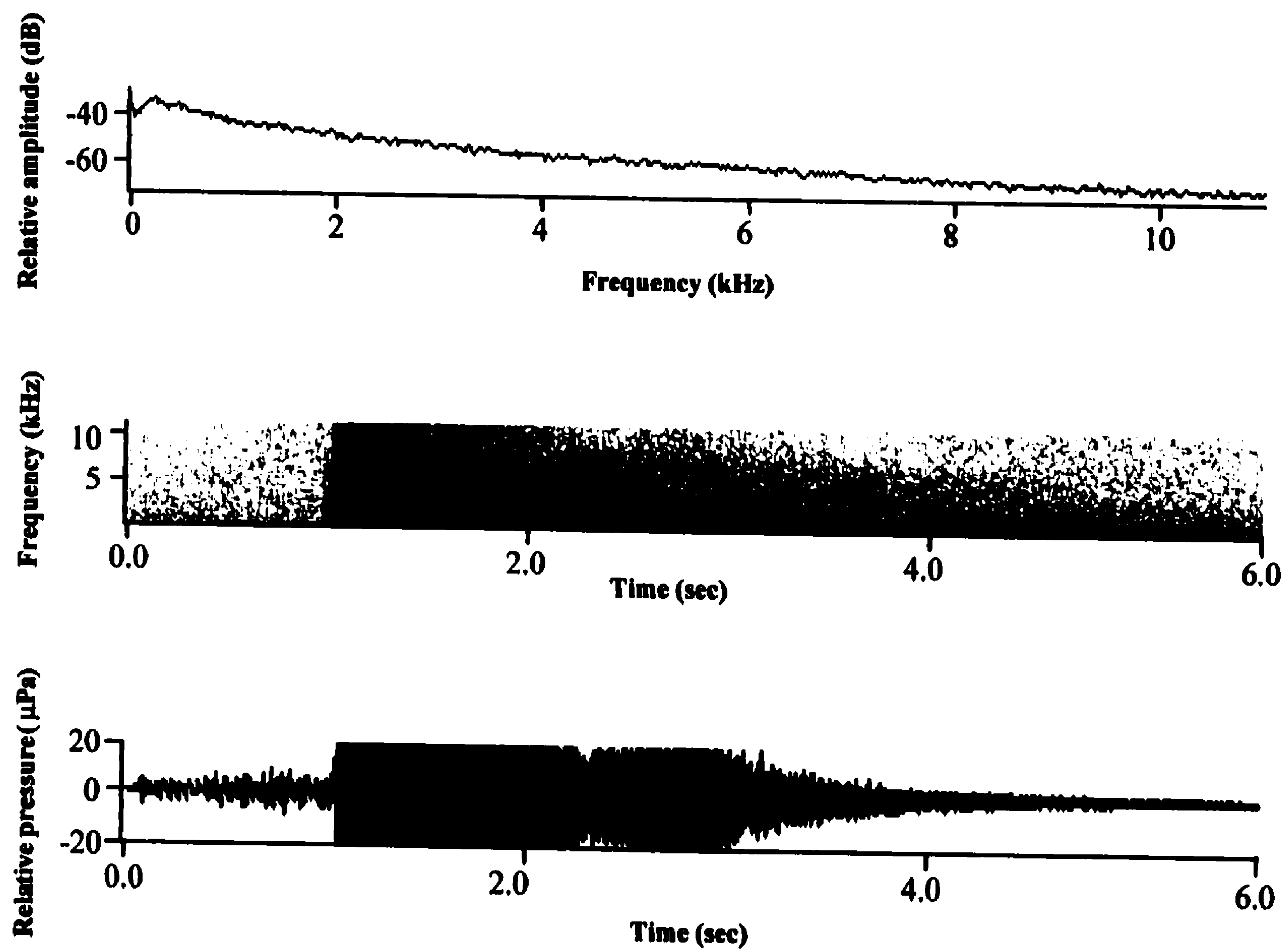
Low-frequency sounds dominated the sound spectra of underwater blast (491 kg), dredge (including some vessel activity), and vessel activity recordings taken at the hydrophone station (Fig. 15). Relative sound pressure levels were highest for the recorded blast (despite clipping which would underestimate level of signal), and were fairly comparable for dredge and vessel activity. Dredge activity levels were not as high throughout the low-frequency range, but dredging was in 24 hr operation throughout the main observation period. Dredge and vessel activity were continuous noises with components that vary with time, so actual sound pressure levels probably fluctuated (Greene and Moore, 1995).

In 1994, blast signals were detected in recordings taken near station 6 and 9 in the experimental area (Fig. 16), but could not be discriminated from ambient noise (which included small boats) in the control area. Low-frequency sounds dominated the sound spectra of blast recordings taken further from the industrial site, and high-frequency sounds diminished with distance (Spindel and Worcester, 1990). This suggested that industrial noise could be detected in the experimental area, but not in the control area at similar distances from the industrial site and under similar conditions.

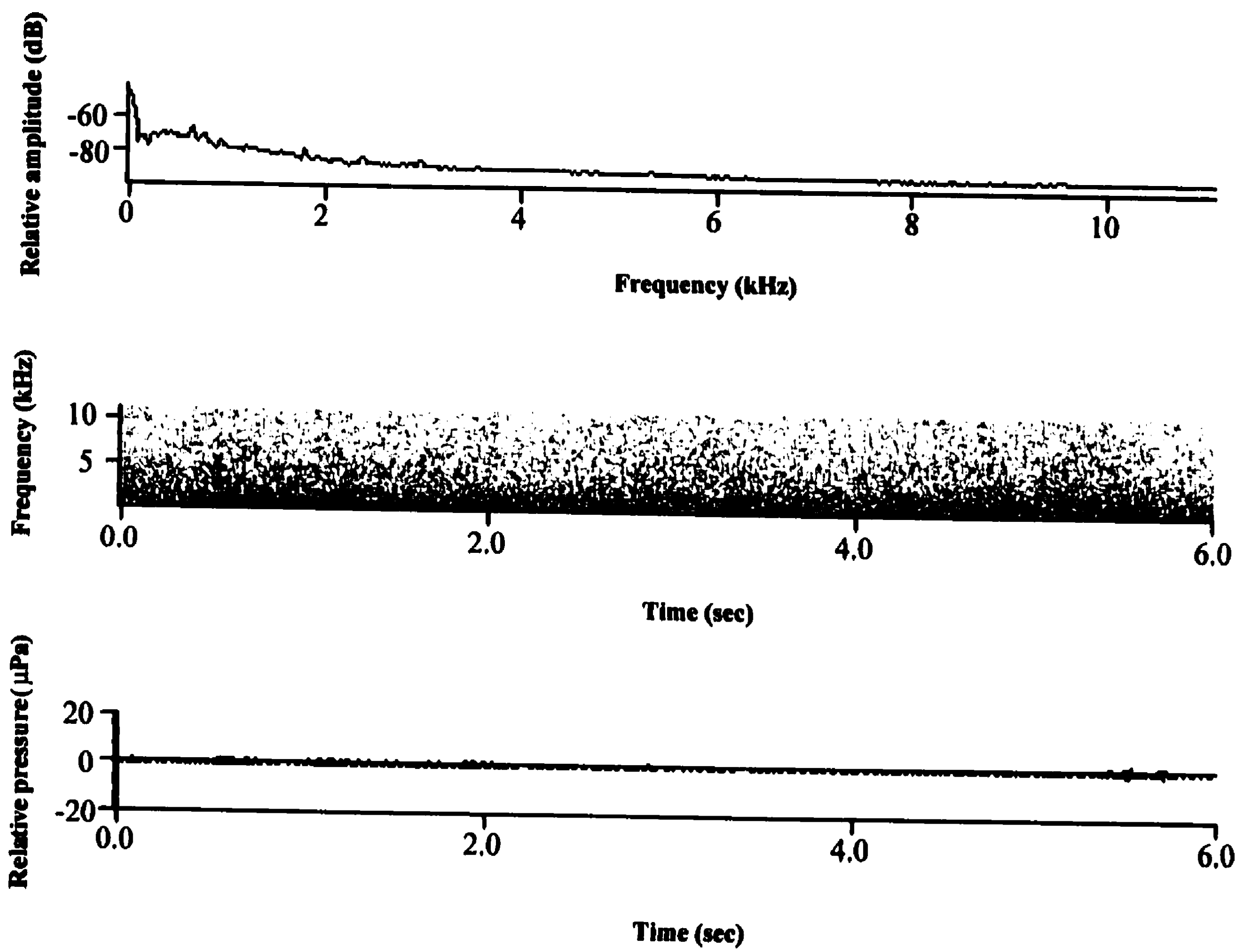
Figure 15.

Spectrum, spectrogram, and waveform of a 6 second recording sample of blast (A) and dredge activity (B) from 1994, and vessel activity (C) from 1995. Note different scales of Y-axis for spectra.

A. 491 kg Blast (14 August 1994)



B. Dredge activity (22 October 1994)



C. Vessel activity (3 July 1995)

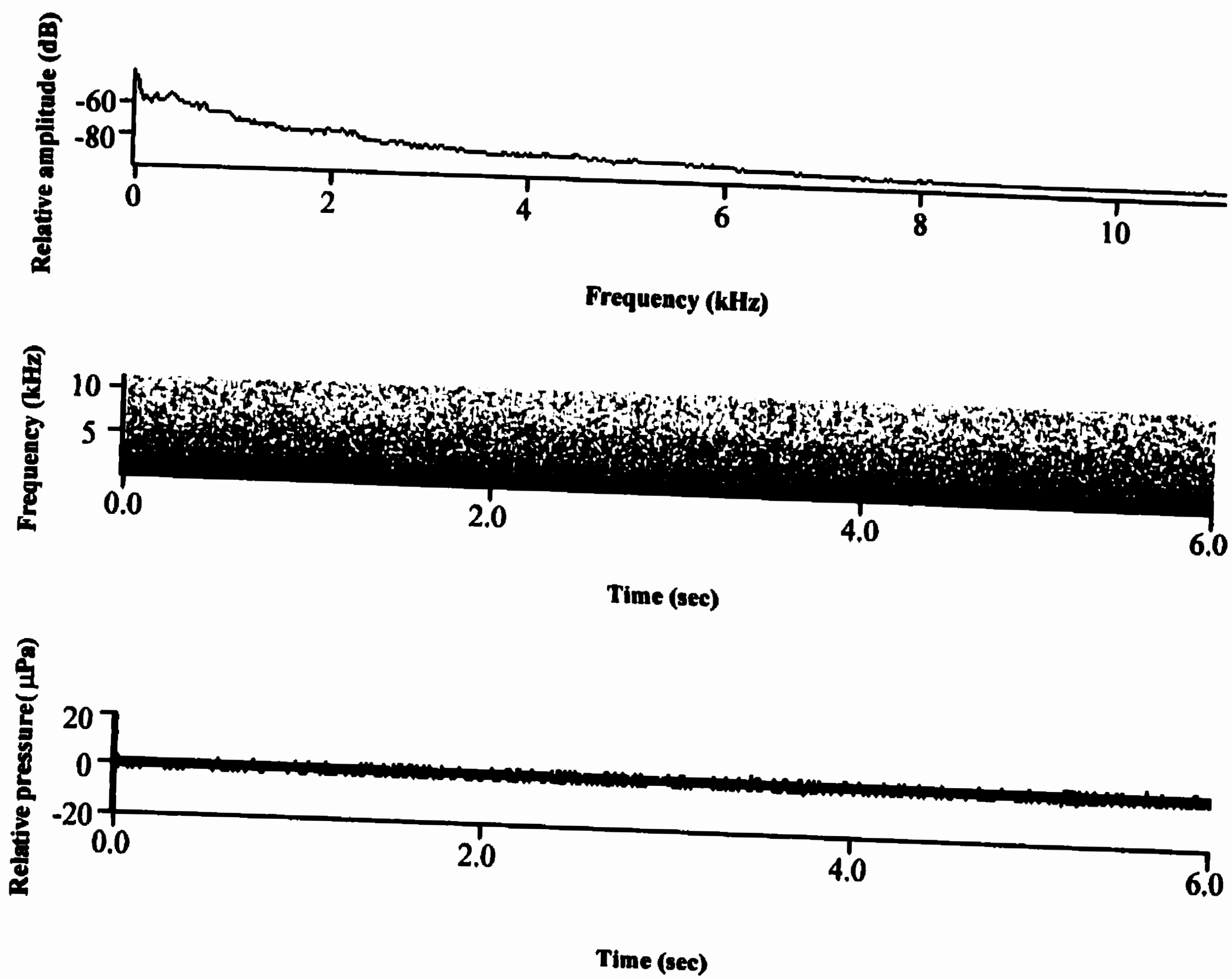
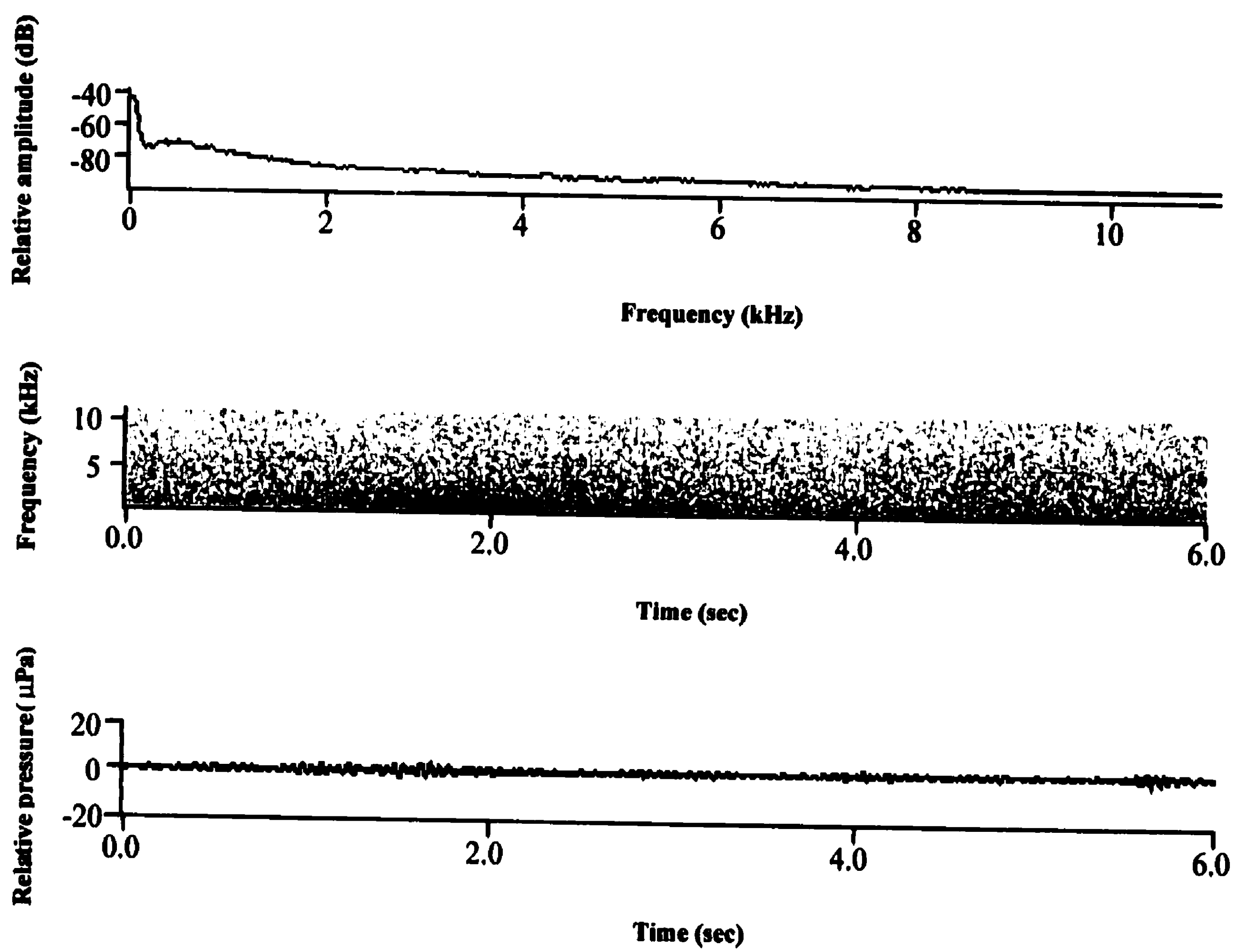


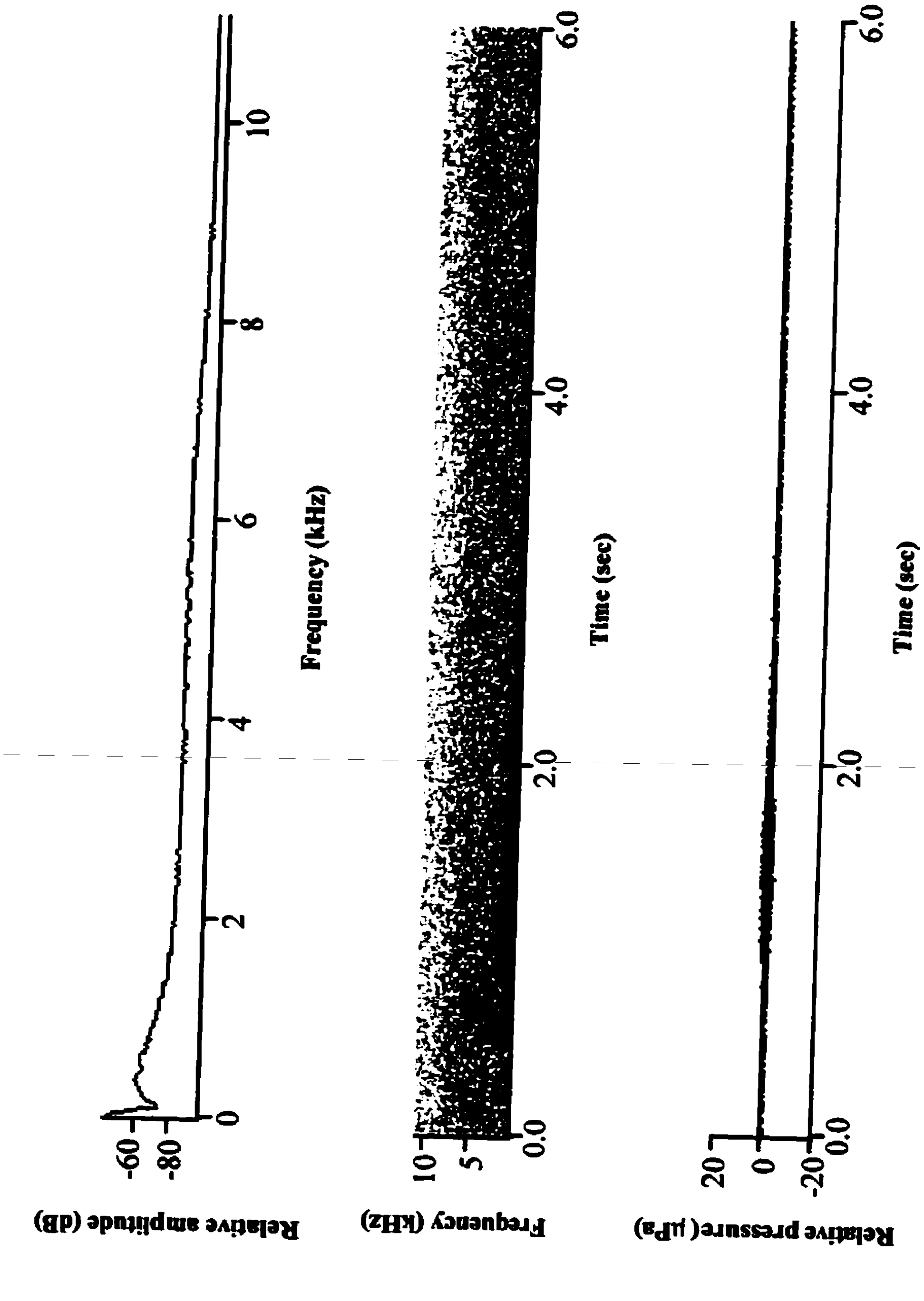
Figure 16.

Spectrum, spectrogram, and waveform of a 6 second recording sample of a blast recorded near station number 6 (A), and a blast recorded near station number 9 from 1994 (B). Note different scales of Y-axis for spectra.

A. 1545 kg Blast (28 August 1994)



B. 904 kg Blast (5 September 1994)



4.2. Prey

In 1994 and 1995, daily observations from Chance Cove indicated capelin were present most of July and into early August (Nakashima, DFO, St. John's, NF, unpubl. data). Daily surface area (m^2) of capelin schools was higher in southern Trinity Bay in 1994 than in any year since 1991 (Nakashima, 1996). In addition, the experimental area had a higher relative abundance of capelin than the control area in 1994. Fish kills at Hibernia indicated that herring were present on various blasting days between 17 August - 17 September 1994.

Echosounder readings, feeding birds, and behavioural observations of whales showed prey were often present near Hibernia until 13 July 1994. This coincided with the time period when dredging frequency and amount of material that was dumped increased. In addition, squid (*Illex illecebrosus*) were also present as landings of this species by fisherpersons began on 17 August 1994, in Sunnyside. In 1995, euphausiids (species not identified), capelin, and herring were present in southern Trinity Bay, based on visual observation and fisherperson's catch. Echosounder readings, feeding birds, and behavioural observation of whales showed prey was present in Bull Arm throughout the 1995 study.

4.3. Oceanographic conditions

The average temperature measurements in the upper 35 m for each station suggest similar seasonal variation within 1994 and 1995 (Fig. 17). Between-year comparisons were not possible because the timing of oceanographic measurements was not the same (due to lack of equipment). However, the temperature of the 10 m layer for each month during 1994 and 1995 (Fig. 18; Nakashima, DFO, St. John's, NF, unpubl. data) shows a similar seasonal pattern, and is consistent with seasonal patterns seen in Newfoundland (cf. Mathieu and deYoung, 1995; Narayanan *et al.*, 1991). This supports overlapping the two years so similar seasonal periods are compared (see section 3.4.2.). Although cetacean abundance is related more to prey than oceanographic conditions (e.g. Piatt *et al.*, 1989), some studies have suggested a relationship to oceanographic conditions (e.g. Whitehead, 1981; Smith and Whitehead, 1993). During the 1992 study the 10 m layer was warmer; comparisons made to 1992 attempted to control for potential differences of season (section 3.6.1.2.).

4.4. 1994 and 1995

4.4.1. Species sighted

Species sighted included humpback, finback (*Balaenoptera physalus*), and minke whales, as well as white-sided dolphin (*Lagenorhynchus acutus*), white-beaked dolphin (*Lagenorhynchus albirostris*), harbour porpoise (*Phocoena phocoena*), and seals (species

Figure 17.

Average temperature measurements (°C) of the upper 35 m for stations number 1, 9, and 13 during the 1994 and 1995 study.

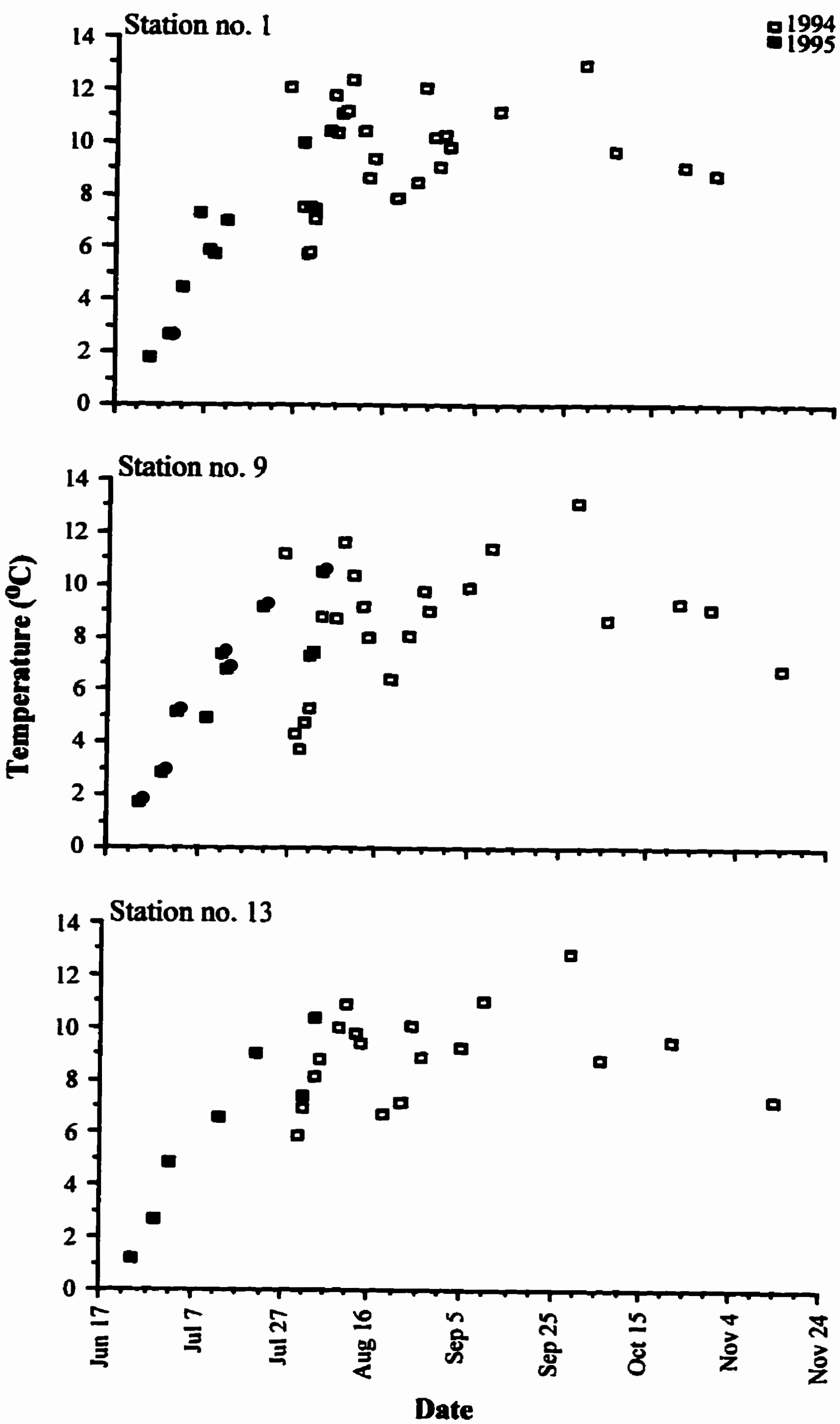
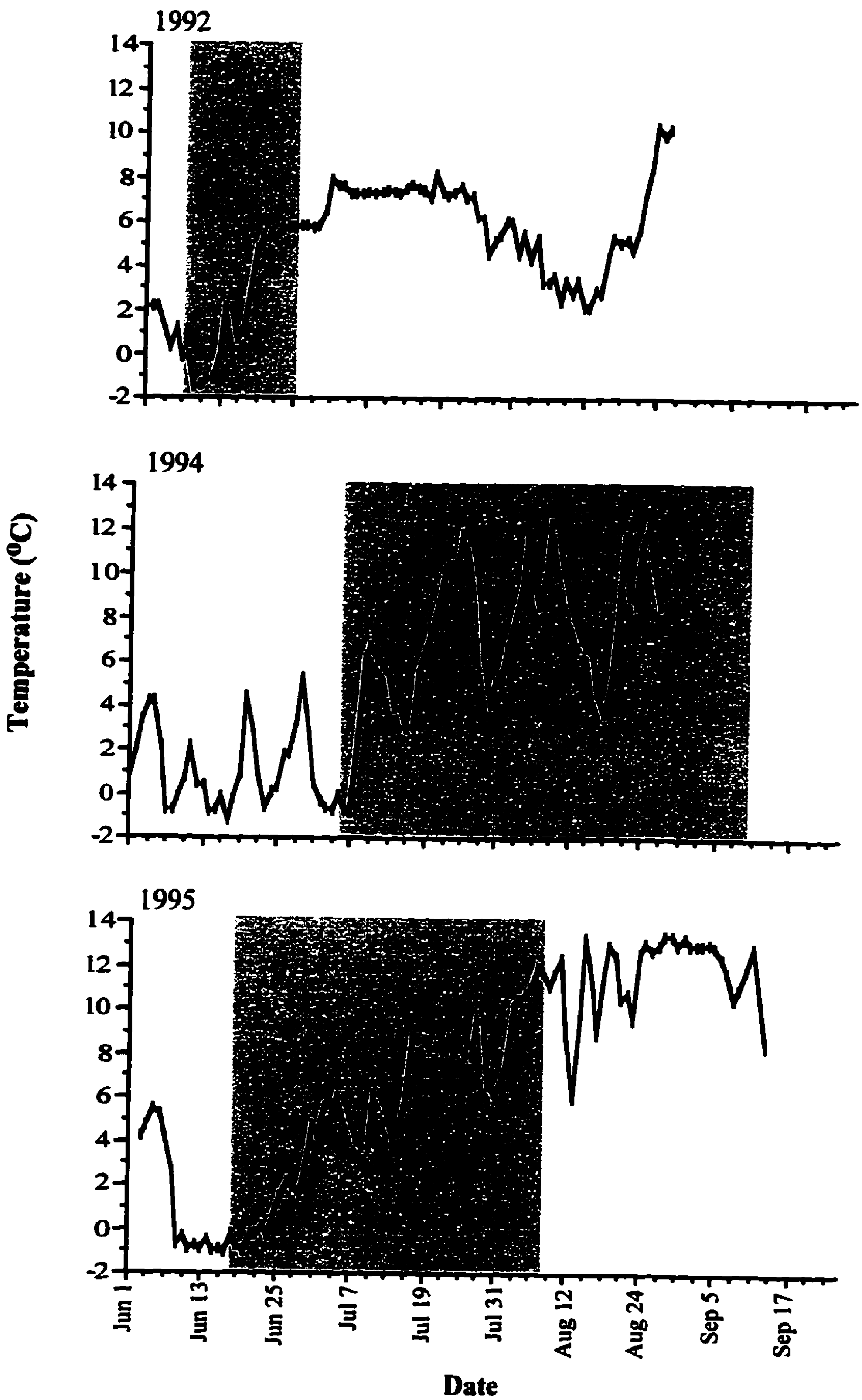

Station no. 1
1994
1995
Station no. 9
Station no. 13
Temperature (⁰C)
0
2
4
6
8
10
12
14
Jun 17
Jul 7
Jul 27
Aug 16
Sep 5
Sep 25
Oct 15
Nov 4
Nov 24
Date

Figure 18.

Average daily temperature (°C) at 10 m in Chance Cove, Trinity Bay in 1992, 1994, and 1995 (Nakashima, DFO, St. John's, NF, unpubl. data). Shaded area indicates main study periods.


1992
1994
1995
Temperature (°C)
14
12
10
8
6
4
2
0
-2
Jun 1
Jun 13
Jun 25
Jul 7
Jul 19
Jul 31
Aug 12
Aug 24
Sep 5
Sep 17
Date

not identified). The numbers of marine mammals observed in 1994 and 1995 are listed in Tables 4 and 5. Humpback abundance in the control area was biased after 13 July 1995 due to a personal communication (see section 3.3.); the animals seen are included in parentheses but were not used in analyses as this could bias abundance estimates. Animals may be present on more than one day. It has been suggested that effects of man-made noise vary with species (Myrberg, 1978; Richardson, 1995b), so species were examined individually. Further analyses used humpback whales, minke whales, and harbour porpoise, based on their abundance in the experimental and control areas.

4.4.2. Environmental conditions

Deteriorating sea conditions (Beaufort scale) and visibility are known to reduce an observer's ability to sight marine mammals (Eberhardt *et al.*, 1979; Barlow, 1988; Clarke, 1982). In 1994 and 1995, sea condition and visibility did not significantly affect sightings of humpback whales, minke whales, or harbour porpoise (Table 6). However, most observation time was spent in low Beaufort scale and good visibility conditions due to the small size of the survey boat.

4.4.3. Areas searched

The time spent searching in each distance category in the experimental area (0-10 and 11-20 km) was similar in 1994 (63.0 and 53.4 hr) and 1995 (27.7 and 24.8 hr). There

Table 4. Minimum number of marine mammal sightings in the experimental and control areas in 1994, without standardizing by searching effort. Some animals may be present on more than one day.

	Humpback (*Megaptera novaeangliae*)	Finback (*Balaenoptera physalus*)	Minke (*Balaenoptera acutorostrata*)	Harbour Porpoise (*Phocoena phocoena*)	Dolphin (*Lagenorhynchus acutus* and *albirostris*)	Seal (species not identified)	Unknown cetacean	Total
Experimental	19	2	45	54	33	11	1	170
Control	30	22	20	27	66	7	2	186
Total	49	24	65	81	99	18	3	356

Table 5. Minimum number of marine mammal sightings in the experimental and control areas in 1995, without standardizing by searching effort. Biased humpback sightings (*Megaptera novaeangliae*), resulting when surveys occurred in an area due to a personal communication, are indicated in parentheses. Some animals may be present on more than one day.

	Humpback (*Megaptera novaeangliae*)	Finback (*Balaenoptera physalus*)	Minke (*Balaenoptera acutorostrata*)	Harbour Porpoise (*Phocoena phocoena*)	Dolphin (*Lagenorhynchus acutus* and *albirostris*)	Seal (species not identified)	Unknown cetacean	Total
Experimental	57	5	51	38	0	12	1	174
Control	29 (72)	22	17	35	5	15	0	123(167)
Total	86 (129)	27	68	73	5	27	1	287(341)

Table 6. Results of analyses on the sightability of humpback whales (*Megaptera novaeangliae*), minke whales (*Balaenoptera acutorostrata*), and harbour porpoise (*Phocoena phocoena*) in 1994 and 1995 during various visibility (0-20, 21-40, and 41-60 km) and Beaufort scale (0, 1, 2, and 3) conditions, controlling for potential seasonal changes with day of the year.

Explanatory variables	No. humpback sightings/searching hr		No. minke sightings/searching hr		No. harbour porpoise sightings/searching hr	
	1994	1995	1994	1995	1994	1995
Beaufort	$F_{3,41}=2.13$, $p_r=0.12$[a]	$F_{3,58}=1.87$, $p_r=0.15$[a]	$F_{3,111}=1.84$, $p_r=0.11$	$F_{3,58}=1.69$, $p_r=0.13$	$F_{3,106}=0.41$, $p_r=0.78$	$F_{3,43}=1.36$, $p_r=0.26$[b]
Date	$F_{1,41}=0.05$, $p_r=0.83$[a]	$F_{1,58}=0.12$, $p_r=0.74$[a]	$F_{1,111}=4.27$, **$p_r=0.03$**	$F_{1,58}=0.65$, $p_r=0.46$	$F_{1,106}=1.02$, $p_r=0.34$	$F_{1,43}=1.53$, $p_r=0.26$[b]
Visibility	$F_{2,14}=1.86$, $p_r=0.21$[a]	$F_{2,36}=1.18$, $p_r=0.32$	$F_{2,52}=1.52$, $p_r=0.24$	$F_{2,36}=1.69$, $p_F=0.20$[a]	$F_{2,51}=2.40$, $p_r=0.11$	$F_{2,26}=1.08$, $p_r=0.35$
Date	$F_{1,14}<0.005$, $p_r=0.99$[a]	$F_{1,36}<0.005$, $p_r=0.99$	$F_{1,52}=6.42$, **$p_r=0.02$**	$F_{1,36}=4.63$, **$p_F=0.04$**[a]	$F_{1,51}=0.22$, $p_r=0.62$	$F_{1,26}=4.12$, **$p_r=0.04$**

[a] L transformed response variable
[b] SQ transformed response variable

was a difference in the amount of searching time between years; however, the number of whales were standardized by effort for further comparisons.

4.5. Humpback Whales

4.5.1. Abundance and distribution

4.5.1.1. 1992

Todd *et al.* (1996) reported a clumped distribution of humpbacks in Bull Arm. Distances of humpbacks from the industrial site in the experimental area did not appear to change with time (Fig. 19; group size was not always indicated, so statistical analysis based on the present method could not be performed).

4.5.1.2. 1994

During dredging in 1994 (Table 7), there was an increase in humpback distance from the industrial site during the main observation period (Fig. 20; $F_{1,15}$=19.26, p_r=0.002), but no change in L-RA relative abundance (Fig 21; $F_{1,11}$=0.02, p=0.91). The L-RA relative abundance was significantly lower in the experimental area ($\overline{RA}$=0.50±0.19) compared to the control area ($\overline{RA}$=5.40±1.49) when common days were compared (Fig. 22; exp/con: $F_{1,15}$=19.44, p_r=0.002; date: $F_{1,15}$=5.96, p_r=0.03).

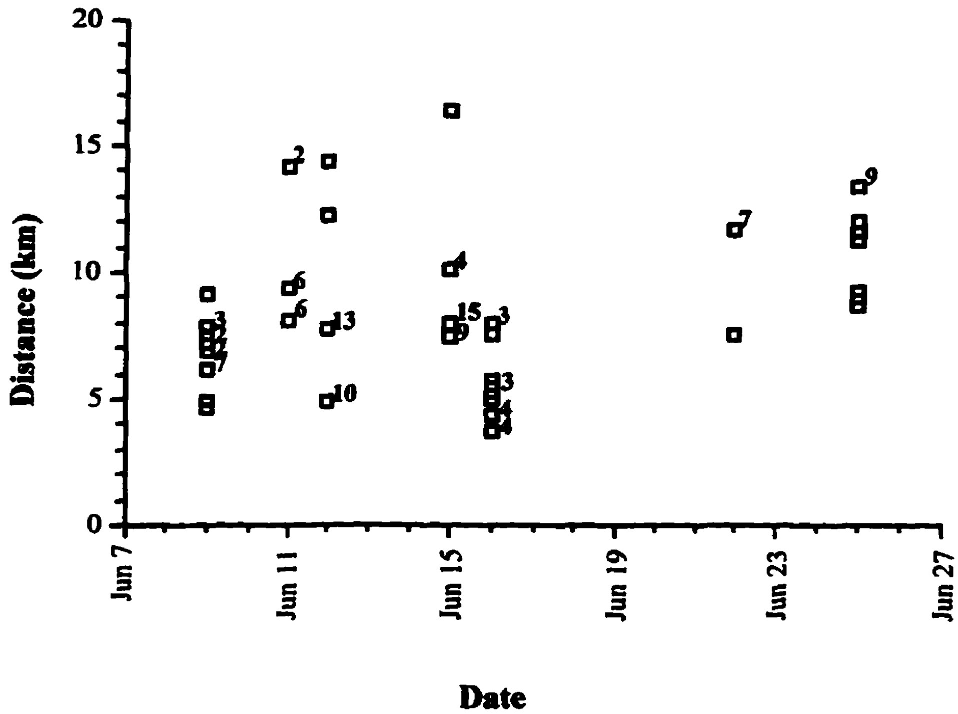


Figure 19.

Distance (km) from the industrial site of all humpback whales (*Megaptera novaeangliae*) observed in the experimental area during blasting, drilling, and dredging activity in 1992 (data from Todd *et al.*, 1996). The average distance (± se) was 8.20 ± 0.24. Numbers indicate total whales, not group size.

Table 7. Results of analyses testing the effect of various explanatory variables on distance, relative abundance, and relative occurrence of humpback whales (*Megaptera novaeangliae*) observed in 1994 and 1995.

Explanatory variables	Distance	Relative abundance	Relative occurrence
1994			
Dates during dredging[a]	$F_{1,15}$=19.26, **p_r=0.002**	$F_{1,11}$=0.02, p_r=0.91[b]	$F_{1,7}$=0.39, p_r=0.55[b]
Experimental vs. control area (controlling for date)	-	**exp/con**: $F_{1,15}$=19.44, **p_r=0.002** **date**: $F_{1,15}$=5.96, **p_r=0.03**[b]	-
1995			
Dates of main observation period	$F_{1,37}$=10.49, **p_r=0.003**[c]	$F_{1,19}$=0.02, p_r=0.92[c]	$F_{1,17}$=0.36, p_r=0.59[f]
Experimental vs. control area (controlling for date)	-	exp/con: $F_{1,13}$=0.09, p_r=0.84 date: $F_{1,13}$=1.33, p_r=0.29[d]	-
Dates of 1994 study	$F_{1,22}$=7.10, **p_r=0.02**[b]	$F_{1,10}$=1.24, p_r=.29[c]	$F_{1,9}$=2.68, p_r=0.12[e]
Dates before 1994 study	$F_{1,13}$=0.07, p_r=0.81	$F_{1,7}$=1.41, p_r=0.27	$F_{1,6}$=0.60, p_r=0.50

- not applicable

[a] same as main observation period

[b] L, [c] SQ, [d] INV, [e] P3, and [f] P4 transformed response variables

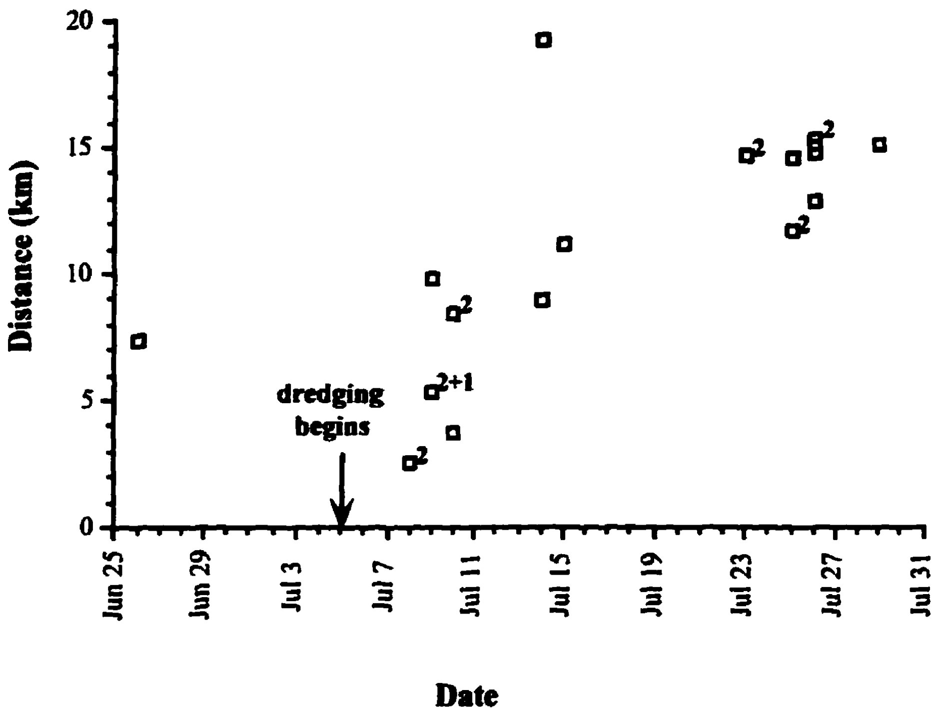


Figure 20.

Distance (km) from the industrial site of all humpbacks whales (*Megaptera novaeangliae*) observed in the experimental area during dredging activity in 1994. The average distance (± se) during dredging was 11.10 ± 1.16. Numbers indicate group size of whales at the same location.

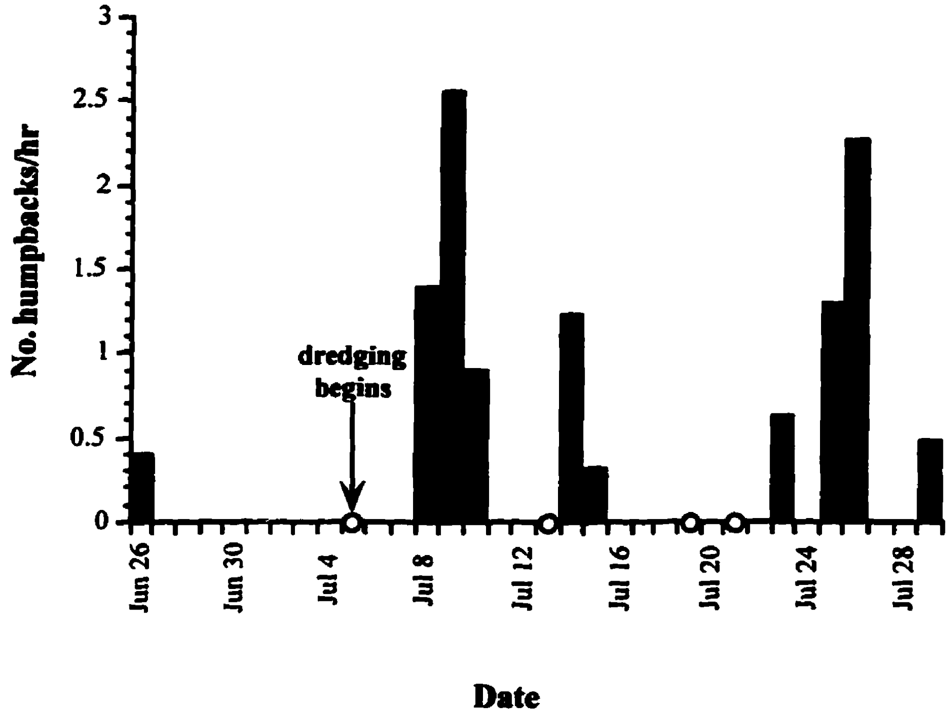


Figure 21.

Number of humpback whales (*Megaptera novaeangliae*) per searching hour in the experimental area in 1994 during dredging. Circles indicate effort with no sightings. The average relative abundance (± se) during dredging was 0.85 ± 0.24.

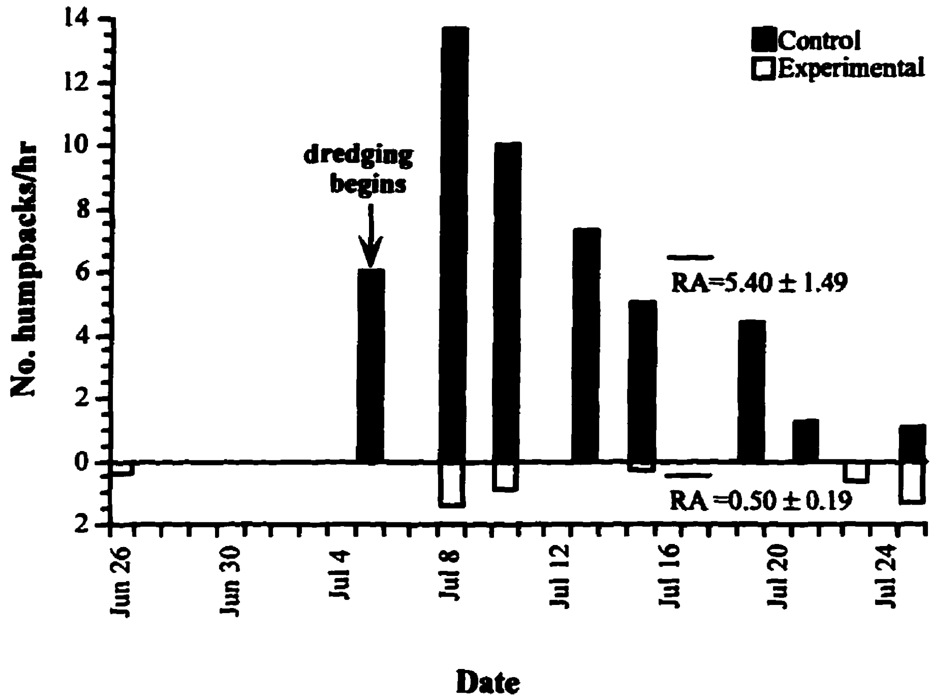


Figure 22.

Number of humpback whales (*Megaptera novaeangliae*) per searching hour in the experimental and control areas in 1994. The relative abundance (RA ± se) was significantly lower in the experimental versus the control area during dredging.

4.5.1.3. 1995

In 1995 (Table 7), there was an increase in SQ-D humpback distance from the industrial site during the main observation period (Fig. 23; $F_{1,37}$=10.49, p_r=0.003), but no change in SQ-RA relative abundance (Fig. 24; $F_{1,19}$=0.02, p_r=0.92). The INV-RA relative abundance was not significantly different in the experimental area ($\overline{RA}$=0.84±0.17) compared to the control area ($\overline{RA}$=1.76±0.50) when common days were compared due to the high variability in sightings (Fig. 25; exp/con: $F_{1,13}$=0.09, p_r=0.84; date: $F_{1,13}$=1.33, p_r=0.29). When the survey period was fixed to test for between year differences in the experimental area, the same trends as in 1994 were found. However, before the fixed survey period there was no change in distance ($F_{1,13}$=0.07, p_r=0.81); this is similar to the trend observed in 1992.

4.5.1.4. Abundance comparisons across years

There were differences in the relative abundance of humpback whales in the experimental and control areas in southern Trinity Bay across years (Table 8). In 1992, more humpback whales per hr occurred in the experimental area (4.05 ± 0.44), as compared to the control area (1.65 ± 0.35), during blasting, dredging, and vessel traffic. The opposite trend occurred in 1994 (exp: 0.40 ± 0.16; con: 1.22 ± 0.25) and 1995 (exp: 0.54 ± 0.11; con: 0.97 ± 0.30). In addition, more humpbacks per hr were observed in 1992. Due to low number of days in each area in 1992, statistical comparisons were not

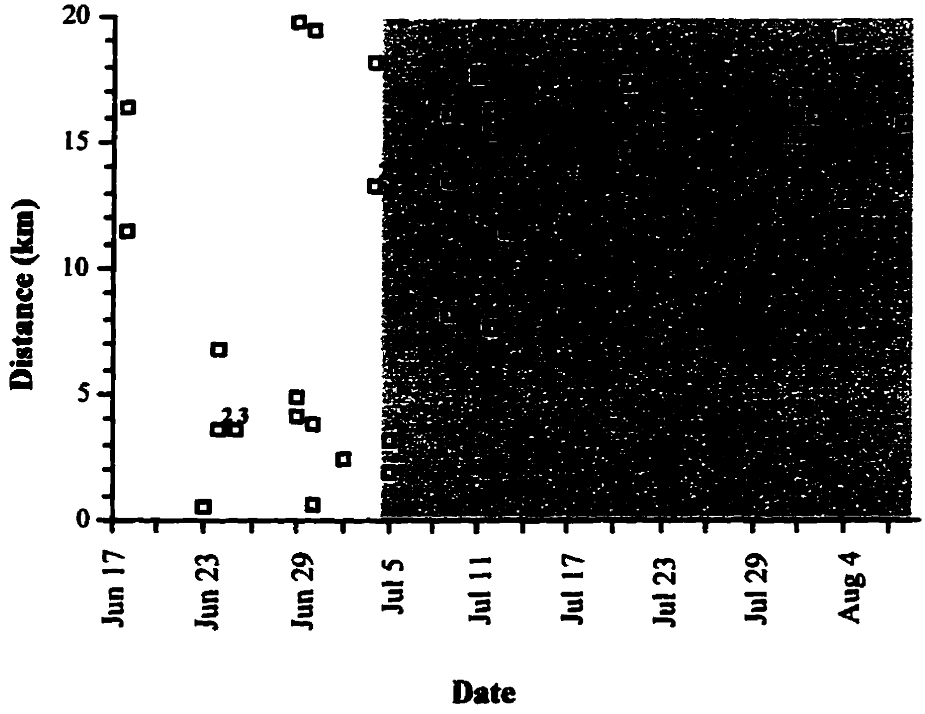


Figure 23.

Distance (km) from the industrial site of all humback whales (*Megaptera novaeangliae*) observed in the experimental area during vessel activity in 1995. Shaded area indicates study period in 1994; the average distance (± se) was 8.61 ± 1.83 before, and 13.90 ± 0.90 during this time period. Numbers indicate the group size of whales at the same location.

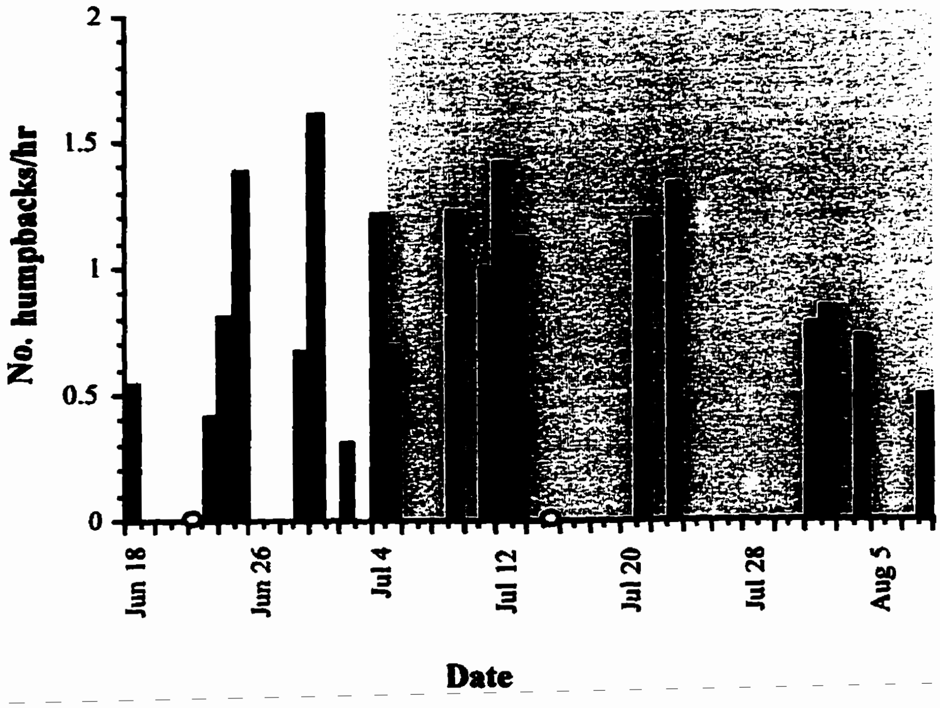


Figure 24.

Number of humpback whales (*Megaptera novaeangliae*) per searching hour during vessel activity in the experimental area in 1995. Circles indicate effort with no sightings. Shaded area indicates study period in 1994; the average relative abundance (± se) was 0.77 ± 0.18 before, and 0.90 ± 0.12 during this time period.

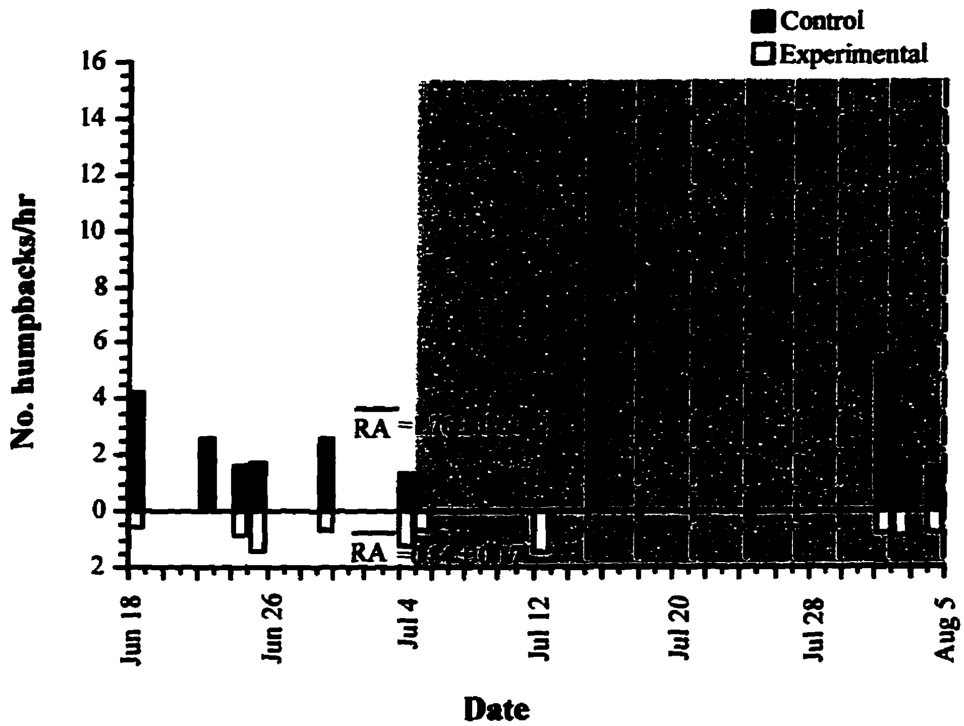


Figure 25.

Number of humpback whales (*Megaptera novaeangliae*) per searching hour in the experimental and control areas in 1995. Shaded area indicates study period in 1994, and dashed area indicates biased numbers due to a personal communication in 1995. No significant difference was found in relative abundance (RA ± se) between the experimental and control areas before the biased numbers.

Table 8. Average relative abundance (no. whales/hr ± se) of humpback whales (*Megaptera novaeangliae*), in the experimental and control areas, during 1992 (data from Todd *et al.*, 1996), 1994, and 1995. Only days on which monitoring occurred in both areas were used.

	1992 (4 days)	1994[a] (9 days)	1995[a] (8 days)
Experimental area	4.05 ± 0.44	0.40 ± 0.16	0.54 ± 0.11
Control area	1.65 ± 0.35	1.22 ± 0.25	0.97 ± 0.30

[a] respiration, oceanographic, and acoustic measurements were conducted during this time period in 1994 and 1995, and deducted from the total time

performed. However, the trends observed are supported by the large numbers of humpbacks observed in the experimental area in 1992, as compared to 1994 and 1995.

4.5.2. Photo-identification

4.5.2.1. Resightings across 1992 and 1994

The proportion of humpbacks sighted in Trinity Bay in 1992, and resighted in eastern Canada in 1993 (0.13), did not differ from the resighting proportion of animals from the rest of Newfoundland (0.24) (Table 9; G_I=3.4, p_F=0.06). However, a significantly smaller proportion of animals sighted in Trinity Bay in 1992 were resighted in Newfoundland in 1993 (0.07), compared to the resighting proportion of animals from the rest of Newfoundland (0.21) (G_I=7.8, p_F=0.005).

A significantly smaller proportion of humpbacks sighted in Trinity Bay in 1992, were resighted in Newfoundland in 1993 (0.07), compared to the resighting proportion of animals from the southeast shore (0.28) (G_I=10.11, p_F=0.002). The proportion of humpbacks sighted in Trinity Bay in 1992, and resighted in Newfoundland in 1994 (0.07), did not differ from the resighting proportion of animals from the southeast shore (0.11); however, the sample size of the 1994 humpback catalogue was considerably smaller than previous years (n= 162) (G_I=0.48, p_F=0.49). Few humpback whales photo-identified in Bonavista Bay in 1992 (n=20), were resighted in Newfoundland in 1993 (n=4) and 1994 (n=2), so comparisons could not be made.

Table 9. Number of humpback whales (*Megaptera novaeangliae*) from Trinity Bay and remaining eastern Newfoundland from 1992, resighted in eastern Canada and Newfoundland in 1993. As well as, the number of humpback whales from Trinity Bay and along the southeast shore from 1992, resighted in Newfoundland in 1993 and 1994.

	Total no. identified 1992	No. resighted in Canada 1993	No. resighted in Newfoundland 1993	No. resighted in Newfoundland 1994
Newfoundland	225	53	48	-
Trinity Bay	67	9	5	5
southeast shore	64	-	18	7

- unknown

4.5.2.2. Southern Trinity Bay resightings across years

In southern Trinity Bay two humpback whales from 1992 (n=67) were resighted in 1994 (n=23), three from 1992 were resighted in 1995 (n=34), and four from 1994 were resighted in 1995. YoNAH whales, sighted in southern Trinity Bay in 1994 and 1995, were often sighted outside the bay in 1992 and 1993 (Table 10). A study in Placentia Bay also found low numbers of resightings between years: only one resighting occurred between 1993 (n=30) and 1994 (n=45) (from Marques, 1996). Whitehead *et al.* (1982) found that greater numbers of humpbacks sighted along the Bay de Verde Peninsula were resighted in the same area as compared to other areas, but believed Bay de Verde was a migratory route. Newfoundland humpback whales are not known to have preferred ranges, and residency is typically reported as less than three days (Whitehead *et al.*, 1980). Thus, the lack of effort in southern Trinity Bay in 1993 should not affect the results of across year resighting analyses.

4.5.2.3. Resightings and residency among years

For animals that were identified on subsequent days, there was movement away from the industrial site when dredging was the predominant activity (1994- 76% of 17 cases), but not blasting (1992- 47% of 53 cases; Todd *et al*,. 1996) or vessel activity (1995- 50% of 80 cases). In addition, individually identified humpbacks were resighted more often closer to the blasting activity in 1992 and vessel activity in 1995, whereas

Table 10. Location histories of YoNAH humpback whales (*Megaptera novaeangliae*) sighted in Newfoundland from 1992-1995.

YoNAH no.	Sighted in 1992	Sighted in 1993	Sighted in 1994	Sighted in 1995
Y0601		√		√ [a]
Y1208	√ [a]		√ [a]	
Y1217	√	√	√ [a]	
Y1223	√			√ [a]
Y1227	√ [a]			
Y1230	√ [a]			
Y1231	√ [a]			
Y1239	√ [a]			
Y1242	√ [a]	√		√ [a]
Y1247	√ [a]			
Y1259	√			√ [a]
Y1264	√ [a]			
Y1283	√ [a]			
Y1286	√ [a]			
Y1288	√ [a]	√		
Y1290	√ [a]			
Y1306	√		√ [a]	
Y1315	√	√	√ [a]	
Y1316	√ [a]			
Y1323	√ [a]			
Y1327	√ [a]			
Y1328	√		√ [a]	√ [a]
Y1340	√		√ [a]	
Y1350	√ [a]			
Y1366	√		√ [a]	
Y1367	√			√ [a]
Y1391	√ [a]	√		
Y1404	√ [a]			
Y1405	√ [a]			√ [a]
Y1423		√	√ [a]	√ [a]
Y1435	√ [a]			
Y1438	√ [a]			

[a] sighted in southern Trinity Bay (there was no effort in this area in 1993)

Table 10. (continued)

YoNAH no.	Sighted in 1992	Sighted in 1993	Sighted in 1994	Sighted in 1995
Y1458	√ [a]			
Y1495	√ [a]			
Y1516	√ [a]			
Y1775	√ [a]			
Y2092	√ [a]	√		
Y2234	√ [a]			
Y2399	√ [a]			
Y2401	√ [a]			
Y2431				√ [a]
Y2567		√		√ [a]
Y2590		√		√ [a]
Y2614		√	√ [a]	√ [a]
Y2668	√ [a]	√		
Y2809		√	√ [a]	

[a] sighted in southern Trinity Bay (there was no effort in this area in 1993)

they were resighted more often further from the dredging activity in 1994 (Fig. 26). Differences in resighting and residency were found between years, with the highest numbers occurring in 1995 (Table 11). In fact, four humpback whales were often resighted near the industrial site in 1995 (Appendix E).

When the 1995 survey period was divided (based on prey presence) to test for seasonal differences, trends similar to the entire 1995 survey period were observed. During the period before 5 July, there was no movement away from the industrial site (45% of 31 cases), and higher average resightings still occurred closer to the site (0-10 km, $\overline{X}$= 8.7, n=3; 11-20 km, $\overline{X}$=1.0, n=3; >20 km, $\overline{X}$=1.8, n=12). From 5 July onwards, there was no movement away from the industrial site (51% of 43 cases), and higher average resightings still occurred closer to the site (0-10 km, $\overline{X}$= 8.0, n=1; 11-20 km, $\overline{X}$=2.7, n=10; >20 km, $\overline{X}$=2.6, n=12). The high resightings and residency for each period in 1995 also remained consistent with the trends observed throughout 1995, even when the two study periods were modified (i.e. days with opportunistic sightings and when only the control area was monitored were subtracted) (Table 11). The earlier time period produced results fairly comparable to 1992, and the later period produced results still higher than 1994.

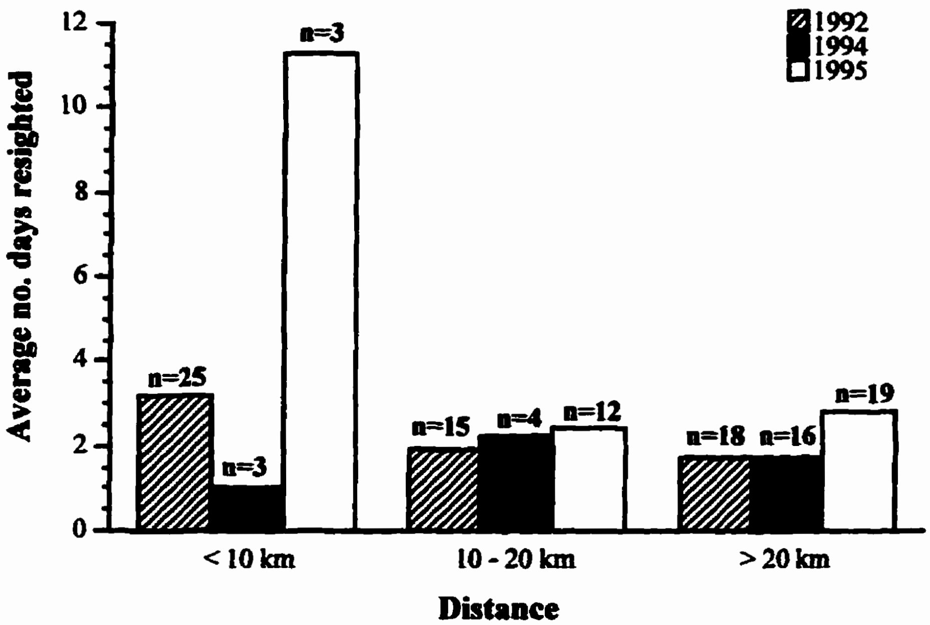


Figure 26.

Distance (km) from the industrial activity of individually identified humpback whale (*Megaptera novaeangliae*) (n= no. of whales) resightings in 1992 (data from Todd *et al.*, 1996), 1994, and 1995. Distance is based on the average of multiple resightings of the same individual (Todd *et al.*, 1996).

Table 11. Resighting and residency of individually identified humpback whales (*Megaptera novaeangliae*) in southern Trinity Bay, Newfoundland in 1992 (data from Todd *et al.*, 1996), 1994, and 1995. The photograph interval (number of days between the first and last photograph), and the number of days photographs were obtained are also noted.

Year	No. humpbacks identified	Average resighting (days)	Average residency of humpbacks seen >1 day (days)	Average residency of all humpbacks (days)	Maximum residency (days)	Photograph interval (days)	No. days photos obtained
1992 (6 - 25 Jun)	67	2.3	7.8	4.6	19	23	9
1994 (5 - 29 Jul)	23	1.7	7.5	3.3	17	24	11
1995 (17 Jun - 8 Aug)	34	3.4	16.7	9.8	44	52	32
17 June - 4 July	18	2.8 (2.4)[a]	8.4 (8.2)	4.2 (4.1)	16 (16)	17 (17)	14 (12)
5 July - 8 August	23 [20][b]	2.9 [2.4]	12.1 [13.5]	7.4 [7.5]	34 [34]	34 [34]	18 [15]

[a] parentheses ( ) indicate results after opportunistic sightings from Sunnyside were removed
[b] brackets [ ] indicate results after days when only the control area was monitored were removed

4.5.2.4. Placentia Bay

Placentia Bay is not free from industrial activity; sources include ship traffic such as ferries and oil tankers. Humpback resighting and residency between 1993 and 1994 were fairly similar, with a comparable number of days between photographs (Table 12; data from Marques, 1996). Although the photograph intervals were different between the two years, the maximum residency number in 1993 was still much lower than the corresponding photograph interval.

4.6. Minke whales

4.6.1. Abundance and distribution

4.6.1.1. 1994

In 1994 (Table 13), minke distance from the industrial site increased during the main observation period (Fig. 27; $F_{1,42}$=9.92, p_r=0.005), and relative abundance decreased (Fig. 28; $F_{1,33}$=9.44, p_r=0.005). Similar trends were observed during dredging, but before blasting. There was no change in distance from the site during blasting ($F_{1,11}$=0.30, p_r=0.63), nor change in L-RA relative abundance ($F_{1,13}$=0.03, p_r=0.88).

No changes in distance ($F_{1,42}$=3.40, p_r=0.08) or relative abundance ($F_{1,33}$=3.03, p_r=0.09) were found before and during blasting. Only one animal was observed while a blast occurred, although animals were sighted before or after blasting activity. This minke

Table 12. Resighting and residency of individually identified humpback whales (*Megaptera novaeangliae*) in Placentia Bay, Newfoundland (1993 and 1994) (data from Marques, 1996).

Year	No. humpbacks identified	Average resighting (days)	Average residency for humpbacks seen >1 day (days)	Average residency for all humpbacks (days)	Maximum residency (days)	Photograph interval [a] (days)	No. days photos obtained
1993	30	1.4	5.4	2.0	10	25	11
1994	45	1.3	5.7	1.4	36	38	11

[a] number of days between the first and last photographed humpback

Table 13. Results of analyses testing the effect of various explanatory variables on distance, relative abundance, and relative occurrence of minke whales (*Balaenoptera acutorostrata*) observed in 1994 and 1995.

Explanatory variables	Distance	Relative abundance	Relative occurrence
1994			
Dates of main observation period	$F_{1,42}=9.92$, **$p_r=0.005$**	$F_{1,33}=9.44$, **$p_r=0.005$**	$F_{1,17}=20.07$, **$p_r=0.003^a$**
Dates during dredging	$F_{1,29}=9.60$, **$p_r=0.01$**	$F_{1,18}=7.93$, **$p_r=0.02$**	$F_{1,9}=17.74$, **$p_r=0.007$**
Dates during blasting	$F_{1,11}=0.30$, $p_r=0.63$	$F_{1,13}=0.03$, $p_r=0.88^a$	$F_{1,6}=0.94$, $p_r=0.47^b$
Before and during blasting	$F_{1,42}=3.40$, $p_r=0.08$	$F_{1,33}=3.03$, $p_r=0.09$	$F_{1,17}=6.39$, $p_r=0.03$
Experimental vs. control area (controlling for date)	-	exp/con: $F_{1,29}=3.09$, $p_r=0.10$ **date**: $F_{1,29}=8.29$, **$p_r=0.006^a$**	exp/con: $F_{1,25}=3.88$, $p_r=0.06$ **date**: $F_{1,25}=8.39$, **$p_r=0.01^a$**
1995			
Date of main observation period	$F_{1,49}=22.51$, **$p_r=0.002$**	$F_{1,19}=3.72$, $p_r=0.07$	$F_{1,16}=1.38$, $p_r=0.25$
Experimental vs. control area (controlling for date)	-	exp/con: $F_{1,21}=0.33$, $p_r=0.56$ **date**: $F_{1,21}=5.25$, **$p_r=0.04$**	exp/con: $F_{1,19}=0.36$, $p_r=0.57$ date: $F_{1,19}=4.03$, $p_r=0.05$
Dates of 1994 study	$F_{1,37}=6.13$, **$p_r=0.02$**	$F_{1,10}=0.04$, $p_r=0.83$	-
Dates before 1994 study	$F_{1,10}<0.005$, $p_r=0.96$	$F_{1,7}=0.02$, $p_r=0.88$	$F_{1,4}=0.03$, $p_r=0.84$

- not applicable
[a] L and [b] P3 transformed response variable

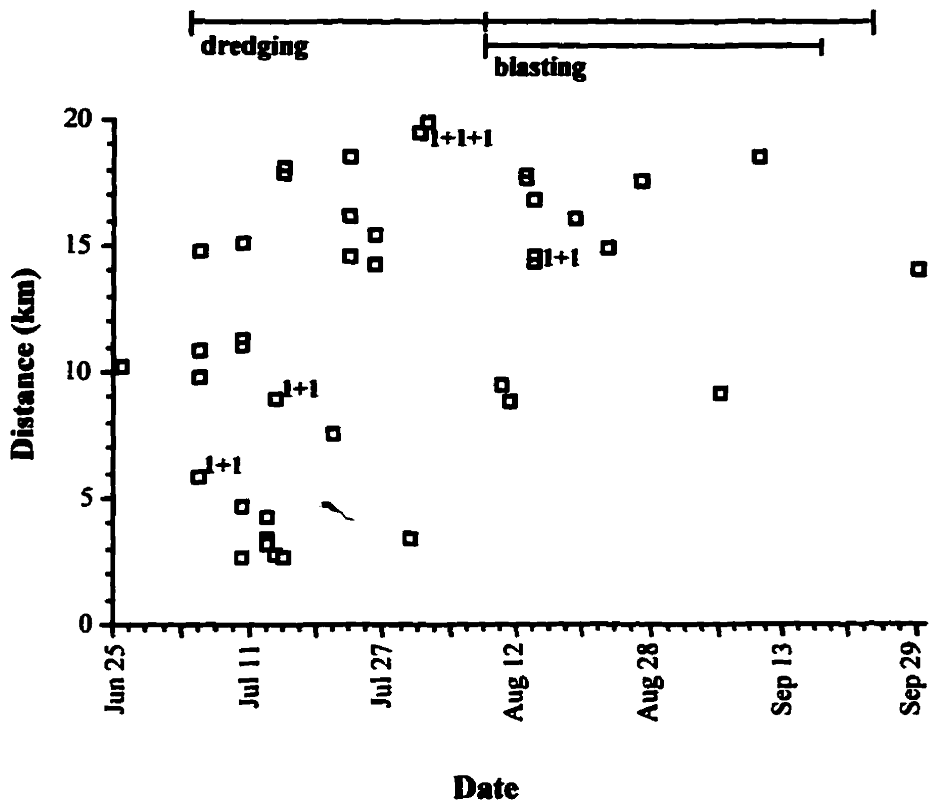


Figure 27.

Distance (km) from the industrial site of all minke whales (*Balaenoptera acutorostrata*) observed in the experimental area during dredging, blasting, and vessel activity in 1994. The average distance (± se) was 11.24 ± 1.11 during dredging (but before blasting), and 14.61 ± 0.95 during blasting; no significant difference in distance was found before or during blasting. Numbers indicate the group size of whales in the same location.

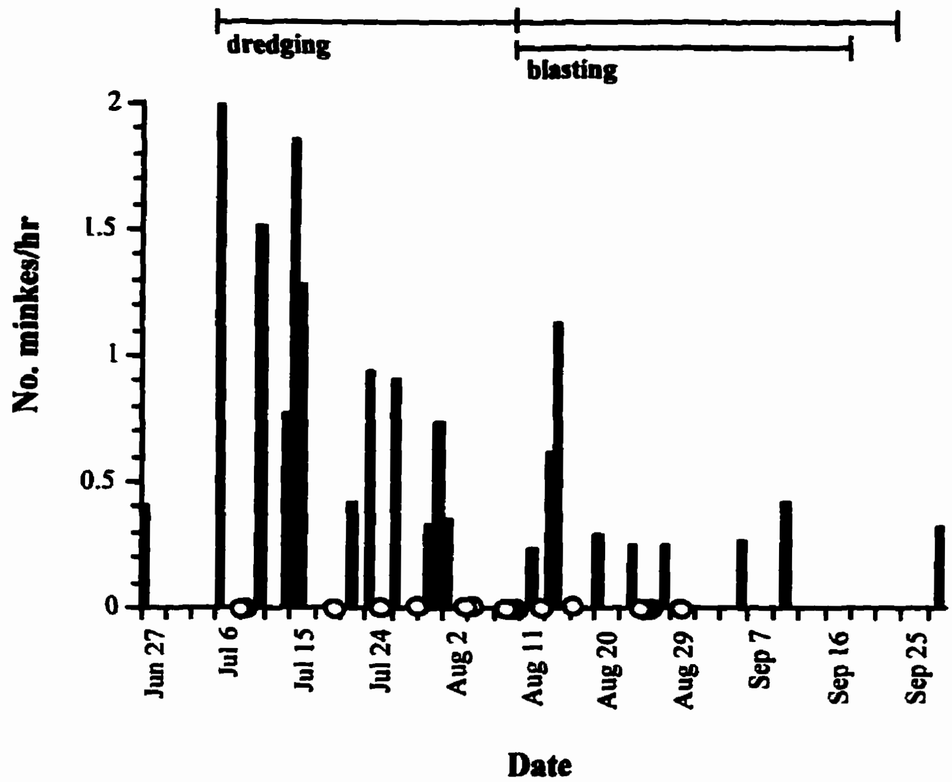


Figure 28.

Number of minke whales (*Balaenoptera acutorostrata*) per searching hour in the experimental area during dredging, blasting, and vessel activity in 1994. Circles indicate effort with no sightings. The average relative abundance (± se) was 0.55 ± 0.15 during dredging (but before blasting), and 0.23 ± 0.08 during blasting; no significant difference was found in relative abundance before or during blasting.

whale did not move away from or toward the blast area (Fig. 29), nor did it show apparent changes in surfacing or diving behaviour (Fig. 30).

There was no significant difference in L-RA relative abundance in the experimental ($\overline{RA}$=0.53±0.16) and control area ($\overline{RA}$=1.10±0.29) when common days were compared (Fig. 31; exp/con: $F_{1,29}$=3.09, p_r=0.10; date: $F_{1,29}$=8.29, p_r=0.006). Testing for L-RO relative occurrence also produced non-significant results (exp/con: $F_{1,25}$=3.88, p_r=0.06; date: $F_{1,25}$=8.39, p_r=0.01). As the data set contained days in which sightings occurred in one area and not the other, the sighting variability was too large to detect potential changes.

4.6.1.2. 1995

In 1995 (Table 13), minke distance increased from the industrial site during the main observation period (Fig. 32; $F_{1,49}$=22.51, p_r=0.002), but relative abundance did not change (Fig. 33; $F_{1,19}$=3.72, p_r=0.07). The relative abundance observed in the experimental area ($\overline{RA}$=0.98±0.26) was comparable to the control area ($\overline{RA}$=0.79±0.25) when common days were compared (Fig. 34; exp/con: $F_{1,21}$=0.33, p_r=0.56; date: $F_{1,21}$=5.25, p_r=0.04). When the survey period was fixed to test for between year differences in the experimental area, the only difference with 1994 was that relative abundance did not change ($F_{1,10}$=0.04, p_r=0.83). No change in distance ($F_{1,10}$<0.005, p_r=0.96) or relative abundance ($F_{1,7}$=0.02, p_r=0.88) occurred before the fixed survey period.

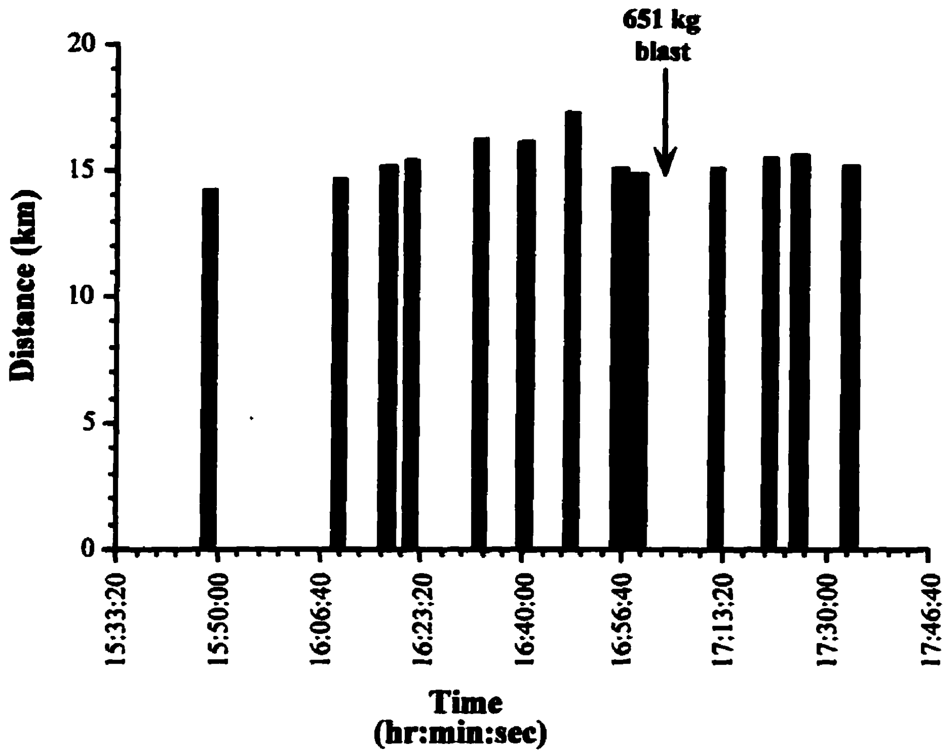


Figure 29.

Distance (km) from the industrial site of a minke whale (*Balaenoptera acutorostrata*) in the experimental area, before and after a 651 kg blast, on 14 August 1994.

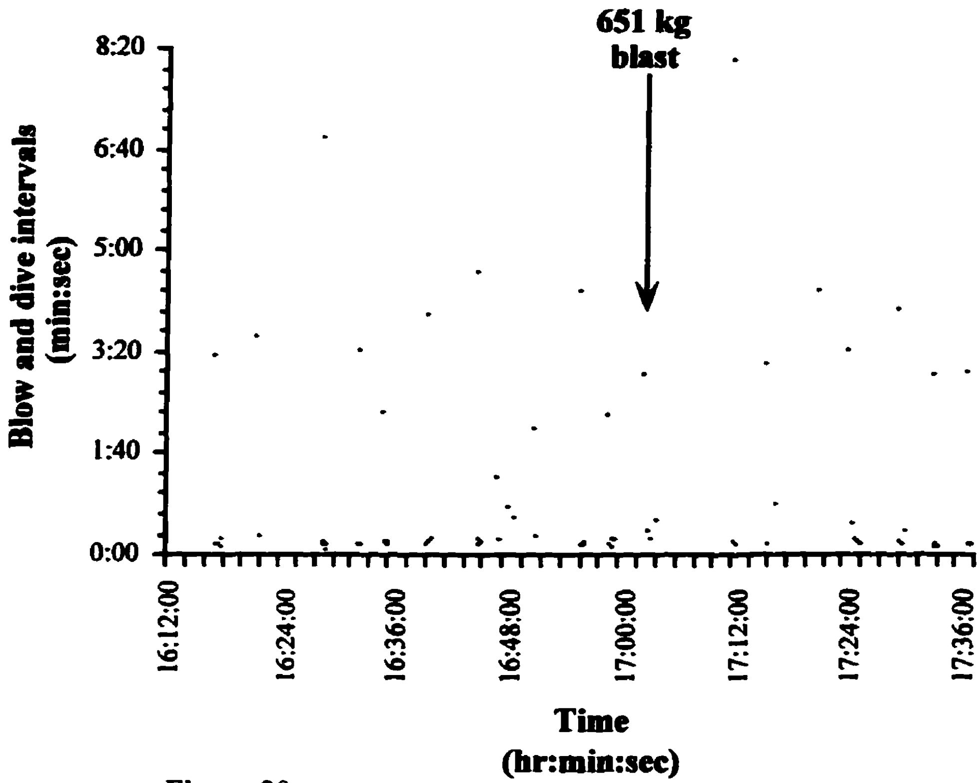


Figure 30.

Blow and dive intervals of a minke whale (*Balaenoptera acutorostrata*) followed through a 651 kg blast, in the experimental area, on 14 August 1994.

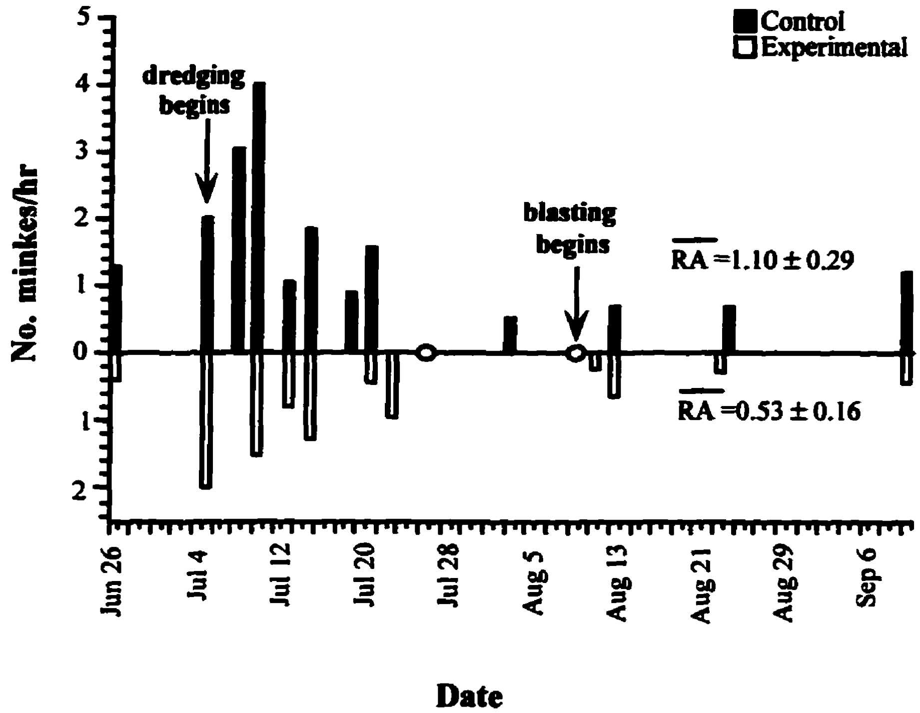


Figure 31.

Number of minke whales (*Balaenoptera acutorostrata*) per searching hour in the experimental and control areas in 1994 during dredging, blasting, and vessel activity. Circles indicate effort in both areas with no sightings. No significant difference was found in relative abundance (RA ± se) between the experimental and control areas.

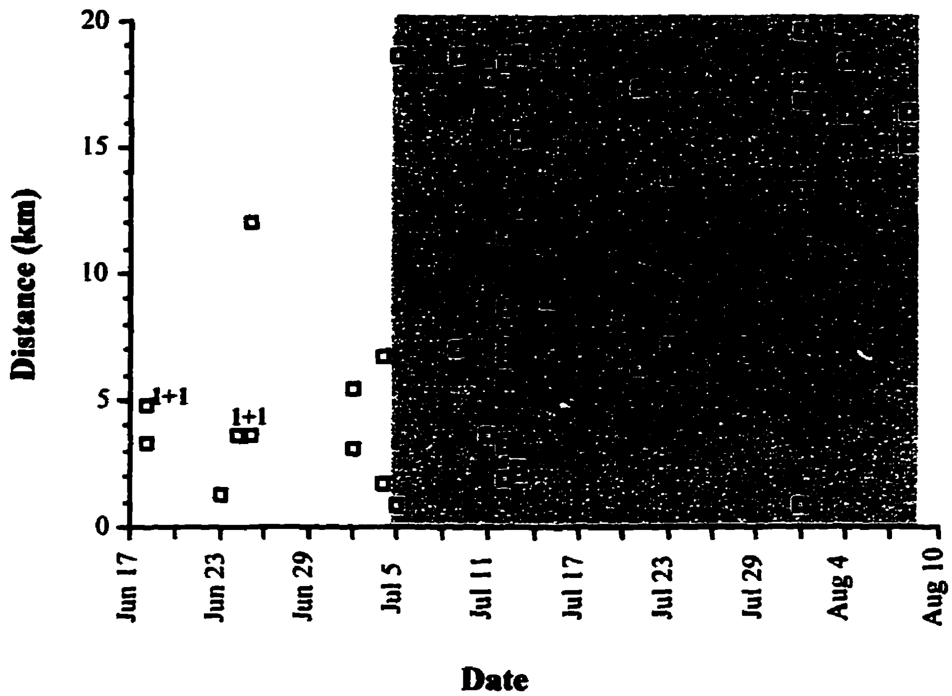


Figure 32.

Distance (km) from the industrial site of all minke whales (*Balaenoptera acutorostrata*) observed in the experimental area during vessel activity in 1995. Shaded area indicates study period in 1994; the average distance (± se) was 4.49 ± 0.81 before, and 11.86 ± 1.03 during this time period. Numbers indicate the group size of whales at the same location.

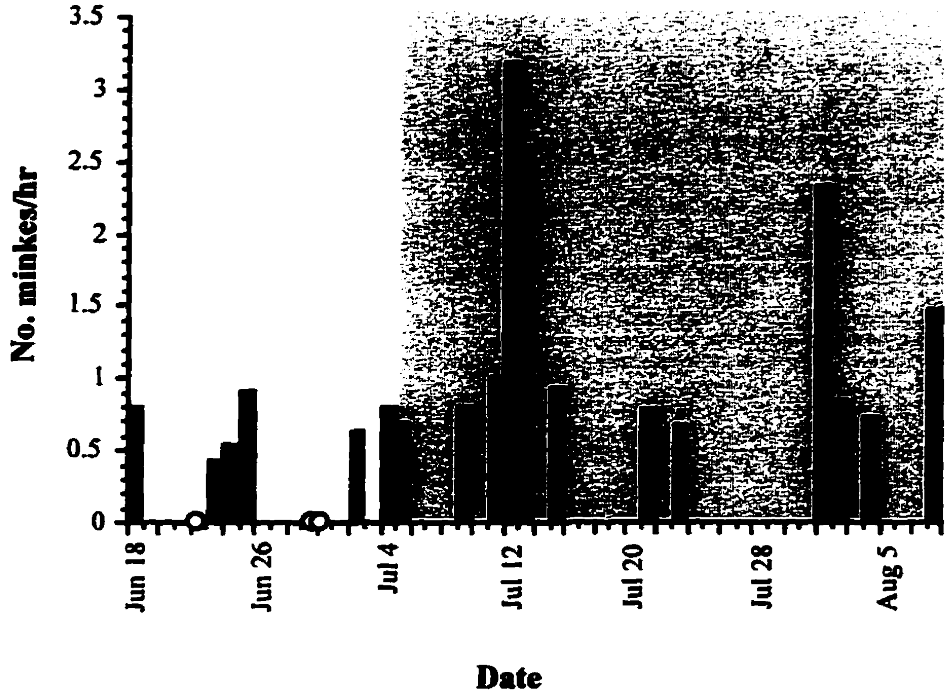


Figure 33.

Number of minke whales (*Balaenoptera acutorostrata*) per searching hour in the experimental area during vessel activity in 1995. Circles indicate effort with no sightings. Shaded area indicates study period in 1994; the average relative abundance (± se) was 0.46 ± 0.13 before, and 1.34 ± 0.25 during this time period.

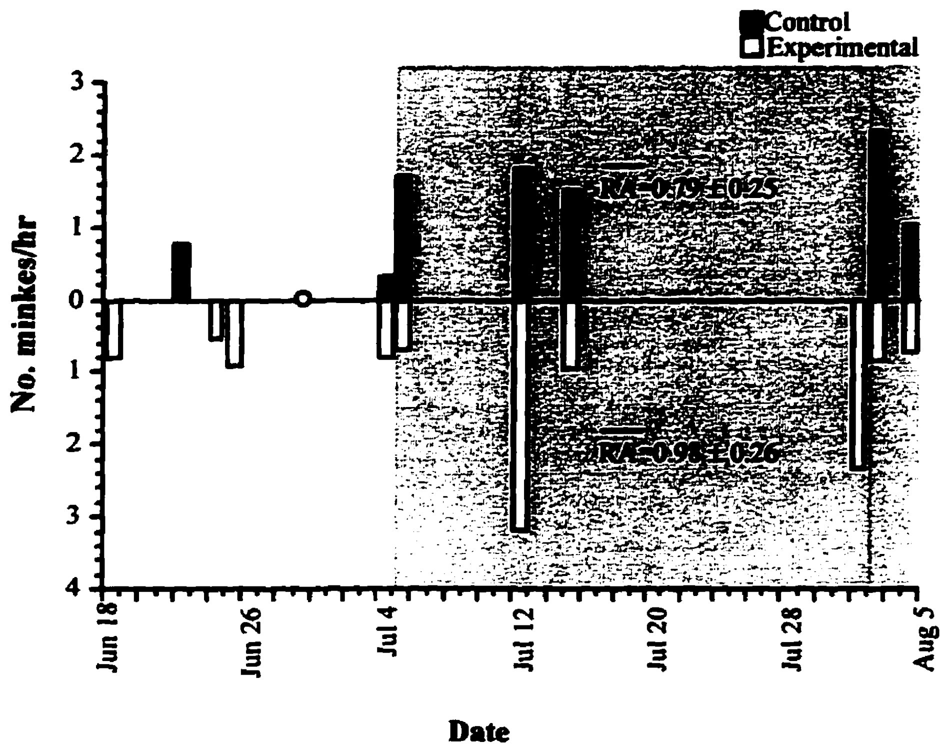


Figure 34.

Number of minke whales (*Balaenoptera acutorostrata*) per searching hour in the experimental and control areas in 1995; shaded area indicates study period in 1994. Circle indicates effort in both areas with no sightings. No significant difference was found in relative abundance (RA ± se) between the experimental and control areas.

4.6.2. Photo-identification

In 1994 only 10 minke whales were identified, and no within year matchings were found. In 1995, with higher photographic effort, there were 26 animals identified, nine identified on more than one day. One animal was resighted on four days, 8 animals resighted on two days, and 17 animals sighted on 1 day. Resighting intervals ranged from 1-45 days ($\overline{X}$=10.1). Animals were seen in the same general area where they were first observed, and no overall directional movement was apparent (Fig. 35). Resightings between 1994 and 1995 indicated that three minkes (+2 based on dorsals only) were resighted in southern Trinity Bay (Fig. 36). Appendix F presents a summary of the positions, with corresponding distances from the industrial site, of individually identified minke whales from 1994 and 1995.

4.7. Harbour Porpoise

4.7.1. Abundance and distribution

4.7.1.1. 1994

In 1994 (Table 14), there was no change in porpoise distance from the industrial site during the main observation period (Fig. 37; $F_{1,20}$=1.36, p_r=0.27), and no change in relative abundance (Fig. 38; $F_{1,32}$=0.68, p_r=0.44). Similarly, no change was found during dredging, but before blasting; during blasting; and before and during blasting.

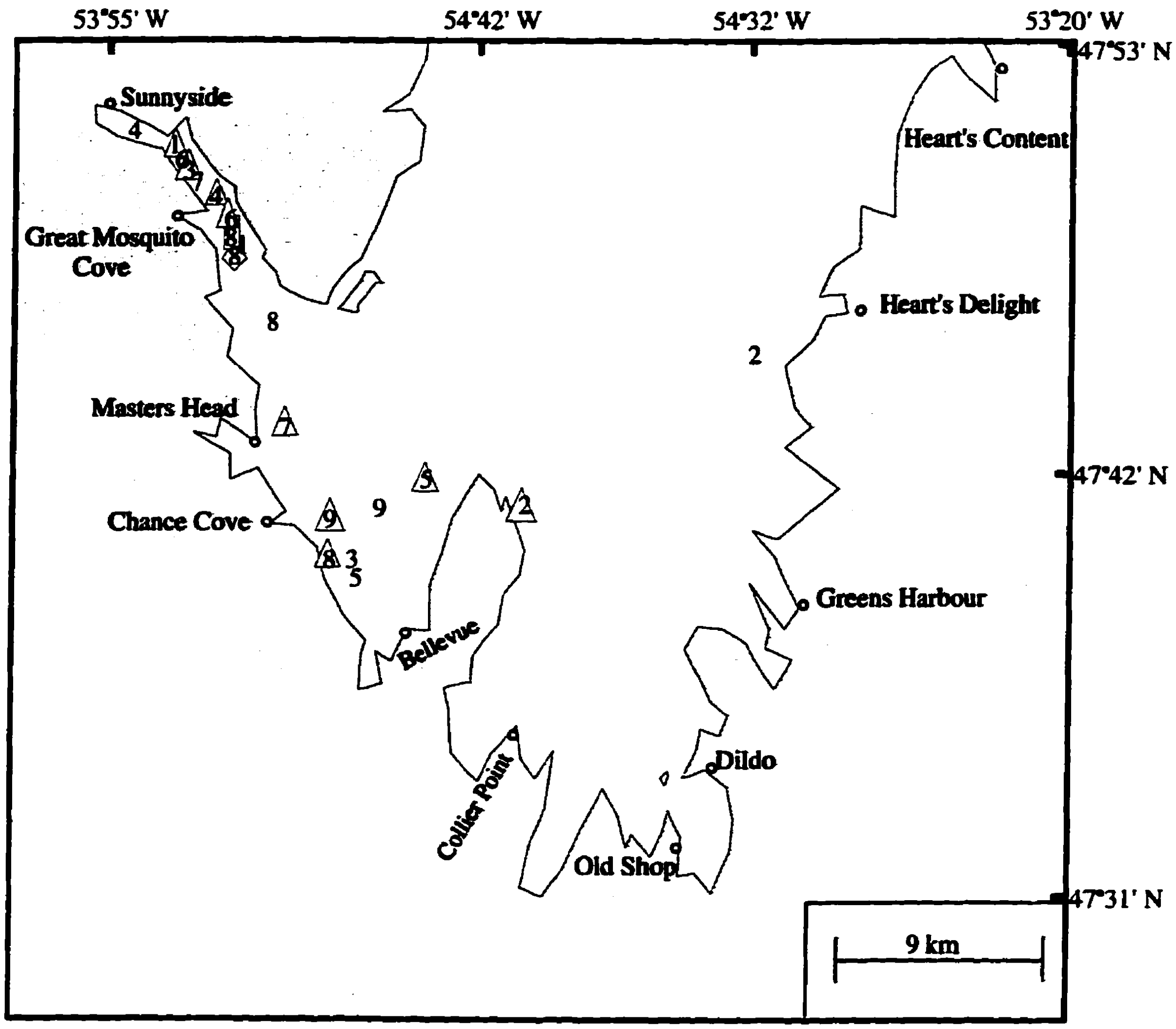


Figure 35.

Resightings of minke whales (*Balaenoptera acutorostrata*) in 1995. Minke whales are numbered 1 through 9; the second (△), third (◇), and fourth (□) resighting are noted.

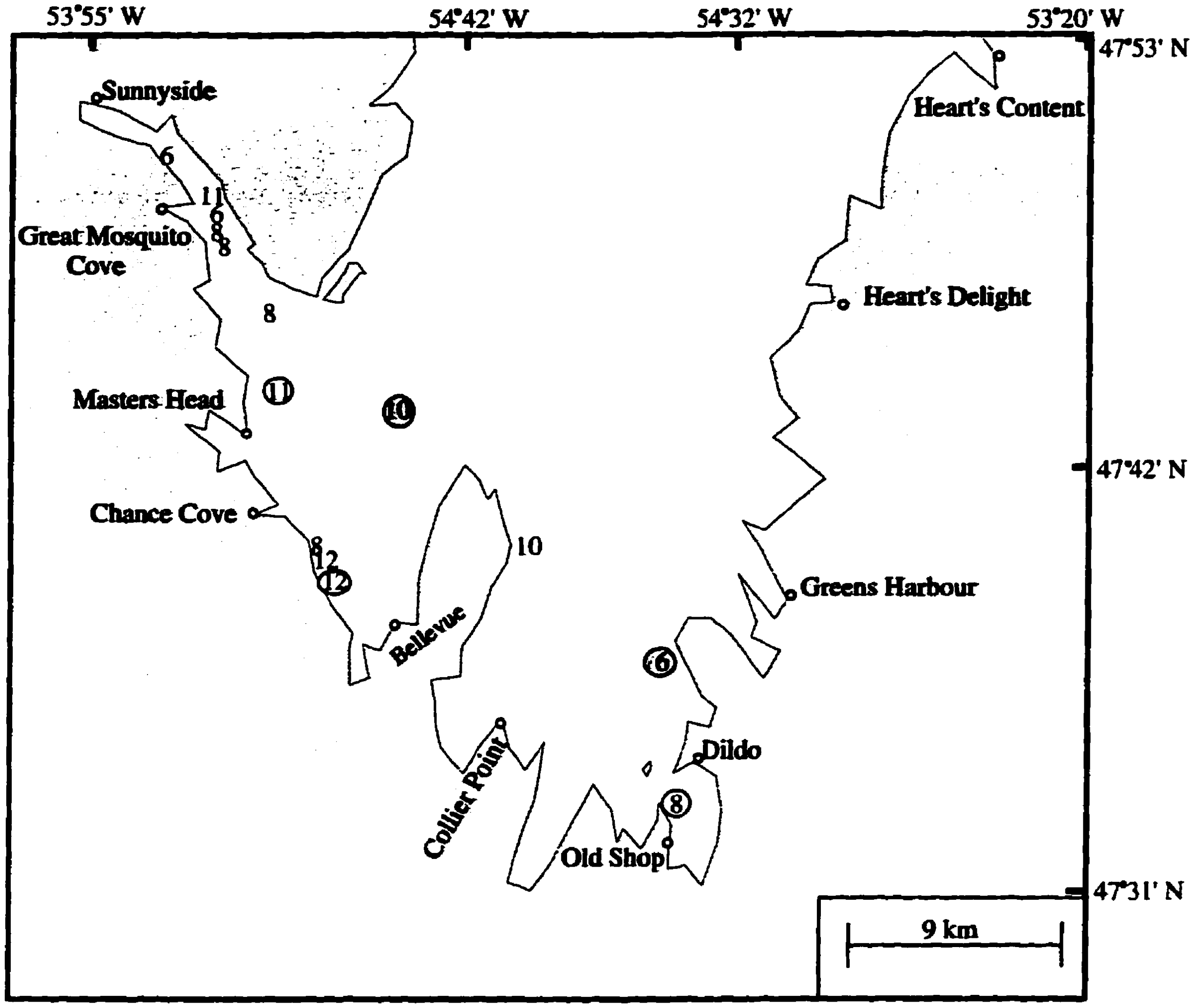


Figure 36.

Resightings of minke whales (*Balaenoptera acutorostrata*) between 1994 (circled) and 1995; shaded circles indicate resights based on dorsal fin only.

Table 14. Results of analyses testing the effect of various explanatory variables on distance, relative abundance, and relative occurrence of harbour porpoise (*Phocoena phocoena*) observed in 1994 and 1995.

Explanatory variables	Distance	Relative abundance	Relative occurrence
1994			
Dates of main observation period	$F_{1,20}$=1.36, p_r=0.27	$F_{1,32}$=0.68, p_r=0.44	$F_{1,12}$=0.18, p_r=0.68
Dates during dredging	$F_{1,9}$=1.12, p_r=0.33	$F_{1,17}$=1.96, p_r=0.17	$F_{1,5}$=0.03, p_r=0.88[b]
Dates during blasting	$F_{1,9}$=3.39, p_r=0.09	$F_{1,13}$=0.36, p_r=0.56	$F_{1,5}$=0.09, p_r=0.79[a]
Before and during blasting	$F_{1,20}$=2.07, p_r=0.17	$F_{1,32}$=0.66, p_r=0.44	$F_{1,12}$=0.30, p_r=0.59
Experimental vs. control area (controlling for date)	-	exp/con: $F_{1,27}$=3.37, p_r=0.07 date: $F_{1,27}$<0.005, p_r=0.95[b]	exp/con: $F_{1,17}$=4.70, p_r=0.05 date: $F_{1,17}$=0.16, p_r=0.68[a]
1995			
Dates of main observation period	$F_{1,17}$=0.70, p_r=0.45	$F_{1,14}$=8.20, **p_r=0.02**	$F_{1,5}$=8.25, p_r=0.04
Experimental vs. control area (controlling for date)	-	exp/con: $F_{1,13}$=0.08, p_r=0.78 date: $F_{1,13}$=1.16, p_r=0.31	-
Dates of 1994 study	$F_{1,14}$=0.87, p_r=0.42	$F_{1,10}$=9.44, **p_r=0.01**[a]	F=$_{1,3}$7.43, p_r=0.06

- not applicable
[a]L and [b]SQ transformed response variable

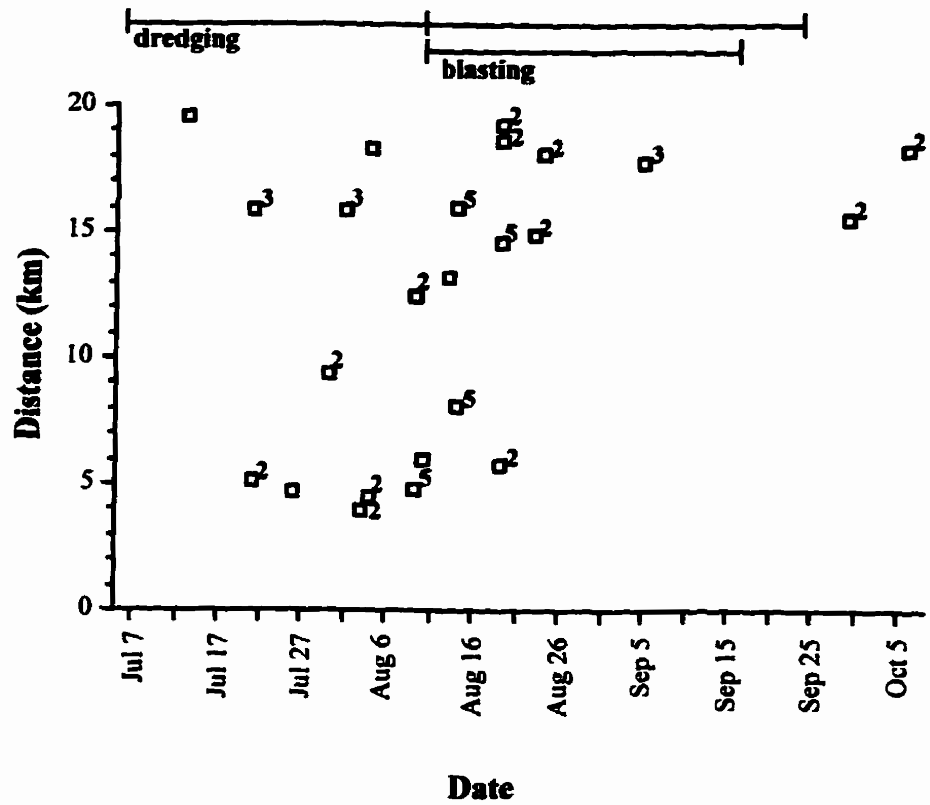


Figure 37.

Distance (km) from the industrial site of all harbour porpoise (*Phocoena phocoena*) observed in the experimental area during dredging, blasting, and vessel activity in 1994. The average distance (± se) was 10.39 ± 1.86 during dredging (but before blasting), and 13.84 ± 1.52 during blasting; no significant difference was found in distance before or during blasting. Numbers indicate the group size of porpoises at the same location.

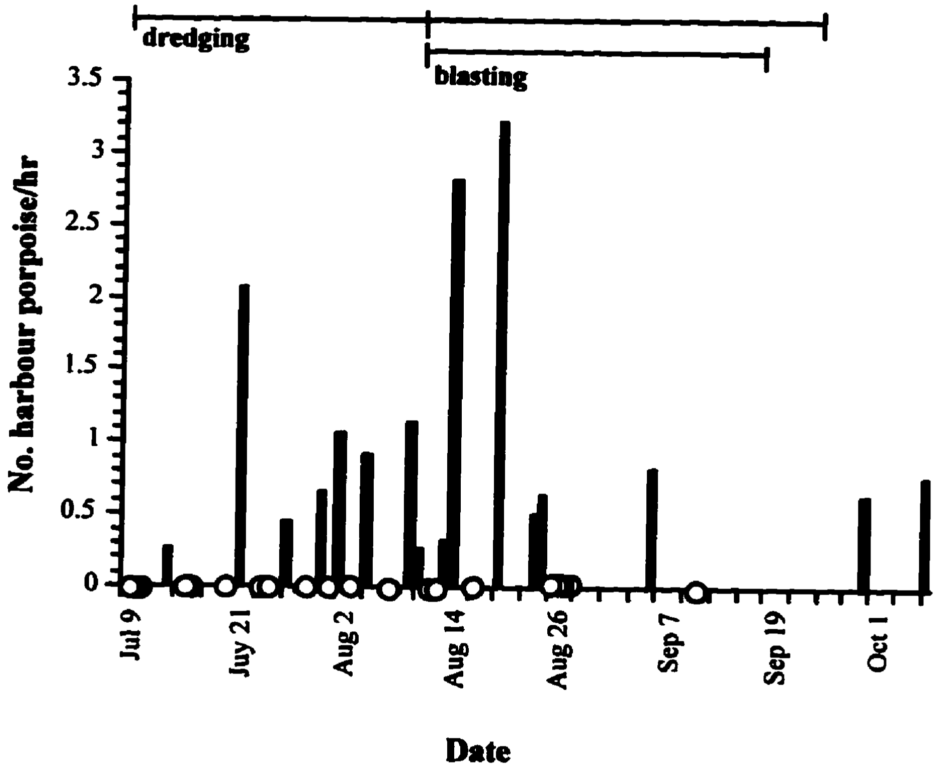


Figure 38.

Number of harbour porpoise (*Phocoena phocoena*) per searching hour in the experimental area during dredging, blasting, and vessel activity in 1994. Circles indicate effort with no sightings. The average relative abundance (± se) was 0.35 ± 0.13 during dredging (but before blasting), and 0.57 ± 0.27 during blasting; no significant difference in relative abundance was found before or during blasting.

There was no significant difference between the SQ-RA relative abundance in the experimental ($\overline{RA}$=0.27±0.14) and control area ($\overline{RA}$=1.26±0.48) when common days were compared (Fig. 39; exp/con: $F_{1,27}$=3.37, p_r=0.07; date: $F_{1,27}$<0.005, p_r=0.95). Testing for L-RO relative occurrence also produced non-significant results due to the high variability in abundance between the two areas (exp/con: $F_{1,17}$=4.70, p_r=0.05; date: $F_{1,17}$=0.16, p_r=0.68).

<u>**4.7.1.2. 1995**</u>

In 1995 (Table 14), there was no change in porpoise distance from the industrial site during the main observation period (Fig. 40; $F_{1,17}$=0.70, p_r=0.45), but there was an increase in relative abundance (Fig. 41; $F_{1,14}$=8.20, p_r=0.02). There was no difference in the relative abundance in the experimental area ($\overline{RA}$=1.00±0.46) and control area ($\overline{RA}$=1.16±0.34) when common days were compared (Fig. 42; exp/con: $F_{1,13}$=0.08, p_r=0.78; date: $F_{1,13}$=1.16, p_r=0.31).

When the survey period was fixed to test for between year differences in the experimental area, the lack of change in distance was similar to 1994. However, harbour porpoise appeared to be distributed at greater distances in 1995 than in 1994. The increase in L-RA relative abundance ($F_{1,10}$=9.44, p_r=0.01) was different from that observed in 1994, but the lack of change in relative occurrence ($F=_{1,3}$7.43, p_r=0.06) was similar to the 1994 results.

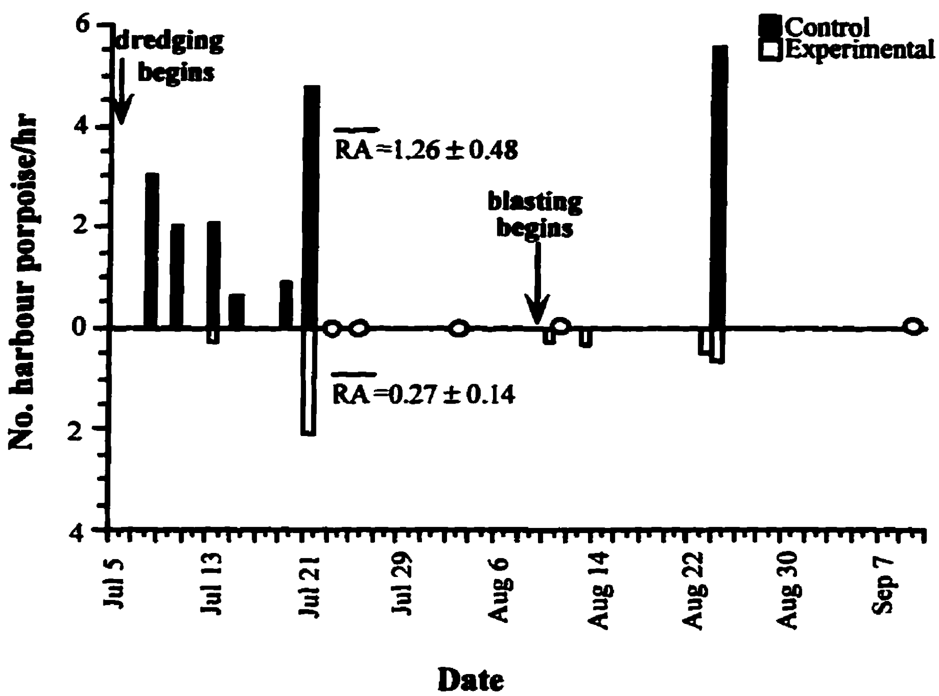


Figure 39.

Number of harbour porpoise (*Phocoena phocoena*) per searching hour in the experimental and control areas in 1994. Circles indicate effort in both areas with no sightings. No significant difference was found in relative abundance (RA ± se) between the experimental and control areas.

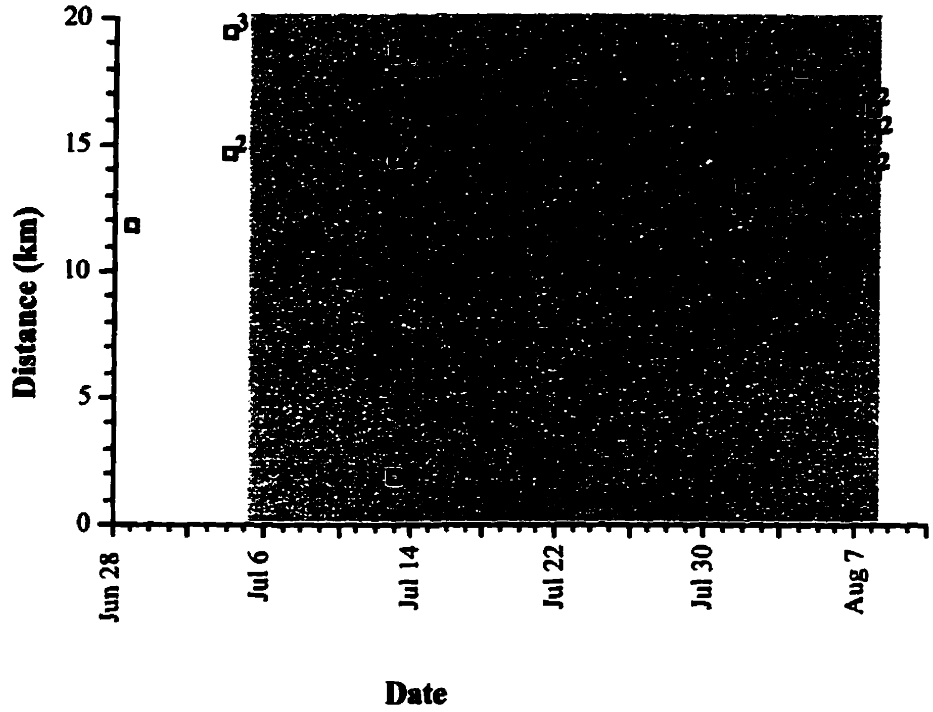


Figure 40.

Distance (km) from the industrial site of all harbour porpoise (*Phocoena phocoena*) observed in the experimental area during vessel activity in 1995. Shaded area indicates study period in 1994; the average distance (± se) was 15.70 ± 1.05 during this time period. Numbers indicate the group size of whales at the same location.

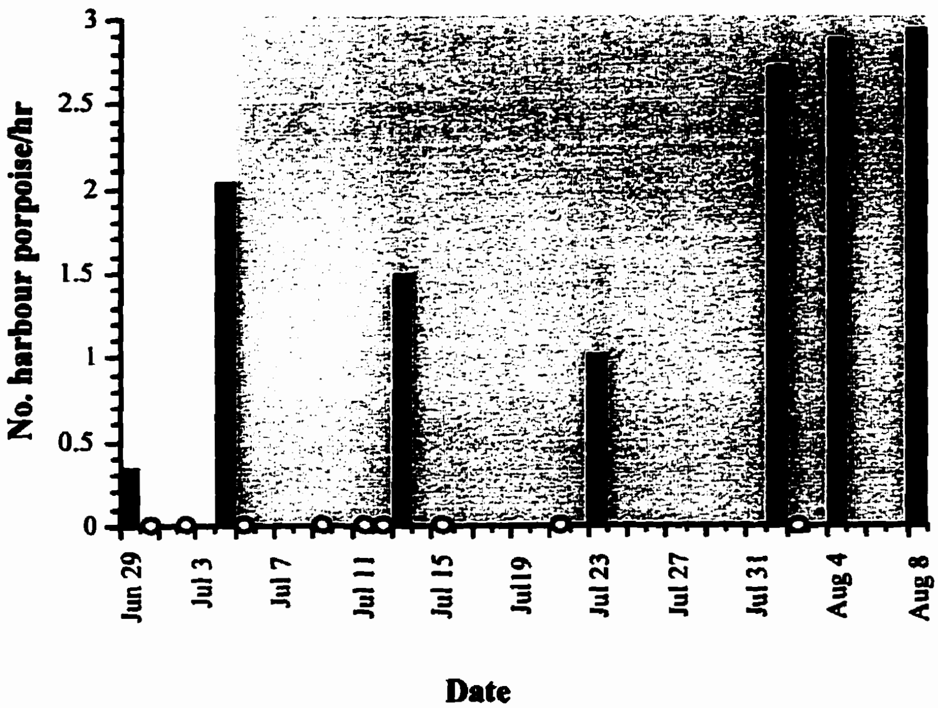


Figure 41.

Number of harbour porpoise (*Phocoena phocoena*) per searching hour in the experimental area during vessel activity in 1995. Circles indicate effort with no sightings. Shaded area indicates study period in 1994; the average relative abundance (± se) was 1.00 ± 0.35 during this time period.

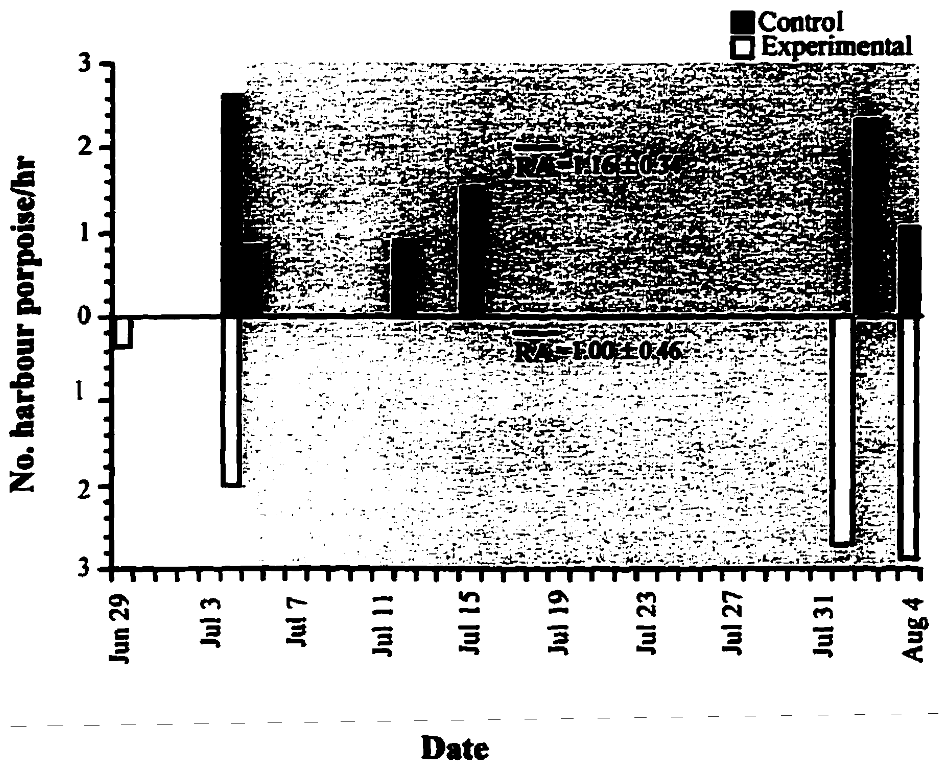


Figure 42.

Number of harbour porpoise (*Phocoena phocoena*) per searching hour in the experimental and control areas in 1995; shaded area indicates study period in 1994. No significant difference was found in relative abundance (RA ± se) between the experimental and control areas.

4.8. Major findings

Major findings from monitoring of marine mammals from 1992-1995 near industrial activity in Trinity Bay are as follows.

4.8.1. Effects on orientation

During underwater blasting and drilling in 1991 and 1992 entrapments of humpback whales in fishing gear occurred significantly closer to Bull Arm, and in greater numbers throughout Trinity Bay compared to previous years (Todd *et al.,* 1996). In addition, the probability of an entrapment in fishing gear within two days after an explosion in Bull Arm was greater than the probability of an entrapment more than two days after an explosion. In 1992, following large blasts, two humpback whales became re-entrapped after release from fishing gear; this suggested orientation problems since re-entrapments were a very rare event.

4.8.2. Anatomical impacts

In 1992, two humpback whales that died in fishing gear near the blasting and drilling activity exhibited ear damage indicative of trauma from underwater blasting as compared to two control animals (Ketten *et al.*, 1993). Ear injuries included round window rupture, ossicular chain disturbance, and hemorrhages.

4.8.3. Lack of effects on abundance, distribution, and respiration

Measures of abundance, distribution, and respiration did not indicate effects of industrial activity with certainty. The high variability in cetacean abundance (e.g. between the experimental and control areas) made it difficult to detect effects. Although decreased abundance of humpback whales in the experimental area since 1992 suggested a reduced use of the area, this change could be within the typical range of variation. Changes in cetacean distance from the industrial site were confounded by season and prey distribution. In addition, respiration measures of animals in the control versus experimental areas, and of animals exposed to blasting activity in 1992 (Todd *et al.*, 1996) and 1994 did not indicate effects.

4.8.4. Changes in resighting and residency of identified individuals

Humpback whales photo-identified in Trinity Bay in 1992 were observed less frequently in Newfoundland in 1993 than were whales identified in other inshore bays. In addition, a lower proportion of humpbacks identified in Trinity Bay in 1992 were resighted in Newfoundland the subsequent year compared with animals monitored in an undisturbed area. Individual minke whales identified in 1994 were resighted in the industrialized area the subsequent year.

In 1994, when dredging was the predominant activity, humpbacks were less likely to be resighted near the industrial activity and exhibited movement away from the site; no such changes were observed during blasting in 1992 (Todd *et al.*, 1996) or during vessel activity in 1995. Humpback resightings and residency were comparatively higher in 1995 than other years. Furthermore, minke whale resightings occurred in an area of heavy vessel activity in 1995.

5. Discussion

5.1. Acoustical environment

Marine mammals were monitored in southern Trinity Bay during 1992 (Todd *et al*., 1996), 1994, and 1995 concurrently with various industrial activities in Bull Arm. The study site afforded the opportunity to assess the impact of different activities. Each year the predominant industrial activity was different: blasting in 1992, dredging in 1994, and vessel activity in 1995. Low-frequency sounds dominated the sound spectra of all activities, with blasting producing the highest relative sound pressure levels.

Although southern Trinity Bay was divided into an experimental area and a control area, it is not known exactly how industrial sounds changed underwater noise levels throughout the entire area: the entire experimental area may not have been characterized by industrial activity sounds, and the entire control area may not have been free from industrial activity sounds. However, recording analyses showed blasting activity was plainly detected within the experimental area outside Bull Arm, and less in the control area; this supported the arbitrary division between the experimental and control areas. Further analyses using calibrated equipment would provide additional information, but were beyond the scope of this study. This monitoring program compares the occurrence of marine mammals in an experimental area close to the industrial activity, and a control area that was further away and less affected by the industrial activity.

5.2. Potential effects

5.2.1. Abundance, distribution, and respiration

Abundance and distribution measures did not indicate that marine mammals were responding to the industrial activity; these measures varied irregularly. Humpback whale distance increased from the industrial site in 1994 and 1995 with no corresponding change in humpback relative abundance; however, distance did not increase during the 1992 or beginning of the 1995 study. In addition, minke whale distance increased from the site in 1994, but there was a concurrent decrease in relative abundance. During the same time period in 1995, there was a similar increase in minke distance; however, during the earlier time period of the study there was no change in distance, and minkes were distributed closer to the site. The decreasing abundance of minke whales during dredging in 1994 is suggestive of impact (no change occurred during the same time period in 1995), although this cannot be concluded with certainty. Thus, changes observed in abundance and distribution measures could not be attributed solely to industrial activity.

Such irregular changes in abundance and distributions are commonly found in such impact studies (e.g. Malme *et al.*, 1985; Richardson *et al.*, 1987; Cosens and Dueck, 1988; von Ziegesar *et al.*, 1994). This may indicate a weak effect from the industrial activity being monitored, or it could indicate that these measures of impact are under relatively strong influence of other environmental conditions. Potential causes for the changes observed in marine mammal abundance and distribution in the present study include season or prey distribution. For example, humpback abundance (Whitehead *et al.*, 1980; Whitehead, 1981; Piatt *et al.*, 1989) and distribution (Whitehead *et al.*, 1980) are related to capelin in Newfoundland. Marques (1996) showed an association between humpback whales and prey (primarily capelin) at small scales, thus suggesting that humpback whales track prey. Minke whale abundance (Piatt *et al.*, 1989) and distribution (Sergeant, 1963) are also related to capelin in Newfoundland. Perkins and Whitehead (1977) found that minke whales occurred close to shore in June and gradually moved offshore in later months. In addition, minke whales have been reported to leave Trinity Bay towards the end of the capelin season in late July and early August (Sergeant, 1963). Thus, these confounding variables make it difficult to attribute causation to the changes in abundance and distribution observed in southern Trinity Bay.

In addition to these confounding factors, it is possible that the measures of abundance and distribution could not detect an impact without comparisons to pre-impact data, or that the measures were not sensitive enough to detect impact. There was no change in humpback relative abundance in 1994 or 1995, but abundance may have already decreased before the start of the study. There was no change in minke whale distance during blasting in 1994, and no change in distance before or during blasting (no change in relative abundance occurred during these conditions). It is possible that minke whales were located at a distance where potential changes from blasting would be difficult to detect as minkes were moving away from the site during dredging in 1994.

Furthermore, harbour porpoise abundance and distribution did not indicate a reaction to the industrial activities in 1994 or 1995. Harbour porpoise were rarely seen near the site, but it cannot be determined if harbour porpoise were avoiding the area due to vessel activity (Barlow, 1988), or if they were naturally distributed further from the site. Even if the industrial sound levels were within the high-frequency sensitivity range of harbour porpoise (Andersen, 1970), research has indicated harbour porpoise will rapidly return to a previously ensonified area (Olesiuk *et al.*, 1995). Additional measures are needed to confirm that the lack of changes in abundance and distribution indicate impacts are not occurring.

Comparisons of abundance between the experimental and control areas were also not able to detect potential impacts with certainty. Although minke whales and harbour porpoise were found comparably in areas with and without industrial activity during 1994 and 1995, the high variability in 1994 made it difficult to detect potential changes. Relative abundance of humpbacks was greater in the control area as compared to the experimental area in 1994, but the high variability in 1995 made it difficult to determine the overall trend. Although the 1994 results suggest humpbacks responded to the industrial activity, it cannot be concluded that no effects occurred in 1995. Consequently, it is difficult to attribute the decrease in number of humpback whales per hour since 1992, and their shift to areas further from the industrial site, to a decreased utilization of the area. With such variability in abundance, confounded by seasonal and yearly changes, assessment of impacts by comparisons between the two areas are difficult to interpret.

For the reasons above, abundance measures may not be an adequate indicator of impact from industrial noise in this study. The variability in abundance experienced in this study could be due to natural fluctuations, occurrence of whales outside the transect route, or industrial activity. Adequate abundance measures are also difficult to select; for instance, if the results of analyses with relative abundance (whales/searching hour/day) and relative occurrence (whales/searching hour/day- only when whales were observed) differed it would be difficult to determine which variable should be used as the abundance measure. The days when no whales were found could either indicate that whales were not present, or that they were outside the transect route. Even with pre-impact data the results could be difficult to interpret. Abundance can be influenced by anthropogenic activity, as well as other variables, so it is often difficult to attribute causation if changes are observed (Reeves *et al.*, 1984; Richardson *et al.*, 1987; Reeves, 1992).

Results of the 1994 and 1995 study suggest that respiration measures did not indicate a response to industrial activity. The individual minke whale observed during a blast in 1994 showed no behavioural change; however, attenuation of sound, masking by boat noise, and individual sensitivity are possible explanations. The high variability and small sample size of humpback respiration measures made detecting potential differences in the experimental and control areas difficult. Richardson *et al.* (1995) found bowhead whales differed in dive and surface times in two areas with varying amounts of human activity, but could not attribute causation even with a large sample size. Respiration measures are often dependent on the depth of dive (Dolphin, 1987), and are naturally variable (Dorsey *et al.*, 1989; Winn *et al.*, 1995). Although changes in respiration measures before and after exposure to anthropogenic activity many indicate a short-term response (Würsig *et al.*, 1985), they may not be able to discern impact over a longer time period.

5.2.2. Resightings and residency

Tracking individual animals was more sensitive in determining the effects of industrial activity. For example, there is little information on how minke whales respond to noise, although they have been sighted close to industrial operations (Richardson, 1995b). Similar sightings were made in this study, but resightings and movements of individual minkes in 1995 showed that some remained in an area with heavy vessel activity. In addition, resightings between 1994 and 1995 showed that individual minkes were resighted in an area with industrial activity. Tracking provided additional information on how minke whales responded to industrial activity.

Impacts of varying activities in southern Trinity Bay were more apparent with further information on resighting, residency, and return rates of individual whales. In 1994, humpback whales were less likely to be resighted, especially near the industrial site, and there was a tendency for individual whales to move away from the site; no such trends were detected in 1992 or 1995. In addition, the lower resightings and residency in 1994 were suggestive of impact, especially since the daily relative abundance of capelin schools was reported higher during this year than other years (Nakashima, 1996). Tracking individual animals indicated that the most apparent changes occurred when dredging was the predominant industrial activity in 1994, compared to blasting in 1992, and vessel activity in 1995.

Differences in tracking information among years agree with previous studies which found that behavioural responses may partially depend on the sound characteristics of the anthropogenic activity (Richardson, 1995b). For example, dredges are a strong source of continuous low-frequency sound (Greene and Moore, 1995), and continuous sounds are thought to produce stronger behavioural responses than transient sounds at similar pressure levels (Green *et al.*, 1994). It is also possible that both dredging and vessel traffic were responsible for the humpback whale responses observed in 1994; these same industrial activities were thought to cause gray whales to abandon a breeding area for a number of years (Bryant *et al.*, 1984). According to Richardson and Würsig (1995), multiple noises could increase the severity of potential effects, such as masking and displacement, caused by single sources. Although the exact component of the anthropogenic activity responsible for changes observed is often difficult to isolate

(Richardson and Würsig, 1995), yearly results suggest resightings and residency fluctuated in response to the type of industrial activity.

In 1995, humpback resightings and residency were higher, especially near the source, when vessel traffic was the predominant activity. Four humpbacks were regularly sighted near the site during this period. Other studies have also reported resightings of humpbacks in an area with vessel activity (e.g. Jurasz and Palmer, 1981; Baker *et al.*, 1983; Watkins, 1985), and humpbacks have been known to habituate to this type of noise source (Norris and Reeves, 1978; Watkins, 1986; Richardson, 1995b). It might appear that vessel traffic did not contribute to changes observed in 1994, but resightings and residency are not available in Trinity Bay for humpbacks not exposed to industrial activity. Long-term impacts of vessel activity on whales are difficult to determine (Cowles and Imm, 1988); vessel traffic could have contributed to the decrease in abundance of humpbacks over the years, and the shift to areas further from the site. Alternatively, vessel traffic could be impacting whales in ways that are not expressed through behavioural responses (Todd *et al.*, 1996). Additional tracking information is needed to determine the long-term effects of industrial activity, especially on whales that remain in the area.

Resightings of humpback whales from 1992 in 1993 suggest long-term behavioural effects of industrial noise. Humpbacks identified in southern Trinity Bay during blasting and drilling activity in 1992 were resighted in Canada in 1993, although significantly fewer were resighted again in Newfoundland waters compared with other previously identified animals in Newfoundland. In addition, fewer resightings of humpbacks from southern Trinity Bay were found in Newfoundland in 1993 compared with animals identified in an area along Newfoundland's southeast shore. These findings are consistent with other studies which have suggested whales abandon an area with industrial activity (e.g. Gard, 1974; Richardson *et al.*, 1987). The present study, however, provides stronger evidence since findings are based on individually identified animals.

Life-history studies may be necessary to detect the consequences of potential long-term effects on both the individual and the population (Richardson and Würsig, 1995). Long-term displacement of humpbacks has been previously suggested in an area with increased anthropogenic activity, but this result was based only on abundance, which could change due to many factors (Norris and Reeves, 1978). In addition, Bauer *et al.* (1993) could not assess long-term impacts when humpbacks increased in numbers in an area where short-term responses to anthropogenic activity were detected. Due to low resightings in southern Trinity Bay, between year impacts to the individual or population could not be determined. Generally, humpbacks in Newfoundland have a low resighting percentage (Katona and Beard, 1990). Animals with high return rates to, and residency in an area would be able to provide further information on potential impacts of industrial activity. Minke whales are known to exhibit small-scale site fidelity (Dorsey, 1983; Dorsey *et al.*, 1990), and the location of resightings in the present study between and within years suggests this possibility. If found to be resident in an area, long-term studies on minke whales could possibly help determine the potential impacts of industrial noise.

Although resightings and residency appear more sensitive for detecting potential impacts when compared to others, they can be influenced by a number of factors. For example, re-identification can be influenced by heterogeneity between individuals and the area surveyed (Hammond, 1990). Mate *et al.* (1992, *in* Reeves, 1992) found that radio-tagged right whales traveled large distances between sightings, and suggested residency times may not necessarily indicate length of stay. In addition, low numbers of identified whales, and interpreting their movements based on small changes in distance could influence results. Nonetheless, differing resightings and residency between years in southern Trinity Bay reflect changes in the whales identified near the site of industrial activity, even after controlling for photograph intervals and number of days photographs were obtained. The movement of individually identified animals varied between 1994 and 1995, although the overall distribution of whales from the industrial site was similar. In addition, resighting and residency results between years in Placentia Bay were not as variable (data from Marques, 1996) compared to southern Trinity Bay, where anthropogenic activity was greater. These results suggest that resightings and residency may remain stable in areas with low levels of anthropogenic activity, but may vary in areas with higher levels (i.e. southern Trinity Bay).

Photo-identification information provides a more complete interpretation of the abundance and distribution results. Individual humpback whales exhibited movement away from the industrial site in 1994, similar to overall abundance and distribution results in which humpbacks were located further from the site. The photographic data in the early part of the 1995 study showed that individual humpbacks did not exhibit movement away from the site, and likewise the overall distribution of humpbacks did not change. However, during the later part of the 1995 study individual humpbacks did not exhibit movement away from the site, although the population data indicated movement away. Additional minke photo-identification information could help determine if the changes in minke whale abundance and distribution in 1994 were due to seasonal change, or to resident animals moving out of the area. In addition, this information could suggest whether the observation of a minke whale feeding close to dredging activity on 13 July 1994, while overall humpback distances were increasing, was possibly due to varying species or individual sensitivities (Ketten, 1995; Richardson, 1995c). Further studies are required to confirm these trends (Bondrup-Nielsen and Herman, 1995), but tracking individual animals appears to detect changes which measures of abundance and distribution alone cannot.

5.3. Conclusions: 1992 - 1995

Easily observable behaviours may not adequately measure the impact of noise on marine mammals (Lien *et al.*, 1995). No changes in behaviour were observed in response to blasting and drilling in 1992 (Todd *et al.*, 1996), but humpback whale orientation appeared to be affected when entrapment rates in fishing gear increased, and occurred closer to the industrial site compared to previous years with no industrial activity (Todd *et al.*, 1996). In addition, damaged ear structures of humpback whales killed in fishing gear near the industrial site were indicative of trauma due to blasting (Ketten *et al.*, 1993). Both behavioural and anatomical information are important to assess the impact of industrial noise on marine mammals (Todd *et al.*, 1996).

Tracking individual animals provided more information on the impacts of industrial activity than abundance, distribution, and respiration measures alone. The response of individually identified animals in this study indicates possible short and long-term disturbance due to varying industrial activities. Humpbacks appeared tolerant of transient blasts (Todd *et al.*, 1996) and frequent vessel traffic, but were more affected by continuous activity from dredging, possibly coupled with vessel traffic. Long-term effects of exposure to blasting appeared be a decreased return rate to a feeding ground, as well as a decreased utilization of an area near industrial activity. Individual minke whales were resighted in the industrialized area, and appeared tolerant of vessel traffic, but data were inadequate to indicate how resightings and residency were affected. Further studies are needed to learn more about how individually identified whales respond to industrial activity, and to test the trends found in this study.

5.4. Recommendations

(1) Research strategies need to be improved in order to adequately assess impact of anthropogenic activity on marine mammals (Green *et al.*, 1994). Many studies have detected short-term responses of marine mammals to anthropogenic activity, but long-term impacts are a greater concern (Richardson, 1995a). Monitoring individual animals in an area with anthropogenic noise over a number of years, including pre-impact years, is necessary to detect such impacts. It is important that impact studies measure variables that are sensitive in detecting changes; often observable behavioural measures are not adequate (Lien *et al.*, 1995). Orientation failures, anatomical evidence (Todd *et al.*, 1996), and tracking of individual animals provide important information as to the short and long-term effects of noise.

(2) The use of humpback whales is encouraged in evaluating impacts due to the large data base available in many areas, and the potential to assess impacts to the individual and population. Yet, future studies should further evaluate the use of minke whales as an indicator species, especially if found to be resident in an industrialized area. Life history studies would provide definitive information on the consequences of the disturbances observed in this study.

(3) Results must be carefully interpreted when measures of abundance, distribution, and respiration are used to detect changes over time. There are often confounding effects of season, and prey availability and distribution, even with baseline information. Comparisons of industrialized and non-industrialized areas could be used to detect changes due to industrial noise if effort occurred simultaneously and frequently in both areas; however, sampling with distance is a better design than impact/control areas when the disturbance attenuates with distance (Ellis and Schneider, 1997). An adequate control area is often difficult to find since it may be affected by the disturbance, and its physical processes may not be comparable to the impact area (Ellis and Schneider, 1997). Monitoring programs must choose appropriate indicators and designs to detect changes, while taking into consideration confounding variables.

(4) More information is needed on the relationship between the distribution of whales and their prey before attributing the responses observed to anthropogenic activity (Richardson *et al.*, 1987). The changes observed in the present study were not due to a lack of prey (section 4.2.), but could have been influenced by prey distribution. For instance, the increased distances of humpback and minke whales from the site could be due to the animals following prey, rather than due to the animals avoiding the industrial site. Thus, information on prey distribution collected simultaneously with disturbance data would help interpret the results of studies. It is important that both the abundance and distribution of prey be considered during any impact study.

The effects of anthropogenic activity on prey species remains an important research consideration (Green *et al.*, 1994). For example, changes observed in 1994 could be an indirect response to the industrial activity due to shifts in prey distribution, as well as a direct response. Many studies have documented that some fish species will avoid highly turbid water (Appleby and Scarratt, 1989, *in* Hibernia Env. Dept., 1995). In addition, Konagaya (1980) showed that fish will respond to dredging sounds by avoiding the area. Although it was concluded that turbidity levels throughout Bull Arm did not affect fish behaviour on a long-term basis (Hibernia Env. Dept., 1995), prey distribution could have been affected on a short-term basis. Further information on this topic is necessary to interpret results, and attribute causation in impact studies.

(5) With uncertainty as to the precise effects of noise on marine mammals, industrial operations need to be conducted in a precautionary manner until more information is obtained (Lien *et al.*, 1995). The public puts a high value on the welfare of marine mammals and, concurrently, industrial operations need to maintain good public relations (Lien *et al.*, 1995). Although it could take years before much of the needed data on the impacts of industrial activity are available, adequate protection and management plans are necessary (Lien *et al.*, 1995),

(6) Measures can be taken which may minimize the impacts of industrial activity on cetaceans (Lien *et al.*, 1995; Richardson and Würsig, 1995), especially with industry and scientists recognizing the responsibility to protect marine mammals (Lien *et al.*,

1995). Monitoring programs are essential (Lien *et al.*, 1995; Richardson and Würsig, 1995), and enable scientists and industry to work together cooperatively so that the most information and protection possible is obtained (Lien *et al.*, 1995). In the present study researchers relayed information on the general activities and behaviours of marine mammals to the Hibernia Environment Department, while receiving information on the occurrence of industrial activities. Such cooperation can allow scientists to learn more about the effects of industrial noise on marine mammals (Lien *et al.*, 1995). This present study took advantage of the opportunity to gain additional information as to the effects of industrial noise on individually identified animals. Industrial activity should also be scheduled to occur during seasonal or time periods when marine mammals are not in the area (Lien *et al.*, 1995; Richardson and Würsig, 1995). Logistic problems at the Hibernia site delayed blasting activity in 1994, yet ensured blasting occurred later in the season. Thus, there are important steps that can be taken in the face of uncertainty with benefits to industry, scientists, and marine mammals.

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Appendices A-F

Appendix A - Blast charges

Dates and sizes (kg) of blast charges in Great Mosquito Cove during 1991, 1992, and 1994. Blank cells indicate charges occurred, but the size is unavailable.

A.1. 1991 (from Todd *et al.*, 1996)

Date	Charge (kg)	Date	Charge (kg)	Date	Charge (kg)
3 Jul		20 Aug		20 Sep	300
4 Jul		20 Aug		20 Sep	300
5 Jul		21 Aug		20 Sep	750
9 Jul		22 Aug		23 Sep	1425
11 Jul		23 Aug		23 Sep	50
11 Jul		23 Aug		24 Sep	575
12 Jul		27 Aug		25 Sep	1000
12 Jul		27 Aug		26 Sep	1050
13 Jul		28 Aug		27 Sep	425
13 Jul		28 Aug		28 Sep	600
15 Jul		29 Aug		30 Sep	1000
17 Jul		30 Aug		1 Oct	1725
18 Jul		30 Aug		2 Oct	125
19 Jul		3 Sep	600	2 Oct	850
23 Jul		4 Sep	1375	5 Oct	1475
23 Jul		5 Sep	1250	5 Oct	900
25 Jul		6 Sep		7 Oct	1000
26 Jul		7 Sep	200	9 Oct	1600
30 Jul		7 Sep	1400	9 Oct	975
2 Aug		11 Sep	175	10 Oct	
2 Aug		11 Sep	1635	10 Oct	400
5 Aug		12 Sep	850	11 Oct	400
6 Aug		13 Sep	1900	11 Oct	2000
7 Aug		14 Sep	1050	16 Oct	800
9 Aug		16 Sep	1650	16 Oct	1250
12 Aug		16 Sep	650	18 Oct	1300
12 Aug		17 Sep		18 Oct	900
13 Aug		18 Sep	550	18 Oct	200
14 Aug		18 Sep	1000	23 Oct	540
16 Aug		18 Sep	200	24 Oct	2030
16 Aug		19 Sep	500	30 Oct	2025

A.1. 1991 (continued)

Date	Charge (kg)	Date	Charge (kg)	Date	Charge (kg)
31 Oct	775	22 Nov	250	7 Dec	250
1 Nov	425	25 Nov	325	9 Dec	500
6 Nov	1800	26 Nov	1350	13 Dec	1650
7 Nov	375	27 Nov	400	16 Dec	1000
13 Nov		29 Nov	1150	18 Dec	583
15 Nov	500	2 Dec	925	19 Dec	400
19 Nov	1020	5 Dec	720		
21 Nov	1550	6 Dec	300		

A.2. 1992 (from Todd *et al.*, 1996)

Date	Charge (kg)	Date	Charge (kg)
9 Jan	1566	9 Jun	1983
10 Jan	500	11 Jun	2100
14 Jan	1000	16 Jun	1450
16 Jan	850	17 Jun	1250
17 Jan	250	22 Jun	1320
18 Jan		23 Jun	1240
22 Jan	1100	25 Jun	1510
24 Jan	820	25 Jun	5500
28 Jan	616	2 Jul	1850
31 Jan	2500	9 Jul	1600
4 Feb	1350	9 Jul	700
7 Feb	600	20 Jul	915
8 Feb	900	21 Jul	480
11 Feb	900	22 Jul	200
13 Feb	440	23 Jul	75
14 Feb	30	28 Aug	500
21 Jan	1075	31 Aug	450
26 Jan	1075	2 Sep	615
28 Jan	900	7 Sep	
6 Mar	1400	14 Sep	300
11 Mar	1660	15 Sep	500
12 Mar	400		
29 Apr	918		
4 May	1625		
6 May	1050		
12 May	1315		
13 May	750		
14 May	615		
20 May	1000		
21 May	400		
26 May	450		
27 May	750		
28 May	770		
3 Jun	1800		

A.3. 1994

Date	Charge (kg)	Date	Charge (kg)	Date	Charge (kg)
9 Aug	173	30 Aug	909	27 Oct	1013
10 Aug	58	31 Aug	545	27 Oct	988
10 Aug	234	1 Sep	909	28 Oct	1130
11 Aug	364	2 Sep	1364	28 Oct	1058
11 Aug	386	2 Sep	909	28 Oct	896
11 Aug	52	5 Sep	904	29 Oct	1480
12 Aug	237	5 Sep	1364	29 Oct	1697
12 Aug	138	6 Sep	1364	30 Oct	745
13 Aug	77	6 Sep	455	30 Oct	667
13 Aug	372	7 Sep	1364	30 Oct	476
14 Aug	491	7 Sep	455	30 Oct	455
14 Aug	651	8 Sep	909	30 Oct	224
15 Aug	591	8 Sep	455	31 Oct	537
15 Aug	136	9 Sep	1636	31 Oct	523
16 Aug	341	9 Sep	545	1 Nov	1367
17 Aug	364	10 Sep	1705	1 Nov	819
17 Aug	409	11 Sep	1364	1 Nov	422
18 Aug	1364	11 Sep	455	1 Nov	551
18 Aug	545	12 Sep	1364	2 Nov	191
19 Aug	673	12 Sep	455	2 Nov	513
19 Aug	455	13 Sep	682		
20 Aug	773	13 Sep	1136		
21 Aug	1091	14 Sep	318		
21 Aug	455	15 Sep	364		
24 Aug	1524	15 Sep	164		
24 Aug	455	15 Sep	136		
25 Aug	447	16 Sep	227		
25 Aug	386	16 Sep	909		
26 Aug	483	17 Sep	909		
26 Aug	727	17 Sep	909		
27 Aug	1528	9 Oct	394		
28 Aug	909	23 Oct	301		
28 Aug	1545	24 Oct	442		
29 Aug	1061	26 Oct	554		
29 Aug	165	27 Oct	819		

Appendix B - Summary of acoustic recordings

Dates and locations of recordings taken of industrial activity in 1994 and 1995; separate recordings of ambient noise were obtained for each.

Date	Location	Industrial Activity
9 Aug 1994	hydrophone station (47°48.378' N, 53°51.166' W)	blast (173 kg)
10 Aug 1994	hydrophone station	blast (58 kg)
10 Aug 1994	hydrophone station	blast (234 kg)
11 Aug 1994	hydrophone station	blast (386 kg)
11 Aug 1994	hydrophone station	blast (52 kg)
12 Aug 1994	hydrophone station	blast (237 kg)
12 Aug 1994	hydrophone station	blast (138 kg)
13 Aug 1994	hydrophone station	blast (77 kg)
13 Aug 1994	hydrophone station	blast (372 kg)
14 Aug 1994	hydrophone station	blast (491 kg)
16 Aug 1994	hydrophone station	blast (341 kg)
19 Aug 1994	hydrophone station	blast (673 kg)
24 Aug 1994	control area (47°38.366' N, 53°34.791' W)	blast (1524 kg)
25 Aug 1994	near station 13 (47°44.089' N, 53°44.089' W)	blast (447 kg)
26 Aug 1994	hydrophone station	blast (483 kg)
27 Aug 1994	near station 6 (47°44.449' N, 53°49.141' W)	blast (1528 kg)
28 Aug 1994	near station 6 (47°44.426' N, 53°49.117' W)	blast (1545 kg)
29 Aug 1994	station 2 (47°49.731' N, 53°52.383' W)	blast (1061 kg)
29 Aug 1994	station 2	blast (165 kg)
5 Sep 1994	near station 9 (47°40.693' N, 53°45.680' W)	blast (904 kg)
10 Sep 1994	Tickle Harbour Point (47°42.056' N, 53°42.671' W)	blast (1705 kg)
22 Oct 1994	hydrophone station	dredge activity
12 Jul 1995	hydrophone station	vessel activity
13 Jul 1995	station 9	ambient
13 Jul 1995	station 13	ambient
13 Jul 1995	hydrophone station	vessel activity
21 Jul 1995	hydrophone station	vessel activity

Appendix C - Additional sightings in 1994 and 1995

Sightings in 1994 and 1995 which were observed opportunistically (without searching effort), or when the experimental area was not fully searched.

C.1. 1994

Opportunistic sightings in 1994 made by the Hibernia Environment Department, and the second boat used for acoustic recordings.

Date	Min/max no. and species	Approximate distance from industrial site (km)	Comments	Sighted by
9 Aug	1/1 minke	2.9		2nd boat
10 Aug	6/8 dolphins	8.4		2nd boat
14 Aug	1/1 harbour porpoise	2.8	observed immediately before blast	2nd boat
15 Aug	1/1 minke	2.0	observed between blasts	Hibernia Env. Dept.
19 Aug	1/1 minke	8.3		2nd boat
19 Aug	5/5 harbour porpoise	8.3		2nd boat
19 Aug	1/2 minke	2.9	observed immediately before blast	2nd boat
2 Sep	1/1 minke	2.8		Hibernia Env. Dept.

C.2. 1995 Humpback whales

Humpback whales (*Megaptera novaeangliae*) in the experimental area in 1995 observed opportunistically, or when the experimental area was not fully searched.

Date	Latitude (N)	Longitude (W)	No. whales	Distance (km)	Whale ID no.
17 Jun	47°48.914'	53°51.593'	1	1.18	2
26 Jun	47°51.260'	53°55.019'	2	4.91	19&33
26 Jun	47°51.387'	53°55.183'	1	5.22	2
27 Jun	47°50.982'	53°53.577'	1	3.40	19
27 Jun	47°51.228'	53°54.223'	2	4.22	2&33
28 Jun	47°51.461'	53°54.714'	1	4.93	2
28 Jun	47°50.760'	53°53.852'	1	3.25	19
1 Jul	47°50.167'	53°52.587'	1	1.51	19
6 Jul	47°50.995'	53°53.995'	2	3.70	1&2
6 Jul	47°44.129'	53°44.474'	1	13.70	34
7 Jul	47°50.840'	53°53.758'	1	3.30	2
7 Jul	47°50.166'	53°52.464'	1	1.47	1
7 Jul	47°44.973'	53°47.033'	1	10.42	31
8 Jul	47°50.009'	53°52.380'	1	1.16	1
8 Jul	47°50.032'	53°52.354'	1	1.20	2

C.3. 1995 Minke whales

Minke whales (*Balaenoptera acutorostrata*) in the experimental area in 1995 observed opportunistically, or when the experimental area was not fully searched.

Date	Latitude (N)	Longitude (W)	No. whales	Distance (km)
17 Jun	47°51.264'	53°54.780'	1	4.71
17 Jun	47°51.264'	53°54.780'	1	4.71
28 Jun	47°51.021'	53°54.527'	1	4.17
1 Jul	47°50.761'	53°53.258'	1	2.85
3 Jul	47°50.712'	53°53.570'	1	2.97
8 Jul	47°48.935'	53°51.163'	1	1.56
26 Jul	47°44.369'	53°49.136'	1	10.06
27 Jul	47°50.051'	53°52.855'	1	1.46
27 Jul	47°50.051'	53°52.855'	1	1.46
28 Jul	47°50.920'	53°56.231'	1	5.74
31 Jul	47°51.189'	53°54.759'	1	4.59

Appendix D - Humpback whale respiration variables

Respiration variables for humpback whales (*Megaptera novaeangliae*) observed in the experimental and control areas in 1994 and 1995.

Table D-1. Comparison of respiration variables for single humpback whales, feeding and traveling in the experimental and control areas, in 1994.

	Whale	Average blow interval (min:sec ± se)	Blow rate (blows/min)	Max. dive interval (min:sec)	Total dive time (%)	Water depth (m)	Activity	Date	Time (hr:min)
Experimental Area									
	a	0:51±0:10	0.95	3:26	0.33	100	feeding	8 July	16:14
	b	0:13±0:01	1.6	11:41	0.67	160	feeding	9 July	13:10
	c	0:13±0:00	1.6	5:21	0.67	115	feeding	26 July	16:51
	d	2:01±0:35	0.5	no dive	no dive	25	feeding	14 July	7:44
	e	0:17±0:02	0.6	5:50	0.86	100	traveling	10 July	15:37
Control Area									
	f	0:15±0:00	1.4	6:45	0.68	165	feeding	15 July	11:12
	g	0:18±0:01	1.2	10:10	0.66	155	feeding	15 July	12:27
	h	0:36±0:11	1.1	4:39	0.35	170	feeding	8 July	8:20
	i	0:23±0:02	0.8	3:29	0.71	200	feeding	10 July	11:20
	j	0:13±0:01	1.15	8:21	0.78	110	feeding	13 July	13:18
	k	0:49±0:19	0.5	5:00	0.65	60	traveling	13 July	15:44

Table D-2. Comparisons of respiration variables for two re-identified humpback whales, feeding in the experimental and control areas, in 1995.

	Whale	Average blow interval (min:sec ± se)	Blow rate (blows/min)	Max. dive interval (min:sec)	Total dive time (%)	Water depth (m)	Activity	Date	Time (hr:min)
Experimental area	l	0:15±0:02	0.95	4:16	0.85	70	feeding	1 July	9:15
	m	0:19±0:01	1.05	8:51	0.7	120	feeding	23 June	7:32
Control area	l	2:11±0:13	0.5	no dive	no dive	80	feeding	22 June	9:48
	m	1:12±0:18	0.55	7:23	0.37	100	feeding	22 June	8:49

Appendix E - Positions of individually identified humpback whales

Positions of individually identified humpback whales (*Megaptera novaeangliae*) in southern Trinity Bay in 1994 and 1995, with their corresponding distance from Hibernia.

Whale ID no.	Date	Latitude (N)	Longitude (W)	Distance (km)
1	5 Jul 1995	47°50.356'	53°52.753'	1.91
1	"	47°50.228'	53°52.625'	1.63
1	6 Jul 1995	47°50.995'	53°53.995'	3.70
1	"	47°50.653'	53°53.203'	2.64
1	7 Jul 1995	47°50.166'	53°52.464'	1.47
1	8 Jul 1995	47°50.009'	53°52.380'	1.16
1	"	47°50.285'	53°52.828'	1.82
1	9 Jul 1995	47°45.243'	53°49.998'	8.16
1	15 Jul 1995	47°35.118'	53°34.995'	34.05
1	"	47°35.309'	53°35.063'	33.72
1	16 Jul 1995	47°34.944'	53°34.769'	34.48
1	19 Jul 1995	47°38.216'	53°39.185'	26.30
1	8 Aug 1995	47°43.832'	53°42.632'	15.76
2	17 Jun 1995	47°48.914'	53°51.593'	1.18
2	18 Jun 1995	47°43.471'	53°49.594'	11.44
2	"	47°51.121'	53°55.057'	4.77
2	24 Jun 1995	47°51.074'	53°53.688'	3.61
2	"	47°49.731'	53°52.383'	0.66
2	"	47°49.462'	53°52.419'	0.28
2	25 Jun 1995	47°51.074'	53°53.688'	3.61
2	"	47°50.812'	53°53.769'	3.26
2	26 Jun 1995	47°51.387'	53°55.183'	5.22
2	27 Jun 1995	47°51.228'	53°54.223'	4.22
2	28 Jun 1995	47°51.461'	53°54.714'	4.93
2	"	47°51.074'	53°54.764'	4.44
2	29 Jun 1995	47°51.255'	53°54.986'	4.88
2	"	47°51.015'	53°54.054'	3.78
2	30 Jun 1995	47°51.008'	53°54.126'	3.82
2	5 Jul 1995	47°50.905'	53°53.521'	3.24

Appendix E - (continued)

Whale ID no.	Date	Latitude (N)	Longitude (W)	Distance (km)
2	6 Jul 1995	47°50.995'	53°53.995'	3.70
2	"	47°50.653'	53°53.203'	2.64
2	7 Jul 1995	47°50.840'	53°53.758'	3.30
2	"	47°49.659'	53°52.067'	0.53
2	8 Jul 1995	47°50.032'	53°52.354'	1.20
2	11 Jul 1995	47°40.965'	53°45.476'	17.72
2	13 Jul 1995	47°43.579'	53°49.091'	11.44
2	21 Jul 1995	47°43.686'	53°44.076'	14.64
2	23 Jul 1995	47°43.313'	53°43.231'	15.87
3	22 Jun 1995	47°42.276'	53°32.760'	27.57
3	29 Jun 1995	47°41.702'	53°31.799'	29.14
3	15 Jul 1995	47°33.700'	53°34.471'	36.52
3	16 Jul 1995	47°34.944'	53°34.769'	34.48
4	12 Jul 1995	47°45.341'	53°50.845'	7.69
4	"	47°46.275'	53°50.585'	6.12
4	"	47°44.418'	53°50.039'	9.60
4	13 Jul 1995	47°42.166'	53°48.762'	14.05
5	18 Jul 1995	47°34.811'	53°38.852'	31.73
6	18 Jun 1995	47°35.619'	53°36.884'	31.87
6	24 Jun 1995	47°39.454'	53°33.987'	29.23
6	29 Jun 1995	47°41.702'	53°31.799'	29.14
6	4 Jul 1995	47°39.326'	53°34.725'	28.67
6	15 Jul 1995	47°33.700'	53°34.471'	36.52
6	16 Jul 1995	47°33.669'	53°34.003'	36.92
6	18 Jul 1995	47°34.811'	53°38.852'	31.23
6	1 Aug 1995	47°41.033'	53°36.930'	24.53
7	18 Jul 1995	47°34.811'	53°38.852'	31.73
7	1 Aug 1995	47°41.196'	53°38.156'	23.17
7	2 Aug 1995	47°36.388'	53°38.222'	29.73
8	18 Jun 1995	47°41.273'	53°46.922'	16.42
9	18 Jun 1995	47°38.870'	53°38.464'	25.94
10	29 Jun 1995	47°43.199'	53°40.072'	18.97

Appendix E - (continued)

Whale ID no.	Date	Latitude (N)	Longitude (W)	Distance (km)
11	22 Jun 1995	47°42.276'	53°32.760'	27.57
12	16 Jul 1995	47°33.669'	53°34.003'	36.92
13	23 Jul 1995	47°41.992'	53°47.023'	15.15
13	"	47°41.132'	53°47.574'	16.35
14	22 Jun 1995	47°45.291'	53°30.917'	27.57
14	"	47°42.276'	53°32.760'	27.57
14	25 Jun 1995	47°42.624'	53°31.292'	28.91
14	29 Jun 1995	47°38.182'	53°34.275'	30.50
14	"	47°41.051'	53°32.038'	29.49
15	13 Jul 1994	47°39.142'	53°38.103'	25.85
15	19 Jul 1994	47°39.276'	53°38.128'	25.66
15	18 Jun 1995	47°35.619'	53°36.884'	31.87
16	15 Jul 1995	47°33.700'	53°34.471'	36.52
16	18 Jul 1995	47°36.211'	53°38.389'	29.88
16	19 Jul 1995	47°37.197'	53°36.150'	30.18
16	2 Aug 1995	47°37.923'	53°37.186'	28.31
17	4 Jul 1995	47°39.458'	53°33.903'	29.30
17	15 Jul 1995	47°33.700'	53°34.471'	36.52
17	18 Jul 1995	47°34.811'	53°38.852'	31.73
17	19 Jul 1995	47°35.113'	53°37.146'	32.43
18	2 Aug 1995	47°42.257'	53°44.888'	16.06
19	22 Jun 1995	47°38.299'	53°34.995'	29.70
19	"	47°45.291'	53°30.917'	27.57
19	24 Jun 1995	47°46.147'	53°49.590'	6.84
19	"	47°49.731'	53°52.383'	0.66
19	"	47°50.372'	53°52.838'	1.98
19	25 Jun 1995	47°51.074'	53°53.688'	3.61
19	"	47°50.812'	53°53.769'	3.26
19	26 Jun 1995	47°51.260'	53°55.019'	4.91
19	27 Jun 1995	47°50.982'	53°53.577'	3.40
19	28 Jun 1995	47°50.760'	53°53.852'	3.25

Appendix E - (continued)

Whale ID no.	Date	Latitude (N)	Longitude (W)	Distance (km)
19	28 Jun 1995	47°51.074'	53°54.764'	4.44
19	29 Jun 1995	47°51.129'	53°54.301'	4.13
19	"	47°50.026'	53°52.334'	1.19
19	30 Jun 1995	47°49.713'	53°52.089'	0.62
19	1 Jul 1995	47°50.167'	53°52.587'	1.51
19	"	47°50.228'	53°52.534'	1.60
19	2 Jul 1995	47°48.108'	53°51.682'	2.47
19	"	47°49.753'	53°52.466'	0.74
19	4 Jul 1995	47°40.530'	53°45.833'	18.23
20	29 Jun 1995	47°38.182'	53°34.275'	30.50
20	"	47°41.051'	53°32.038'	29.49
20	4 Jul 1995	47°42.915'	53°47.567'	13.32
21	21 Jul 1994	47°38.613'	53°35.119'	29.32
21	29 Jun 1995	47°39.685'	53°45.497'	19.83
21	30 Jun 1995	47°39.789'	53°45.935'	19.43
21	4 Jul 1995	47°39.458'	53°33.903'	29.30
21	15 Jul 1995	47°35.118'	53°34.995'	34.05
21	16 Jul 1995	47°34.944'	53°34.769'	34.48
22	23 Jul 1995	47°41.992'	53°47.023'	15.15
23	21 Jul 1995	47°40.567'	53°47.505'	17.36
23	23 Jul 1995	47°41.746'	53°47.610'	15.27
23	1 Aug 1995	47°41.550'	53°45.439'	16.79
23	4 Aug 1995	47°40.160'	53°45.124'	19.24
24	22 Jun 1995	47°33.327'	53°34.613'	36.97
24	15 Jul 1995	47°33.700'	53°34.471'	36.52
25	15 Jul 1995	47°35.118'	53°34.995'	34.05
25	"	47°33.700'	53°34.471'	36.52
25	18 Jul 1995	47°36.211'	53°38.389'	29.88
25	19 Jul 1995	47°34.947'	53°39.333'	31.20
25	1 Aug 1995	47°40.994'	53°37.244'	24.28
25	4 Aug 1995	47°42.807'	53°35.115'	24.53

Appendix E - (continued)

Whale ID no.	Date	Latitude (N)	Longitude (W)	Distance (km)
26	19 Jul 1995	47°34.947'	53°39.333'	31.20
27	15 Jul 1995	47°35.118'	53°34.995'	34.05
27	"	47°35.309'	53°35.063'	33.72
27	18 Jul 1995	47°35.433'	53°37.833'	31.46
27	19 Jul 1995	47°38.216'	53°39.185'	26.30
27	1 Aug 1995	47°40.994'	53°37.244'	24.28
28	9 Jul 1995	47°41.599'	53°46.433'	16.13
28	12 Jul 1995	47°41.137'	53°47.668'	16.30
29	9 Jul 1994	47°46.688'	53°50.927'	4.64
29	13 Jul 1994	47°39.012'	53°38.530'	25.62
29	13 Jul 1994	47°39.142'	53°38.103'	25.85
29	15 Jul 1994	47°37.996'	53°36.023'	29.20
29	21 Jul 1994	47°36.328'	53°37.849'	29.81
29	26 Jul 1994	47°42.279'	53°48.967'	12.83
29	29 Jun 1995	47°41.703'	53°31.799'	29.14
30	12 Jul 1995	47°41.480'	53°48.361'	15.42
30	"	47°44.910'	53°50.228'	8.66
31	7 Jul 1995	47°44.973'	53°47.033'	10.42
31	"	47°45.275'	53°48.452'	8.95
31	9 Jul 1995	47°43.149'	53°46.540'	13.55
31	11 Jul 1995	47°40.407'	53°47.543'	17.63
31	12 Jul 1995	47°41.480'	53°48.361'	15.42
31	13 Jul 1995	47°42.166'	53°48.762'	14.05
32	4 Jul 1995	47°42.915'	53°47.567'	13.32
33	22 Jun 1995	47°37.597'	53°35.460'	30.21
33	23 Jun 1995	47°49.623'	53°51.989'	0.52
33	"	47°50.224'	53°52.614'	1.62
33	24 Jun 1995	47°51.074'	53°53.688'	3.61
33	"	47°49.731'	53°52.383'	0.66
33	"	47°50.372'	53°52.838'	1.98
33	25 Jun 1995	47°51.074'	53°53.688'	3.61

Appendix E - (continued)

Whale ID no.	Date	Latitude (N)	Longitude (W)	Distance (km)
33	25 Jun 1995	47°50.812'	53°53.769'	3.26
33	26 Jun 1995	47°51.260'	53°55.019'	4.91
33	27 Jun 1995	47°51.228'	53°54.223'	4.22
34	10 Jul 1994	47°39.195'	53°39.306'	24.69
34	10 Jul 1994	47°39.323'	53°39.043'	24.76
34	19 Jul 1994	47°39.333'	53°37.548'	26.14
34	18 Jun 1995	47°35.619'	53°36.884'	31.87
34	24 Jun 1995	47°40.485'	53°32.381'	29.70
34	6 Jul 1995	47°44.129'	53°44.474'	13.70
35	15 Jul 1994	47°40.237'	53°35.474'	27.17
35	15 Jul 1994	47°40.028'	53°35.234'	27.64
35	19 Jul 1994	47°38.720'	53°35.651'	28.68
36	8 Jul 1994	47°42.152'	53°34.835'	26.04
36	13 Jul 1994	47°38.867'	53°38.094'	26.20
36	15 Jul 1994	47°40.028'	53°35.234'	27.64
36	15 Jul 1994	47°40.185'	53°35.267'	27.44
37	10 Jul 1994	47°40.684'	53°36.313'	25.84
38	13 Jul 1994	47°37.902'	53°40.756'	25.25
38	15 Jul 1994	47°40.237'	53°35.474'	27.17
39	10 Jul 1994	47°50.380'	53°52.499'	3.70
40	13 Jul 1994	47°39.142'	53°38.103'	25.85
40	13 Jul 1994	47°39.012'	53°38.530'	25.62
40	21 Jul 1994	47°38.613'	53°35.119'	29.32
40	25 Jul 1994	47°39.848'	53°36.601'	26.45
41	8 Jul 1994	47°42.010'	53°34.926'	26.06
41	8 Jul 1994	47°43.913'	53°34.427'	25.22
42	25 Jul 1994	47°41.559'	53°48.019'	14.55
42	26 Jul 1994	47°41.291'	53°47.717'	15.17
43	26 Jul 1994	47°40.886'	53°48.709'	15.31
44	5 Jul 1994	47°38.034'	53°39.881'	25.76
44	8 Jul 1994	47°48.494'	53°51.440'	2.56

Appendix E - (continued)

Whale ID no.	Date	Latitude (N)	Longitude (W)	Distance (km)
44	9 Jul 1994	47°46.688'	53°50.927'	4.64
44	9 Jul 1994	47°44.058'	53°49.213'	9.81
44	19 Jul 1994	47°39.721'	53°35.248'	27.95
45	15 Jul 1994	47°37.996'	53°36.023'	29.20
46	10 Jul 1994	47°45.360'	53°48.570'	8.45
47	26 Jul 1994	47°41.310'	53°48.378'	14.76
47	29 Jul 1994	47°41.283'	53°47.893'	15.08
48	8 Jul 1994	47°43.913'	53°34.427'	25.22
49	8 Jul 1994	47°42.132'	53°34.044'	26.94
50	8 Jul 1994	47°42.152'	53°34.835'	26.04
51	9 Jul 1994	47°46.688'	53°50.927'	4.64
52	5 Jul 1994	47°38.086'	53°39.623'	25.90
53	5 Jul 1994	47°38.240'	53°39.231'	26.02

Appendix F - Positions of individually identified minke whales

Positions of individually identified minke whales (*Balaenoptera acutorostrata*) in southern Trinity Bay in 1994 and 1995, with their corresponding distance from Hibernia.

Whale ID no.	Date	Latitude (N)	Longitude (W)	Distance (km)
1	12 Jul 1995	47°47.907'	53°50.913'	3.19
1	13 Jul 1995	47°50.819'	53°53.016'	2.83
2	5 Jul 1995	47°44.798'	53°31.849'	26.74
2	12 Jul 1995	47°41.081'	53°40.495'	21.21
3	13 Jul 1995	47°39.992'	53°46.754'	18.69
3	23 Jul 1995	47°50.051'	53°52.855'	1.46
4	17 Jun 1995	47°51.264'	53°54.780'	4.71
4	1 Aug 1995	47°49.472'	53°51.559'	0.83
5	1 Aug 1995	47°39.544'	53°46.504'	19.57
5	2 Aug 1995	47°42.095'	53°43.774'	17.12
6[a]	3 Aug 1994	47°36.855'	53°34.699'	31.84
6	4 Jul 1995	47°50.177'	53°52.864'	1.66
6	12 Jul 1995	47°48.648'	53°51.181'	1.88
7	5 Jul 1995	47°49.696'	53°52.713'	0.84
7	12 Jul 1995	47°43.546'	53°49.020'	11.53
8	3 Aug 1994	47°33.319'	53°34.291'	36.93
8	4 Jul 1995	47°46.244'	53°49.550'	6.71
8	5 Jul 1995	47°39.873'	53°47.358'	18.64
8	12 Jul 1995	47°47.822'	53°50.740'	3.44
8	13 Jul 1995	47°48.458'	53°51.148'	2.18
9	1 Aug 1995	47°41.550'	53°45.439'	16.79
9	4 Aug 1995	47°41.250'	53°47.315'	16.26
10[a]	14 Aug 1994	47°43.597'	53°44.594'	14.33
10	12 Jul 1995	47°39.987'	53°40.005'	23.12
11	10 Aug 1994	47°44.343'	53°49.123'	9.43
11	8 Jul 1995	47°48.935'	53°51.163'	1.56
12	31 Jul 1994	47°38.939'	53°46.967'	19.49

[a] between year resight based on dorsal only

Appendix F - (continued)

Minke no.	Date	Latitude (N)	Longitude (W)	Distance (km)
12	9 Jul 1995	47°39.777'	53°47.694'	18.67
13	12 Jul 1995	47°41.897'	53°42.695'	18.25
14	2 Aug 1995	47°42.413'	53°41.306'	18.75
15	5 Jul 1995	47°39.997'	53°33.548'	29.04
16	13 Jul 1995	47°42.844'	53°44.686'	15.33
17	5 Jul 1995	47°44.798'	53°31.849'	26.74
18	4 Aug 1995	47°37.894'	53°36.201'	29.18
19	13 Jul 1995	47°40.674'	53°44.762'	18.62
20	17 Jun 1995	47°51.264'	53°54.780'	4.71
21	1 Aug 1995	47°42.615'	53°48.767'	13.26
22	22 Jun 1995	47°33.408'	53°34.847'	36.67
23	2 Jul 1995	47°50.845'	53°53.501'	3.13
24	2 Jul 1995	47°46.881'	53°50.000'	5.40
25	28 Jul 1995	47°50.920'	53°56.231'	5.74
26	13 Jul 1995	47°40.674'	53°44.762'	18.62
27	5 Jul 1995	47°44.798'	53°31.849'	26.74
28	23 Aug 1994	47°41.168'	53°48.678'	14.85
29	14 Aug 1994	47°40.527'	53°47.075'	16.79
30	10 Sep 1994	47°42.076'	53°42.091'	18.53
31	10 Sep 1994	47°39.472'	53°40.409'	23.35
32	31 Jul 1994	47°38.939'	53°46.967'	19.49