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Assessment of a Large Mortality Event of Scallops in the Bay of Fundy

by

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Les Documents de recherche sont publiés dans la langue officielle utilisée par les auteurs dans le manuscrit envoyé au secrétariat.

Abstract

A large recruitment of giant scallops occurred in 1988 from the 1983 and 1984 year-classes into the Cape Spencer area. These year classes were observed to have higher than normal mortality rates compared to scallop populations in other areas of the Bay of Fundy. The prevalent thought in industry was that because of the high numbers of scallops present, the increased mortality was due to starvation as there were too many animals present for the available food supplies. Increased pressure was applied to the managers of the fishery to lift all fishing restrictions so that as much harvest as possible could be taken from the stocks before it was lost to natural mortality in the form of starvation. This study examined the starvation theory through traditional drag surveys, remote underwater vehicles (ROV) and through biochemical techniques (RNA/DNA ratios). No evidence was found to support the idea of starvation and an alternate suggestion is made that the mortalities were due to fishing pressure.

Résumé

En 1988, une grande quantité de pétoncles géants des classes d'âge de 1983 et 1984 a été recrutée à la pêche dans la région du cap Spencer. On a constaté que ces classes d'âge présentaient un taux de mortalité supérieur à la normale des populations de pétoncles d'autres endroits de la baie de Fundy. Dans l'ensemble de l'industrie, on attribuait ce phénomène à l'abondance des pétoncles, la mortalité accrue étant imputée à la mort par inanition engendrée par la présence d'un trop grand nombre de pétoncles pour la nourriture disponible. Des pressions accrues ont donc été exercées sur les gestionnaires des pêches pour qu'ils lèvent toutes les restrictions sur la pêche, afin de permettre la capture de la plus grande quantité possible de pétoncles avant que ceux-ci ne meurent naturellement d'inanition. La présente étude avait pour objet de vérifier la théorie de l'inanition au moyen d'expériences de pêche à la drague traditionnelle, de véhicules sous-marins télécommandés et des techniques biochimiques (rapport ARN/ADN). Il s'avère qu'elle ne confirme aucunement la théorie de la mort par inanition, ce qui permet de penser que la mortalité observée était due à la pression de pêche.

Introduction

There was a large recruitment pulse in 1983 and 1984 in the Bay of Fundy to populations of the giant scallop, Placopecten magellanicus. The recruitment into the commercial fishery in 1988 was particularly noticeable in the Cape Spencer area off Saint John, New Brunswick and an intensive fishery quickly developed. In the fall of 1989, fishermen who were exploiting the year-class off Cape Spencer began reporting high incidences of dead scallops with articulated shells (clappers). The proportion of clappers in a population has been shown to be indicative of the mortality rate experienced by scallops (Merril & Posgay, 1964). The prevalent thought in industry was that because of the high numbers of scallops present, the increased mortality was due to starvation as there were too many animals present for the available food supplies. Increased pressure was applied to the managers of the fishery to lift all fishing restrictions so that as much harvest as possible could be taken from the stocks before it was lost to natural mortality in the form of starvation.

There have been previous reports of large mortalities of scallops. Dickie and Medcof (1963) reviewed several instances in both the Bay of Fundy and the Gulf of St. Lawrence and concluded that mortalities were caused by influxes of warm water into scallop beds or by outbreaks of predators. They also reported that a large mortality off Maces Bay in the Bay of Fundy was thought to be due to drags burying and smothering scallops. Medcof and Bourne (1964) indicated that fishing mortality could also impact scallop populations.

The objective of this study was to test the hypothesis that mortality of scallops in the Cape Spencer population was caused by starvation. The population was studied using standard Digby scallop drag surveys to examine the patterns of mortality, a remote operated underwater vehicle (ROV) to visually assess the scallop beds, and a biochemical technique (RNA/DNA ratios) to examine whether starvation was prevalent in the population in comparison with other areas in the Bay of Fundy.

Materials and Methods

Drag Survey Procedure

Stations, in the Cape Spencer area near Saint John, were randomly selected from an area approximately 1373 km^2 extending from Point Lepreau to Quaco Head and extending approximately 37 km offshore (Fig. 1). At each station, 8-minute tows were made with a standard 4-gang Digby scallop drag. Each bucket measured 76 cm wide and 23 cm high with bags made of 76 mm diameter rings knitted together with rubber washers. Two alternate buckets were lined with 38 mm mesh netting to retain those juvenile scallops between 38 mm and 75 mm shell height (distance from hinge to ventral edge of shell). All articulated scallops captured were measured for shell height and categorized live or dead. During the tow, Loran C bearings were recorded every 30 s to determine tow distance and location. Catches were prorated to a standard 800 m tow and used to determine the mortality rate at each station. One area (ROV site) which showed higher than normal mortality in the 1989 survey was surveyed in 1990 and 1991 with scallop drags to follow the change in mortality rate. Stations from other sites in the Bay of Fundy were surveyed identically except that a stratified random design was used for station selection based on previous data from the area of interest (Robinson and Chandler, 1990). The mortality rate of the surveyed populations was defined as:

$$M = \frac{\Sigma \, Clappers}{\Sigma \, Scallops} \times 100 \qquad (1)$$

ROV Survey

An opportunity arose in mid-August of 1990 to use the remotely operated underwater vehicle (ROV) HYSUB 5000 belonging to the Department of Fisheries and Oceans aboard the CSS Dawson to view a scallop bed in the Cape Spencer area. On August 16, 1990 a 5.6 km transect was videoed in the high scallop density area (ROV site) (Fig. 2) . Bottom speed of the ROV was approximately 0.5 m/s at 0.25 m above the bottom and the field of view illuminated by the lights on the ROV was ca. 0.5 m wide by 3 m in depth. Images from a colour video camera showing the live and dead scallops on the bottom were recorded on Super VHS video tape.

The video tapes were later analyzed using a VCR with a jog and shuttle control to view the scallops along the videotaped transect. All scallops were counted for each minute of recorded videotape. Densities of scallops were expressed in number of scallops per minute. One minute of video tape equalled approximately 15 m^2 .

Biochemical Studies

Individual scallop tissue samples of the adductor muscle (n = 40 to 50) per site were taken from near Cape Chignecto, Cape Spencer, southern Grand Manan, and Passamaquoddy Bay during the assessment cruises in the July to early September period. The samples were immediately frozen onboard ship in liquid nitrogen and were transferred to an ultra-low freezer upon return to shore.

In the laboratory, RNA/DNA ratios were measured to study protein growth rates in the scallops. We used the technique of Lepecq and Paoletti (1966) which had been modified by Karsten and Wollenburger (1972, 1977) to measure the nucleic acids, RNA and DNA. This method involves the use of a fluorescent dye ethidium bromide (2,7-diamino-10-ethyl-9-phenyl-phenanthidinium bromide) which increases in fluorescence when it interacts with nucleic acids and is sensitive to small amounts of nucleic acids at concentrations down to 0.05 μg/mL-1 for DNA and 0.1 μg/mL-1 for RNA. Prasad et al. (1972) have shown that results from this technique are comparable with those from the traditional Schmidt-Thanhauser method. This technique is based on the premise that the amount of protein synthesis occurring in a cell is proportional to the amount of RNA present. The amount of DNA present in a sample is directly proportional to cell number or animal size. Therefore, a ratio of RNA/DNA will give a size independent measure of the amount of protein synthesis that is occurring and has been shown to be highly sensitive to changes in food levels and growth (Buckley, 1984).

The frozen samples were thawed and each sample was placed in 3 mL of ice-cold phosphate buffered saline and homogenized and sonicated with a Polytron tissue grinder at 24,000 rpm for two 10-s treatments. Two replicates of 0.5 mL aliquots were taken and processed for determination of DNA and two for the total nucleic acids (Fig. 3) and the RNA/DNA ratio was derived using the mean value for each nucleic acid fraction. Fluorescence was measured using a FOCI Ratio Fluorometer-2 (Farrand Optical Company Limited) on sample mode. The nucleic acid standards used were obtained from Sigma Chemical Company; DNA (D1626) and RNA (R7250).

Results

Drag Survey

Mortality rates were observed to be significantly higher ($p < 0.01$, t-test) for the general Cape Spencer area and the ROV study site compared to other areas surveyed in the Bay of Fundy (Fig. 4). Average mortality rates for Grand Manan and Passamaquoddy Bay ranged from 3 to 9 % while Cape Spencer and the ROV site ranged from 3 to 68%. There was an increasing trend in the latter two sites from 1989 to 1991 while the two former sites remained relatively constant. Two samples from the upper Bay of Fundy did not show the higher mortality rate experienced in the Cape Spencer area (i.e. 14 and 7 % for 1986 and 1990 respectively).

The frequencies of the 1983-84 year-class at Cape Spencer continued to increase from 1989 to 1991 (Fig. 5). The modes of each year matched the predicted values for ages 4, 5, and 6 years predicted by the growth curve in Chandler et al. (1989) for Cape Spencer and is indicated by arrows in Fig. 5.

ROV Survey

Analysis of the video footage of the ca. 5.6 km ROV transect revealed that the scallop bed structure was quite patchy (Fig. 6). Clappers were found along the entire length of the transect in variable proportions to the live animals. The density of scallops observed ranged from 0 to 68 scallops per minute. The percent mortality for samples with over 4 scallops per minute along the transect ranged from 0 to over 75% (Fig. 7). Overall, the mean mortality observed was 22.1% (s.d. = 19.8). Higher mortality rates were observed on the ends of the transect compared to the middle section. There was some suggestion of an inverse relationship between scallop density and mortality rate although the data showed a large amount of variation (r^2 = 0.02, n = 181, n.s.) (Fig. 8).

RNA/DNA Ratios

Analysis of the adductor muscle of the scallops from the four sample areas indicated that there were no apparent indications of starvation in the populations tested. All of the animals had RNA/DNA ratios in excess of 3 indicating positive growth rates (Fig. 9). Grand Manan and Passamaquoddy Bay had the highest ratios followed by Cape Spencer and the Upper Bay of Fundy.

Discussion

There was no indication of any starvation occurring in the scallop populations in the Cape Spencer area. The animals all grew according to a growth curve derived from a survey of the Cape Spencer area in 1987 and the RNA/DNA ratio indicated that all animals sampled were well above the level of starvation of approximately 2 (Robinson, unpublished data). It also appeared that the highest levels of mortalities were not neccessarily found in the highest density beds which would be contrary to the starvation theory (compare Figs. 6 and 7). It is unlikely that disease was adversely affecting the population as a drop in the growth rate would also be expected to occur and affect the highest densities of animals. This assumes that growth of the scallop is indicative of the general condition of the animal. Therefore, based on the above observations, it does not appear that starvation or any other biological form of density dependent regulation was involved in the increase of scallop mortality.

The mortality rates which were derived from the drag survey data are probably over-estimates of the actual mortality rate on the bottom. Video observations clearly showed that the clappers had a much higher profile on the bottom than live animals which were often cryptic and in slight depressions. The resilium of the scallop shell kept the valves wide open and would probably increase the catchability coefficient of the dead scallops as opposed to the live ones. Mortality rates in the other parts of the Bay of Fundy generally reflected values from other studies such as Dickie (1955) and Merrill and Posgay (1964).

An alternate explanation of the increased mortality rates observed is that the mortality was caused by fishing pressure. This area has received heavy pressure since 1989 from scallop vessels from Digby and southwestern New Brunswick. Some boats were observed to be 'deck-loading' the scallops in the summer months in 1990 (pers. obs.) to be sorted later and shucked when possible. This would kill a large number of scallops which may be later returned to the water due to small size etc. During our surveys, we found that the shells of the scallops we caught were thinner than those in the southern parts of the Bay (i.e. Grand Manan and Passamaquoddy Bay) and that there was a higher incidence of shell breakage, sediment impacted in the shell, and shells slicing through each other's adductor muscle as they were packed into the steel ring bag. Any damaged scallops remaining on the bottom or returned to the bottom from a vessel would also be more vulnerable to predation. The video tape showed several types of marine life present. Cod, wolf fish, sculpins, skates, flounder, starfish, Cancer crabs, and hermit crabs were all abundant at the site. Caddy (1973) noted that predatory fish and crabs were attracted to dredge tracks within one hour of fishing and that their densities increased 3 to 30 times over areas with no dredging activity. Dickie and Medcof (1963) reported that some mass mortalities have been associated with increased predation and Medcof and Bourne (1964) indicate that causes of fishing mortality include damage on the bottom by dredging, damage in the drags, dumping on deck, culling, shovelling, air exposure and shucking. All of the above factors may have contributed to the large numbers of cluckers observed in this area.

The definitive determination of the causes of large mortality events in scallop populations is very difficult to achieve. This is because the investigator usually only sees the results after the mortality has occurred and not while it is happening. Often, the best one can achieve is to try and find out what didn't cause it by using indirect means. In this study, we could find no evidence of any starvation occurring in the population at Cape Spencer. We have suggested an alternative explanation of fishing mortality but, there is little direct evidence to show this other than references from the literature on the effects of fishing.

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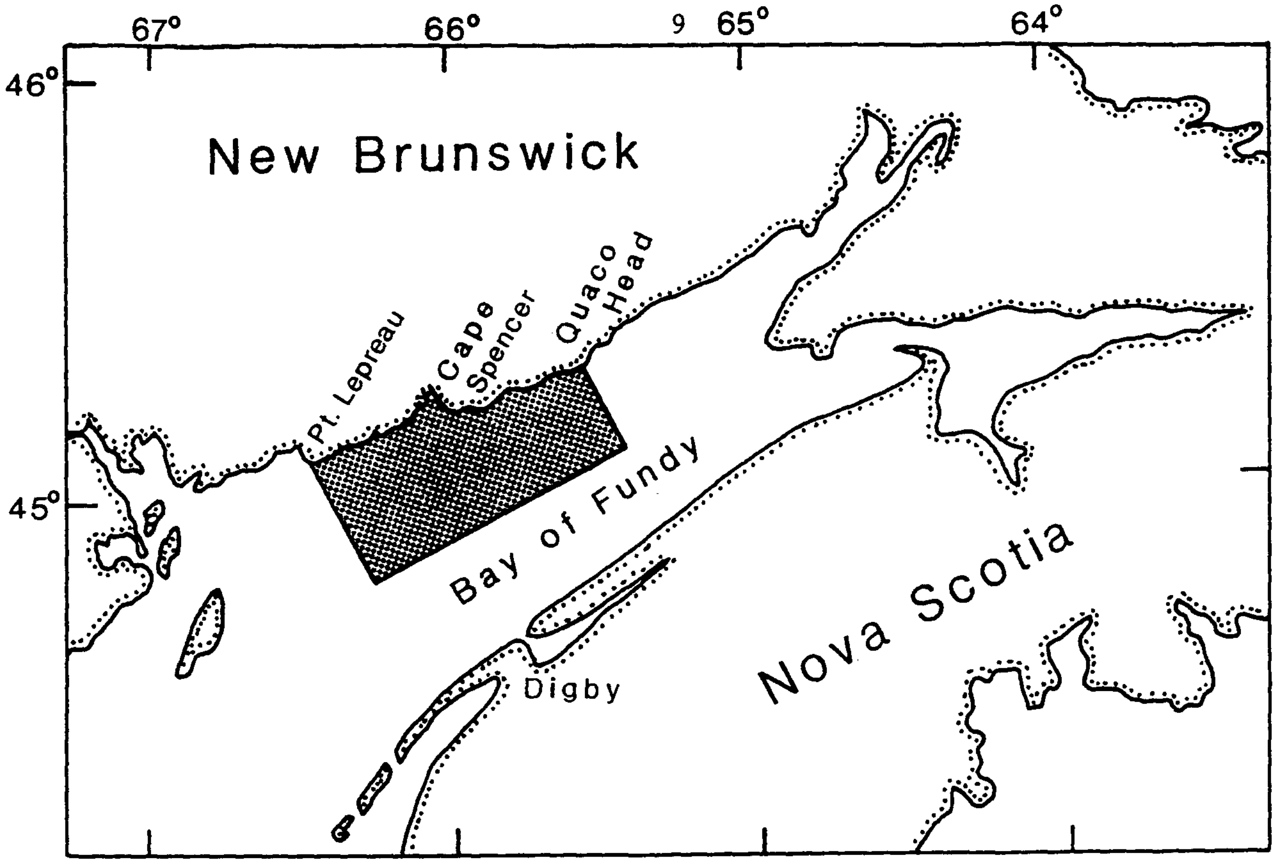

Figure 1. Location of survey area for assessment cruises off Cape Spencer.

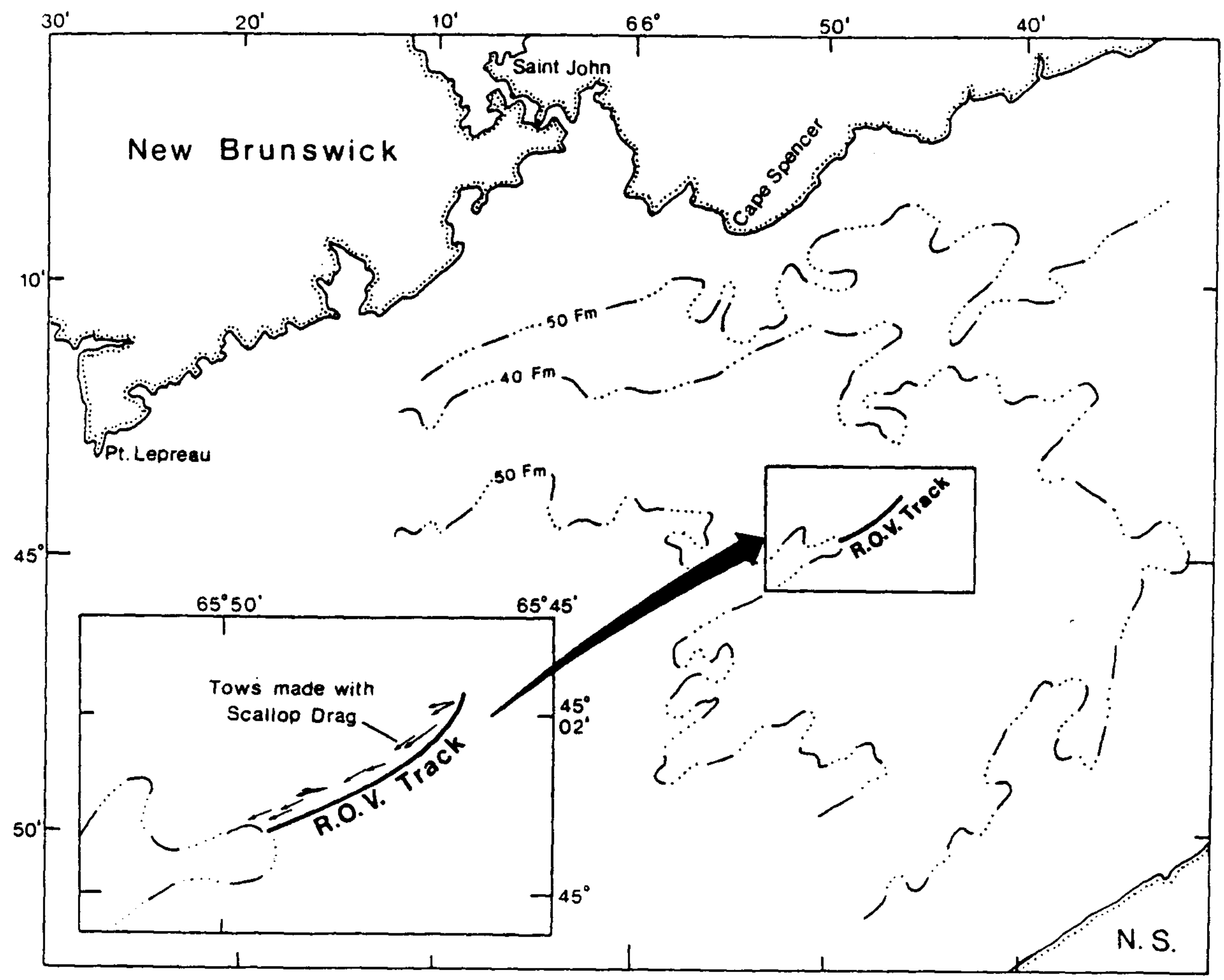

Figure 2. Location of ROV transect off Cape Spencer.

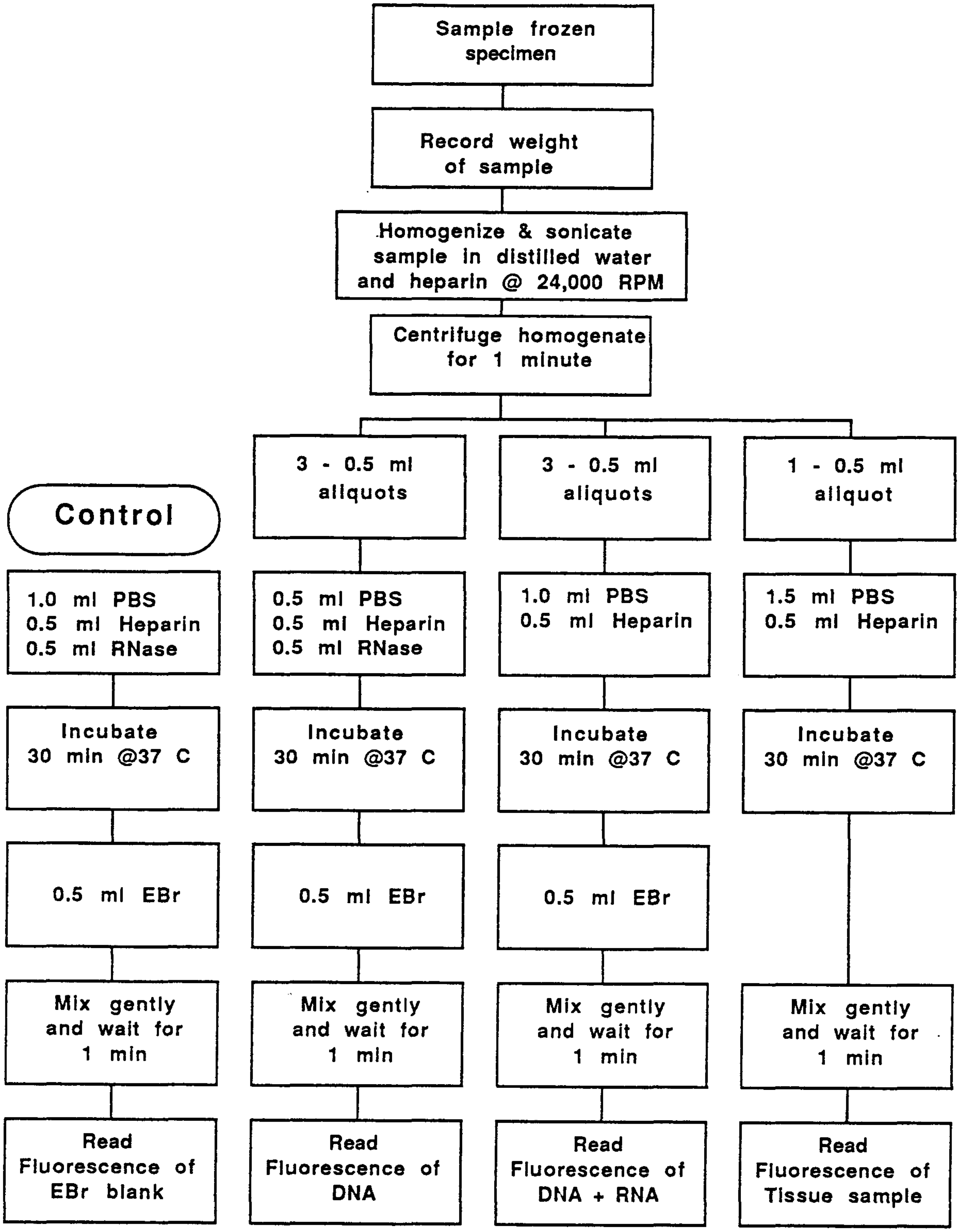

Figure 3. Schematic diagram of sample processing for the determination of RNA/DNA ratios in scallop samples.

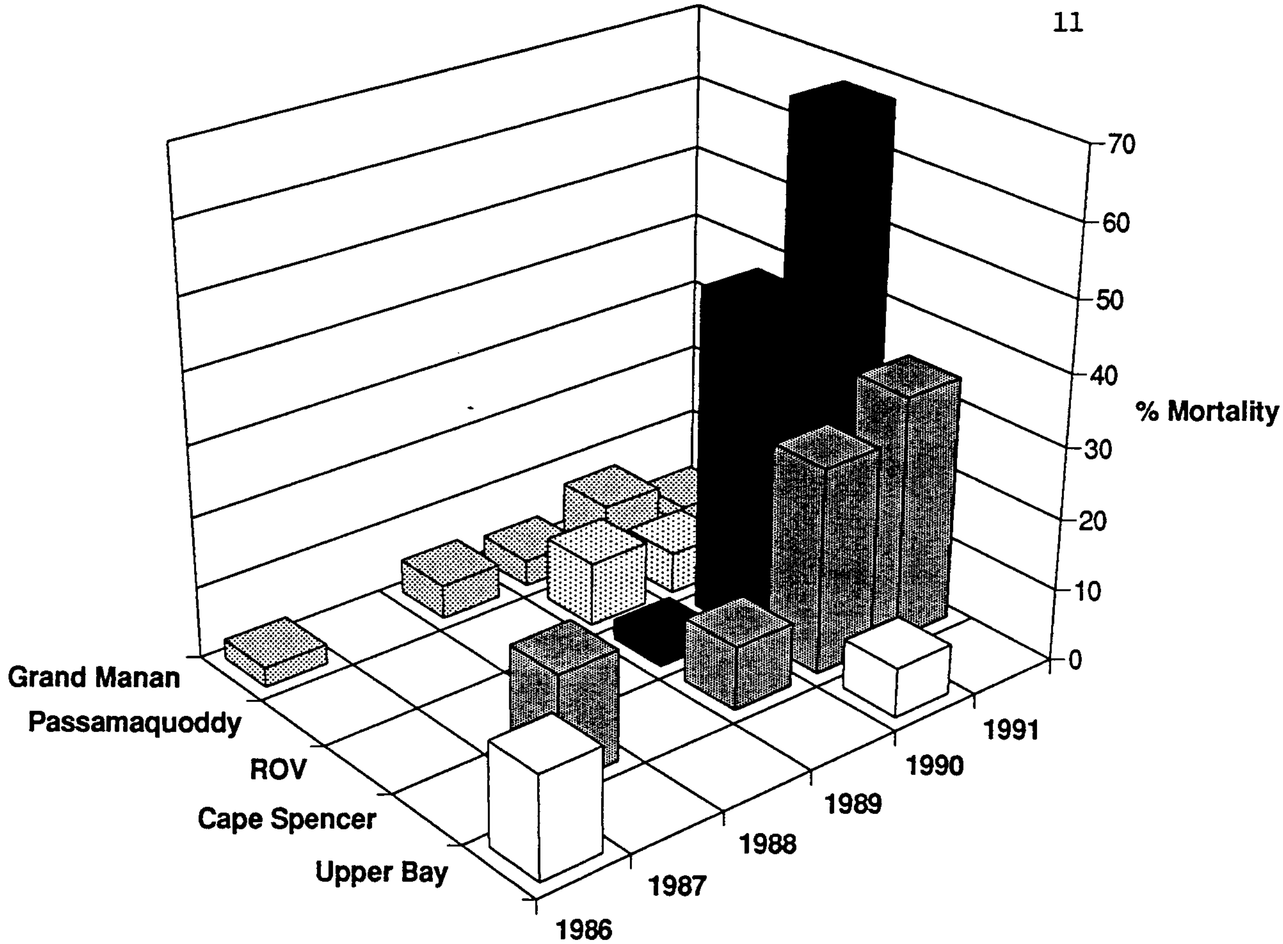

Figure 4. Summary of mortality rates in giant scallops in the Bay of Fundy based on past research cruises.

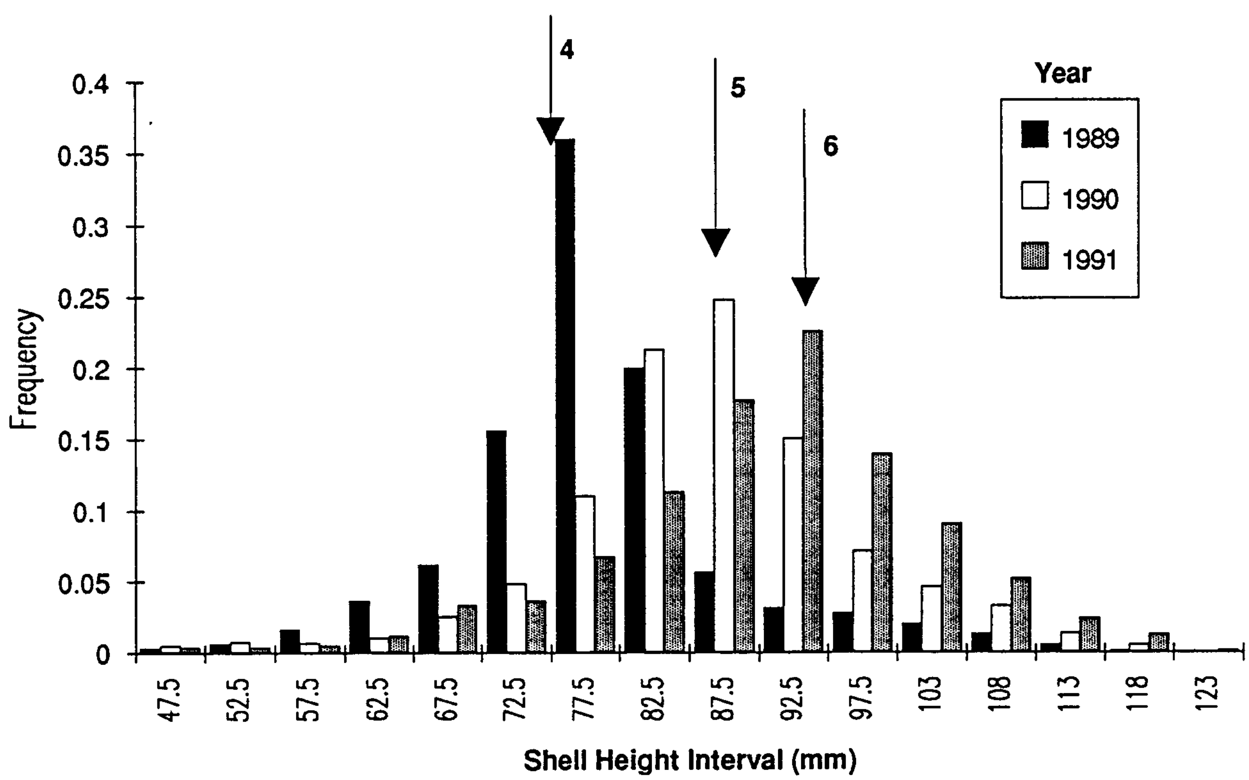

Figure 5. Size frequency of scallops captured in the Cape Spencer area from 1989 to 1991. The arrows indicate predicted sizes at age from a growth curve of scallops off Cape Spencer produced by Chandler et al. (1989).

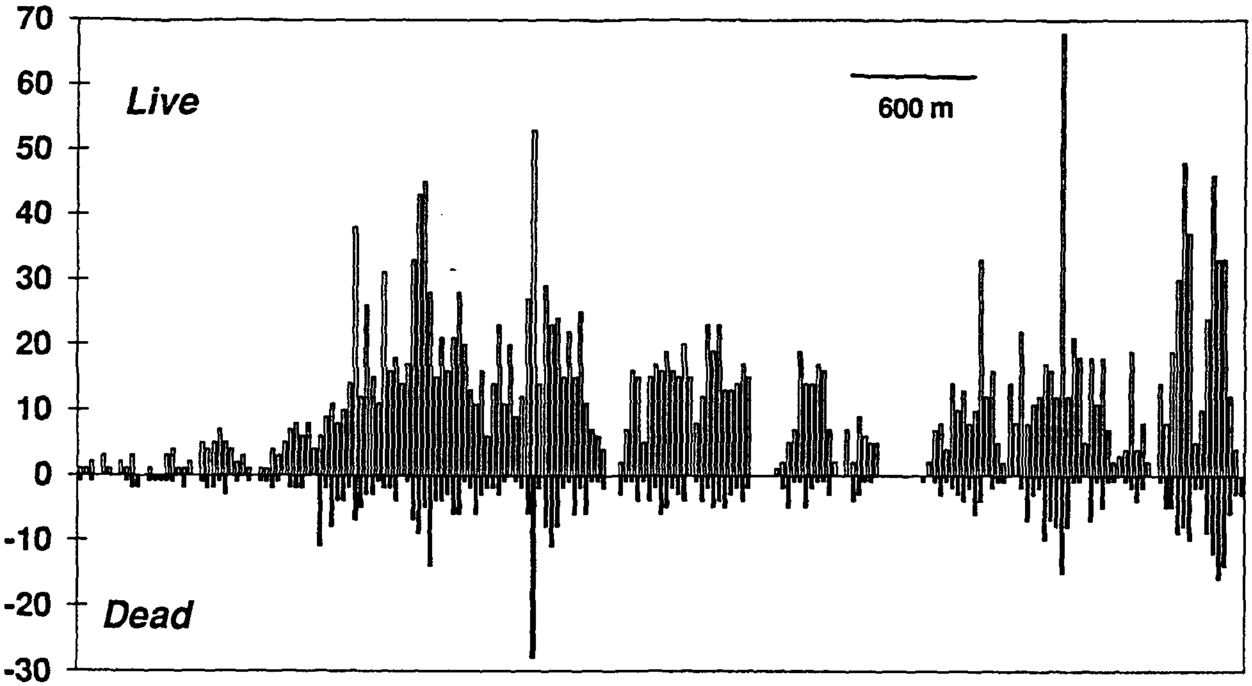

Figure 6. Number of live and dead scallops observed per minute along the ROV transect done in August 1990.

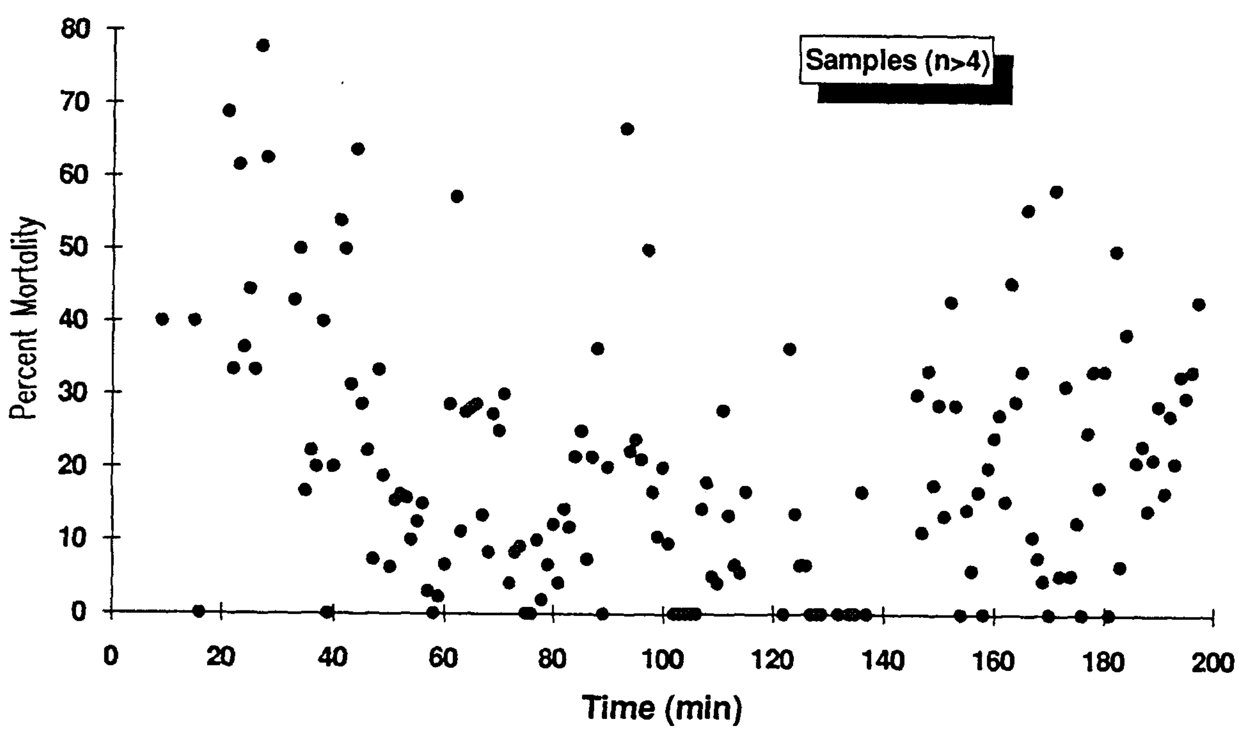

Figure 7. Mortality rate observed of scallops per minute along the ROV transect. Only sample minutes with more than 4 animals were included in the analysis.

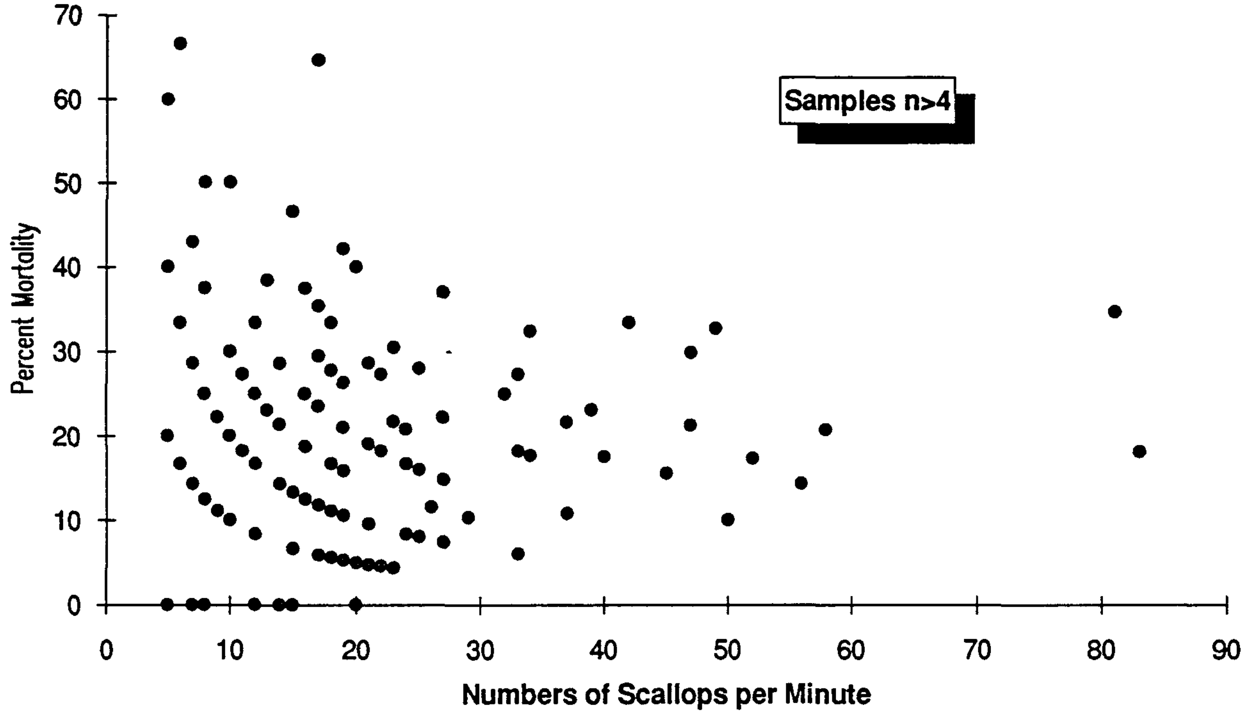

Figure 8. Relationship between mortality rate and the density of scallops observed per minute along the ROV transect. Only sample minutes with more than 4 animals were included in the analysis.

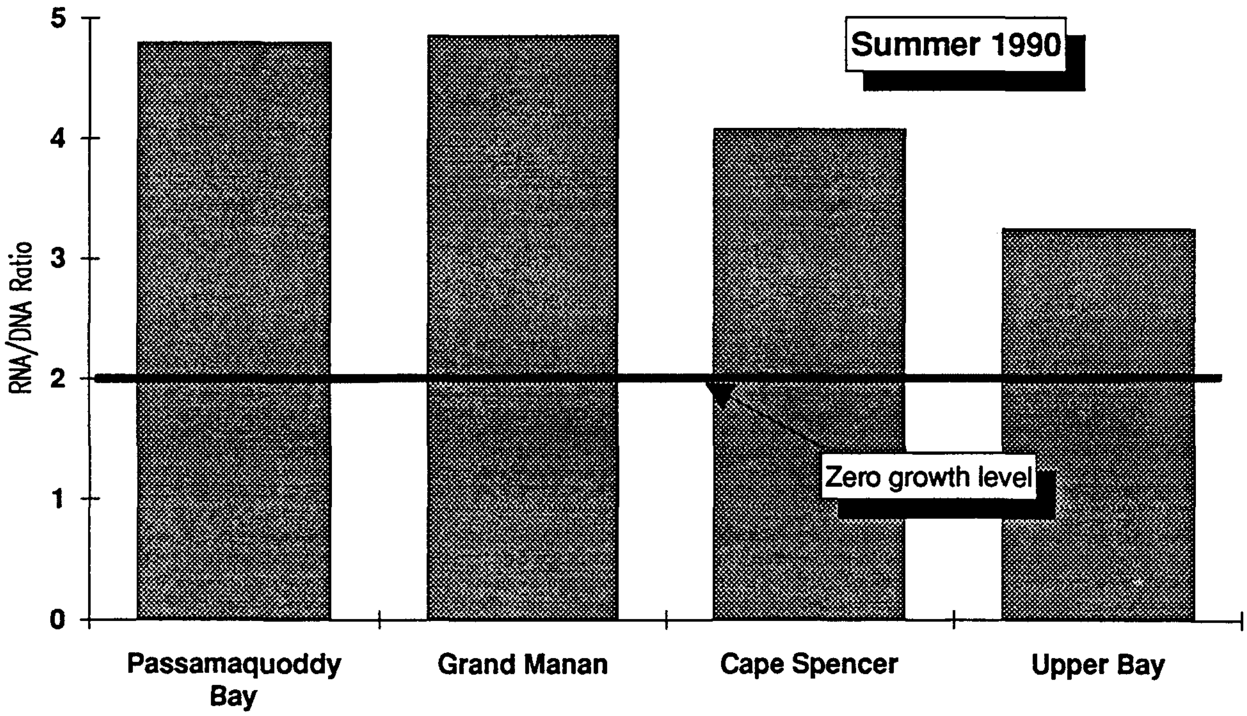

Figure 9. Mean RNA/DNA ratios from scallop adductor muscle in four different locations in the Bay of Fundy from 1990.