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A Review of DFO Concerns Regarding Possible Impacts of a Fixed-Link Crossing of Northumberland Strait

by

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Abstract: The history of proposals for fixed crossings from New Brunswick to PEI is reviewed. Possible impacts of current proposed structures on the marine ecosystem and fisheries are discussed. It is concluded that the tunnel, as proposed, would have negligible impacts. Impacts of proposed bridges are impossible to evaluate at this time. Biological impacts would probably be consequences of interactions of the bridge structures on sea ice and physical oceanographic properties of the strait. Studies done on these interactions were thought to be incomplete primarily by not considering possible important factors, and by making some questionable assumptions about the interactions which were considered. With inadequacies in the ice-physical oceanography-bridge interactions, projections of biological impacts consequent to the physical oceanographic impacts were considered unreliable. Specific areas of concern are detailed for ecosystem dynamics, invertebrates, and finfish.

Résumé

On examine rétrospectivement les propositions de lien fixe entre le Nouveau-Brunswick et l'Île-du-Prince-Édouard et on étudie les effets possibles des structures actuellement proposées sur l'écosystème marin et sur les pêches. Il s'avère, en conclusion, que le tunnel, tel qu'il est proposé, n'aurait qu'une incidence négligeable. Il est impossible d'évaluer pour le moment les effets de l'éventuelle présence d'un pont. Les interactions entre l'ossature du pont, les glaces marines et l'océanographie physique du détroit auraient sans doute des répercussions biologiques. On a jugé les études de ces interactions incomplètes, d'abord parce qu'elles ne tiennent pas compte de facteurs qui pourraient se révéler importants et aussi parce qu'elles comportent des hypothèses discutables au sujet des interactions considérées. Compte tenu de ces insuffisances, les projections des phénomènes biologiques résultant de l'incidence sur l'océanographie physique sont sujettes à caution. On décrit en détail certains points d'intérêt particulier en ce qui concerne la dynamique de l'écosystème, les invertébrés et les poissons.

1.0 Introduction

The Marine Environment and Ecosystems Subcommittee of CAFSAC was convened in August 1988 to consider aspects of the possible environmental consequences of a fixed-link crossing of Northumberland Strait. Consideration was to focus on sea ice dynamics, and changes in biological properties which resulted from impacts of the proposed structures on ice dynamics, but extended beyond that specific focus in several areas. Five working papers; an overview, ecosystem dynamics, physical oceanography, invertebrates and finfish were presented at the meeting, and formed the basis of further discussion. This research document consists of five sections, each corresponding to one of the working papers presented at the meeting. Together they form a summation of peer evaluation of the work done to date evaluating the potential impacts of the fixed link crossing on the marine ecosystem and fisheries.

2.0 History of the Fixed-link Proposals

The subject of connecting Prince Edward Island to the mainland with some form of "Fixed Link" (causeway, tunnel, bridge or a combination of these) has been a hotly debated topic for well over a hundred years (see background paper entitled "The Northumberland Strait Crossing Project - A Fisheries Perspective"). It is fair to say that, for most of that time, the controversy surrounding such a development had far more to do with economic and socio-economic concerns than the impact that such a link would have on the environment.

Indeed, during the last serious reincarnation of this proposal in the 1960's, the Fisheries Research Board of Canada (a pre-cursor to the Science Branch of DFO) was on record as believing that even a structure comprising long causeway stretches obstructing 95% or more of the Strait's cross-sectional area would produce insignificant, or at least undetectable impacts. (See memo from J. L. Hart, Director of the St. Andrew's Biological Station, to the Office of the chairman, Fisheries Research Board, dated 10 March, 1967).

This judgment went even farther in downplaying the risks than previous FRB statements pertaining to the structure for which construction was actually approved in 1965, involving approximately 50% bridge and 50% causeway sections. (See "Fisheries" chapter from Phase II Engineering Report, January 1965). This also conformed with observations recorded in an internal memorandum of H. G. Acres and Company Consulting Engineers dated November 15, 1964 which recorded the results of an informal workshop involving among others Dr. D. G. Wilder, Dr. L. Lauzier, Dr. R. W. Trites, Dr. B. Blackpool and Dr. Loring. At that session it was concluded that a restriction to as little as 35% of the existing Strait cross-sectional area would produce only local and acceptable levels of marine environmental change.

It is interesting to note too that in these early analyses the authors drew a great deal of comfort and certainty in their predictions from the belief that the Canso Causeway had been predicted to cause minimal impact and, in their view at that time, had indeed done so. Looking back now with the benefit of a further twenty years of post-construction observations, some of that confidence regarding the effects of the Canso Causeway seems to have been premature and ill-advised.

2.1 Present Proposals

In early 1985 the federal government received expressions of interest from two and later three private consortia proposing several alternative designs for a fixed link between NB and PEI. The renewed interest was coincident with the expiry of the 20 year regional development agreement signed by the government of PEI and Canada in lieu of completion of the crossing in the 1960's.

These later proposals consisted of a rail tunnel, a combination causeway-bridge-tunnel, and a total bridge from shore to shore. The interesting feature of these proposals was that they all believed they could construct and operate such a facility with no more financial commitment from the federal government that the continuance of a grant already paid to offset ferry deficits. Because earlier attempts at constructing such a crossing had failed as a direct result of spiraling costs to the federal government, such a proposition could not be ignored. However, after due consideration, government felt it would be unreasonable to simply select among conceptual proposals already received and, therefore, set about to design a more structured tendering procedure allowing for the acceptance of all statements of interest responding to Terms of Reference outlined by government.

One of the steps considered essential to the preparation of the Terms of Reference was the completion of an Initial Environmental Evaluation (IEE) demonstrating, at least in "generic" terms, that such a crossing was environmentally acceptable and offering guidance on the possible design features which would be mandatory in order to ensure adequate mitigation of anticipated environmental effects.

In the late winter of 1986/87 the government agency given responsibility for this review, Public Works Canada, set about to order the necessary background studies required for the preparation of what was to be known as the Generic IEE (GIEE).

2.2 The Generic IEE

Fisheries and Oceans' involvement with the Fixed Link Project, now known as the Northumberland Strait Crossing Project (NSCP), actually began in 1985 when several meetings concerning the original three proposals took place. However, the level of DFO involvement was relatively low key until December of 1986 when PWC approached the department and requested assistance in the preparation of Terms of Reference for biological and physical oceanographic studies considered essential to preparation of the GIEE.

At the outset some doubts were expressed within DFO regarding the perception that this might raise on departmental impartiality. Such doubts were soon laid to rest, however, when DFO participation in the planning process was instrumental in the PWC decision to automatically disallow any proposal designs which would entail even a partial causeway crossing. Although DFO was in no better position to conclusively demonstrate that a causeway would result in negative impacts, the specter of the Canso Causeway, as well as numerous other smaller estuarine causeways in the Maritimes was far too daunting to run the risks of being wrong.

In any event, the decision was made for DFO to become an active participant along with PWC and later DOE and provincial agencies in planning, assisting in the completion, and reviewing the outcome of a variety of background studies. DFO established a scientific and technical working group in order to carry out this task.

Initially ten studies were prepared:

- Fishery and environmental resources
- Erosion and scour
- Winds, waves, tides, and currents
- Ice climate
- Vessel traffic and bridge safety
- Social impacts
- Financial and economic feasibility
- Substructure design
- Superstructure design
- Tunnel feasibility

Inevitably, each one of these studies uncovered data gaps which led to the need for further analysis with the result that, in all, over two dozen background studies were undertaken.

While admittedly such a profusion of new research was overwhelming in the information it generated, the chief flaw in all of this was the failure to provide adequate coordination among the twenty or more consulting firms engaged to carry out the work. Indeed, the consortium selected to prepare the GIEE did not appear on the scene until most of these studies were either completed or so well along that their direction could not be altered. Individual consultants neither shared their preliminary findings with those working on related topics nor did they all have a common conception of what form the hypothetical crossing would take. Of course, quality of experimental design and confidence in conclusions varied tremendously from study to study as well.

For any individual or group to take the results of this body of work and construct a cohesive and credible generic IEE was indeed asking a lot. To complicate matters further the GIEE consultants insisted upon the use of a Risk Scoping Matrix methodology as the corner-stone of their treatise. That approach was neither entirely agreed to by specialist advisors in government nor adequately verified internally through quality control and testing procedures.

The risk scoping method entailed the construction of a giant matrix of some 40,000 interactions between hundreds of specifically defined project activities and several hundred Ecological Components at Risk (ECAR's). The contents of the list of ECAR's was criticized for its redundancy on the one hand (a result of a failure to employ any form of multi-factoral analysis to reduce the list and eliminate duplication) and on the other hand its failure to include all the vital ecological interactions as ECAR's. The list was also internally inconsistent in that items were included which were by any standard not at risk nor ecologically important, alongside of, and with equal weight as, other factors which were of enormous significance and sensitivity.

Each interaction between ECAR and project activity was scored on three factors which were then multiplied to derive a single overall score. These factors were the importance of the ECAR (I), the possibility that an interaction would take place (P), and the magnitude of that change if it occurred (M). Both the P and M factors were arbitrarily accorded a maximum score of 5 while importance was only scored out of 4 in order that the product of these 3 would total 100. It is interesting to note what impact even such a minor subjective decision had upon the results of the matrix.

As an example, suppose that an interaction involving a most important ECAR (4) whose disturbance would result in the greatest magnitude of change (5) was determined to have a possibility of occurrence of only 2. The product of this calculation yields a score of 40. If, on the other hand, the authors of the matrix had chosen to reverse the maximum scores possible for the I and P factors, the product of the same interaction would now be 5x5x2 or 50. This is significant, because the authors also arbitrarily set the level of significance for an interaction to be considered a high risk at 50. Thus, in the first case the interaction described would be ignored whereas, in the second case it would be considered significant to the point of requiring special attention in the IEE and possibly a mitigative strategy.

For the reasons expressed above, DFO concluded that, although the GIEE final draft was an impressive effort and much improved over its initial drafts, several of its conclusions regarding environmental impacts in the marine environment could not be accepted.

2.3 Ice Climate Controversy

Other sections of this document will focus on the critical concern of DFO for ice climate as affected by a bridge structure. It is only mentioned briefly here as an example of how even well-prepared background studies may be internally flawed, resulting in compounded misunderstanding in other areas of impact analysis.

Original ice climate analyses prepared by F. G. Bercha and Associates used numeric modeling techniques which employed a variety of deterministic and probabilistic variables depending upon the availability of reliable data sets. Crucial information on ice distribution, floe velocity and floe thickness was largely extrapolated from limited data files. The physical dynamics described by the equations in the model were somewhat conjectural as well, because no tested and proven model for ice dynamics in a semi-diurnal tidal regime exists.

Despite these uncertainties the authors were prepared, based upon their lengthy experience in this subject area, to come to some relatively definitive conclusions. DFO scientists examining the same data and methodology would have preferred a more cautious approach. Nevertheless, the report was submitted and interpreted simply as concluding that ice dynamic changes to the extent of delayed ice out or altered micro-climate were not at issue. With this in hand, other consultants preparing reports on fisheries and the environment simply eliminated potential ice-related interactions from consideration. This left the authors of the GIEE with no choice but to follow suit and deny the possibility of ice climate impacts as a serious risk.

The consequences of a mistake in evaluating ice climate impacts is far more devastating than would be the consequences of mistakes in some other areas where conclusions have been drawn from background reports. However, other background studies also are limited in their predictive ability by weak data bases and, in some cases, questionable hypotheses and methodologies, which nonetheless were ignored when their results were absorbed into the GIEE analysis. Furthermore, all background studies considering the bridge option are additionally limited in their generality by the structural design criteria they assumed. The assumed design criteria were neither consistently observed between reports nor necessarily consistent with the criteria of any of the six bridge designs being evaluated. Thus their conclusions must be challenged and reviewed once a final design is on the table. This will be the task of those charged with preparing a final, specific IEE (SIEE).

2.4 Fish, Fish Habitat, and Fisheries Issues

In summary, the DFO scientific and technical working group has raised for consideration a variety of fisheries-related concerns, some of which are adequately addressed in the GIEE and studies carried out to date and some which have been either downplayed or ignored. A listing of the most crucial of these, though not necessarily in strict order of priority includes:

2.4.1 Ice Climate

The effect pier spacing and design may have on ice dynamics is not at all certain. If the bridge should act to jam ice to the west of the crossing a number of possibilities occur. Prolonged ice cover during the season may affect light penetration and primary production, surface water temperature (with effects on production, herring migration, lobster molt cycles, etc.) and possibly other ecological features through synergistic or cumulative interactions. A consistent delay in the date of ice out could similarly alter the time of arrival of herring on the spawning grounds and also affect fishermen's ability to take part in early spring fisheries for herring and scallop throughout the Strait. A tendency to either diminish ice distribution or reduce floe size east of the crossing would interfere with grey seal pupping.

An acknowledged tendency for ice accretion outward along the piers will extend the limit of land fast ice (anchor ice) possibly resulting in greater distribution of bottom scouring during ice-out in particular.

2.4.2 Sediment Movement

Once again, pier design and spacing may have an appreciable effect on local sediment scour action, particularly in the shallow shore zone where coastal erosion is already a problem. Redistribution of destabilized sediments would be most harmful to sedentary benthic species like scallops but could also harm those species which have demersal, adherent eggs (eg. herring). Overall destabilization of the benthic community would be particularly important in winter when it takes on principal significance as the site of most primary production.

Dredging likewise would liberate sediment particles with similar effects to those described above. This would be of shorter term duration and somewhat more mitigable. However, dredging normally has more acute impacts on fishing gear and fishermen.

2.4.3 Water Movement

Blockage of the Strait's cross-sectional area has been estimated at anywhere between 7% and 18%, depending on the specific design proposed for piers, pier protection, and pier spacing. Background studies by Sandwell, Swan, Wooster Inc., on winds, waves, tides, and currents considered a hypothetical blockage of 10% and concluded that only highly localized changes in these features might possibly be observable. With some designs now proposed to almost double this blockage, fears are renewed that changes will occur that will further destabilize an already dynamic body of water.

Consequences are unknown but would be tied in with the sediment movement problems already described and might also alter patterns of fish and invertebrate distribution, such as the patchy concentration of scallops for which no present explanation is available. Increased currents would also aggravate the navigational hazards constituted by 46 to 86 new obstructions (piers) traversing the Strait.

2.4.4 Habitat Destruction/Alienation

No matter what design is chosen, a considerable portion of productive bottom will be consumed. This will affect habitat availability for at least three commercial important species (scallops, lobsters, and herring) as well as a diverse array of beneficial lower organisms and non-commercial fish. Although there may be merit in some suggestions under consideration regarding the modification of pier design to optimize habitat replacement value, it is doubtful that the reduction in production of desirable species can be totally offset.

2.4.5 Environmental Contaminants

These can arise from many sources: dredging, vessel accidents, road spills, and the use of routine maintenance products such as urea. Mitigative measures are feasible to combat most if not all of these, given the commitment to do so.

2.4.6 Interference with the Fishery

Causes are diverse; exclusion zones during construction, gear damage or loss caused by construction vessels or dredging, concentration of fishing effort, navigational hazards due to the structure (eg. impact on drift netting) and the ephemeral and unpredictable likelihood of permanent ecological change affecting commercial landings. At this stage, all of these are the subject of contingency planning or compensation or both. There is no assurance the planning will prevent all problems from arising.

2.5 Conclusion

There are many potential changes brought about by the construction of a bridge of any design in the Northumberland Strait. Some of these changes are certain, some are conjectural, and some may never be detected in the background of dynamic variability. Experience has shown that there will also be changes that none of us would predict. All that can be expected at this time is to focus attention on a few critical changes that are likely to occur so that through proper planning and mitigation their impact will be lessened to acceptable levels.

3. Ecosystem Dynamics

3.0 Introduction

Assessment of the impacts of the environmental changes, either natural or man-made, on ecosystems and the biological resources we harvest from them requires an understanding of the natural variability of the system. Effects of changes may have positive or negative impacts, but without knowledge of existing variability before changes occur, assessments of impacts afterwards are not possible. The task is analogous to an engineering design problem where the mean, variance, and maximum probable limits for stress and strain by physical forces on a structure have to be known before structural designs can be made. Environmental impacts of a fixed-link crossing between PEI and NB as they affect harvestable resources of concern to DFO occur where physical and biological processes intersect. Tidal activity, the extent, movement and timing of ice cover and suspended sediment load are physical variables in Northumberland Strait which affect biological production processes. Few studies exist to quantify the natural variability of these processes or to assess their linkage to production of harvested species.

3.1 Historic Concerns

The idea that a road linkage between PEI and NB could have environmental impacts on fisheries resources has existed in all previous proposals. D. Scarrett provided correspondence and memos exchanged between scientists and the Chairman of the Fisheries Research Board 30 years ago when the construction of a causeway was discussed. While proponents have moved away from a concept for a structure that would block movement of ice and water, the concerns expressed then are still relevant today. The following is taken from a memo(June 21, 1958) from Dr. J. Hart at St. Andrews to Dr. J. Kask, Office of the Chairman, FRB, Ottawa...

"The effects on fisheries must for the most part be predicted from the expected changes produced in the hydrography of the region. Some uncertainty must in turn attach to these so that in effect our statement will be a prediction based upon a prediction. The basis is obviously shaky, especially since the detail of the hydrographic state will depend partly upon the construction of the causeway, where and how navigation channels are left in it and whether they are fitted with locks. It is noted, however, that the proposed causeway is near the meeting place of eastward and westward flowing tides between Baie Verte and Hillsborough. This suggests that interference with major tidal currents will be small. What changes do occur will probably involve a reduction of the west to east net movement, generally warmer waters in the Northumberland Strait region, and some trapping of trash and any pollutants added in the vicinity."

3.2 Gaps in Present Knowledge

Reviews were carried out for DPW during the current (1987-88) proposal for a fixed link crossing, to develop the terms of reference for the Initial Environmental Evaluation. The Fisheries Resources Section of the IEE pointed out that there have been no full seasonal studies of production by phytoplankton, zooplankton or benthic communities in any area of the Northumberland Strait. Previous reviews of benthic fauna, shellfish, and inshore fishery resources in Northumberland Strait (Amaratunga 1976 a, b; Caddy et al. 1977; Stasko et al. 1977) reported species and biomass distributions but no information on levels of productivity. Thus, there is no background data on spatial and seasonal differences in biological production against which changes due to construction activity or the crossing structure itself can be evaluated. Only two studies of phytoplankton production have been carried out (Citarella, 1980; Hargrave et al. 1985) and these were restricted geographically (NW basin Northumberland Strait, St. Georges Bay off the SW end of the Strait) and seasonally (summer-fall periods). There is no evidence that production rates measured in these studies are representative of the tidally well-mixed region across the Strait at the proposed site of the crossing.

The DFO Working Group on the Fixed Link identified a lack of information on ice formation and dynamics as an important obstacle to evaluation of the environmental impact of a bridge. Information on ice floe size and thickness is needed to assess the probability of ice-jamming. There is a biological dimension to this concern since seals and their pups produced in the Strait are transported out of the Gulf onto the Scotian Shelf. Peak seasonal concentrations in suspended particulate organic carbon and chlorophyll also occurred in St. Georges Bay within floes of broken ice during January and February (Hargrave et al. 1985) indicating that the presence of ice during winter stimulates phytoplankton productivity in this tidally active area. Changes in ice formation, breakup pattern and movement will impact these production processes, but the direction of the effect is uncertain.

Dredging and side-casting of bottom material will be required for pier support construction. The proportion of area in the Strait disturbed by these activities is small relative to the total area, but the impact will be visible and have the most impact on species, such as scallops, that are substrate selective in their settlement areas. There is a major scallop bed in the central Strait at the proposed crossing site which will be directly affected. Most other commercial benthic invertebrate species and all fish are mobile and may be expected to avoid sites of bottom disturbance (unless dislodgment and injury increases the food supply and attracts benthic feeders). However, suspended matter, increased in concentration around dredging sites, will be transported by tidal action for some distance above and below the zone of construction.

Concentrations of suspended particulate matter are naturally high in the Strait (Kranck 1971) due to tidal resuspension and high production by phytoplankton and attached macrophytes. The impact of increased turbidity would be to decrease light penetration in the water column even further and thereby decrease phytoplankton production. Benthic fauna can be buried and die from anoxia if sedimentation rates increase beyond the animal's abilities to burrow to the surface.

3.3 Natural Variability in the Ecosystem

Physical and biological characteristics within the Northumberland Strait and proximate regions of the southern Gulf of St. Lawrence are highly variable. Complex patterns of water advection occur through wind-driven circulation and tidal mixing. There is a seasonal impact of runoff from the St. Lawrence River on salinity and vertical stratification which may vary as freshwater discharge is regulated within the river drainage systems. A review of ice formation and distribution within the Gulf of St. Lawrence (Bugden et al. 1982) concluded that excess stratification during winter, caused by high runoff during the previous months, may profoundly affect the rate of ice formation. Air surveys of ice cover in the Gulf, as well as the Northumberland Strait, are extensive but qualitative in nature and there is little information on ice thickness or biological production processes associated with moving pack ice.

In the absence of extensive time series data needed to predict future changes in ecosystem variables, we can look at records available from harvested species that may indicate long-term trends against which man-induced changes are compared. This correlation approach has been used to identify the coherence in patterns of changes in lobster landings (Dadswell 1979), for example, which imply that oceanographic factors influence recruitment over large areas inside and outside of the Strait.

Figure 1, taken from Dadswell (1979), shows generalized patterns of residual currents around the Maritime provinces derived from surface and seabed drifter studies. Hydrographic areas that create gyres (such as St. Georges Bay) are thought to lead to long-term stability in landings due to the creation of "recruitment cells" where larvae are trapped within a defined hydrographic region. Areas which experience fluctuations in landings tend to be those where populations are maintained by advective transport of larvae. Thus, Georges Bay has shown a relative stability in landings (expressed as a percentage of the mean values for 1947-57) in contrast to Chedabucto Bay, although both areas have shown a decline in landings since the Canso Causeway was built in 1956 (Fig. 2).

In contrast, lobster landings in fishing districts on each side of Northumberland Strait on the same percentage basis continuously declined between 1960 and 1975 (Fig. 3). The trends are similar for all districts in the middle regions of the Strait (Fig. 4). More recent data (1976 to 1986) provided by G. Harding (BIO) and plotted as absolute landings (tons) per km of shoreline shows that the trend has reversed in fishing districts along the Strait (Fig. 5). A smaller but similar trend towards increased landings is evident in data from St. Georges Bay (Antigonish Co.) (Fig. 6). Any future changes in lobster landings in these areas can be expected to be at least as large as these historic changes and effects through environmental modification must be assessed against this level of background variability.

There have been few quantitative observations of chemical or biological variables that can be correlated with these time series for lobster landings. Data for air and sea surface temperature, salinity and river runoff from 1940 to 1977 were summarized for various areas of the Gulf of St. Lawrence (Bugden et al. 1982) but no separate records for Northumberland Strait exist.

Correlation analyses were used to infer that runoff variability controls recruitment and to some extent adult lobster stock size, however, the oceanographic mechanisms remain unidentified. A data set does exist, however, for lobster larval production and distribution in Northumberland Strait over 15 consecutive years (1949-63) (Scarratt 1964, 1973). Harding et al. (1982) examined these data, which showed a standard deviation of 41% in production of stage I larvae over 15 years and found significant correlations between production of larval stages I, II, and IV and landings 4 and 8 years later. The observations show that high between-year variance in larval production is reflected in subsequent recruitment of harvested individuals. The causes for the between-year variation are unknown but they are not entirely attributable to changes in fishing effort. The magnitude of the variance indicates that it would be impossible to detect smaller changes in recruitment due to man-induced changes in the environment.

3.4 Research Recommendations

Positive correlations have been identified between annual stage I lobster larval production in Northumberland Strait over 15 years and lobster landings 4 years later (Harding et al. 1982). Thus, although causes of long-term trends in lobster landings in the region are unknown, annual surveys of larval production in the Northumberland Strait could be carried out for comparison with the historical data set derived from Scarratt's earlier studies. Predictions of landings 4 years ahead could be compared with observed landings to assess impacts of construction activities and a fixed-link structure. Productivity changes greater than the 40% already observed to occur through natural variability in lobster production could be attributed to environmental changes associated with the fixed link.

4. Physical Oceanography

4.0 Introduction

Assessing all the potential impacts of a fixed crossing link on the oceanographical regime of Northumberland Strait is close to an impossible task as it presupposes an almost perfect knowledge of the various space and time scales of different phenomena before and after construction. Such, obviously, is not the case. Discussion has been limited to first order effects, i.e. those which can be clearly identified and are amenable to analysis and, most importantly, to measurement. Based on the above criteria, there are four areas to look at: a) tidal dynamics and changes due to alterations in bottom topography and cross-sectional area, b) sea ice regime and the process of ice jamming, c) enhanced mixing zones due to bridge piers embedded in an alternating, stratified tidal flow, and d) sedimentary regime and the problems related to dredging and dumping.

4.1(A) Tidal Dynamics

The comprehensive tide (water level) and current observations of Farquharson (1970) were paramount in giving us a reasonable picture of the major semi-diurnal and diurnal tides within Northumberland Strait. Based on these measurements, the tide and currents in Northumberland Strait result from the interference of the semi-diurnal waves propagating into the Strait from the western and eastern entrances. The oscillation at the western end of the Strait is advanced by several hours from that at the eastern end. The narrows off Cape Tormentine form a partial barrier between the eastern and western halves of the Strait, the effect of which is that some of the oscillation from the east is reflected back, resulting in an increase in range in that part of the Strait (Figure 7). The rest of the oscillation (from the east) is propagated through the Narrows in opposition to that from the western entrance, creating a standing oscillation in the western part. This zone of strong currents and reduced amplitudes shown in Figure 7, is displaced over the seasons by some 20 nautical miles (southward during the winter months), (Godin, 1987) and makes the total tidal picture in this area very difficult to predict with any great accuracy. It also oscillates cyclical around these mean positions during the succession of neap and spring tides in the Gulf of St. Lawrence and, in addition, it may suffer additional short-lived displacements due to weather events.

The response of any embayment to forcing at its boundaries is intricately dependent on the natural frequencies of the embayment and the frequencies of forcing. Yuen (1973), using a one dimensional numerical model, calculated the lowest frequencies of gravity waves in Northumberland Strait. The fundamental period was calculated at 11.6 hrs., which is close to the period of the dominant semi-diurnal tide (12.4 hrs.). Results based on these analyses suggest that changes in the tidal regime, due to changes in the resonant characteristics of Northumberland Strait, may have measurable effects; probably increasing tidal elevations and currents, changing the residual currents due to tidal stress, and probably enlarging or changing the location of vertically mixed water (Figure 8 from Pingree and Griffiths, 1980). Other effects which could spin off from such an alteration, but which would be difficult to detect, would be an increase in coastal erosion and, perhaps increasing harbour dredging.

4.2(B) Sea Ice and Ice Jamming

The distribution of sea ice within Northumberland Strait is highly variable and the determination of the effects of a bridge structure on the ice regime difficult to quantify. As part of the initial environmental assessment, Bercha and Associates (1987, 1988) carried out an analysis of possible jamming effects due to the structure and concluded that, with appropriate arrangements of spans, the structure will have minimal effect on the length of the ice season.

Our evaluation, although in accord with the general conclusions of that report, i.e. increase in length of the ice season due to the bridge structure will be small, leads us to conclude that:

(i) if anything happens to impede the net transport of ice through the Strait, no matter how small the initial influence, then with constant conditions, the area upstream of the "crossing" will eventually become 100% covered, and the mean ice thickness will be increased. It is also quite possible that the area of 100% cover will become so large that the ice sheet essentially stabilizes.

- We are unable to evaluate the consequences of a 100% stationary cover west of the bridge for 2 months during the winter.

(ii) granting an increase of ice thickness and concentration, there is sufficient heat in the atmosphere and ocean to remove the ice cover within the variable time based on historical data.

4.3(C) Enhanced Mixing Zones due to Bridge Piers

Parts of Northumberland Strait are strongly stratified for at least 6 months of the year (Lauzier, 1957). Are these piers able to destratify the water structure leading perhaps to increased productivity?

Studies of transverse flows around obstructions in shallow estuaries show that a variety of effects can be observed. Transfer shear layers develop and, depending on the strength of the background flow, vortex streets can be formed. These vertices would have horizontal scales somewhat smaller than the underwater scales of the pier structure, but would also have a vertical scale commensurate with the total depth.

4.4(D) Sediment Transport

Although some concerns have been raised regarding the amount of sediment to be dredged/dumped during the operation of building a fixed link, the quantities involved (300,000 m , generic IEE, 1987) must be put in perspective to the total sediment transport (bed load, suspended load) occurring naturally as a result of coastal erosion, reworking of existing sediments and import due to rivers. The bottom sediments of Northumberland Strait have been described by Kranck (1971), and the distribution of sediments as a function of tidal current were presented by Kranck (1972). Figure 9, based on Kranck (1972) illustrates the areal distribution of sediments and shows their relationship to the average maximum tidal currents. It shows that muddy (<0.018 mm) sediments are being deposited as a blanket over older sediments in areas where tidal currents are less than 0.5 knots, while sand and gravels occur in areas where currents exceed this. According to Kranck (1972), net sediment transport due to tidal currents is from the central area near Cape Bald/Cape Egmont towards both western and eastern entrances. The effect of residual currents on net sediment transport is more difficult to evaluate as our knowledge of the residual currents within Northumberland Strait is very crude.

According to Lauzier (1965, 1967) and based on drift returns, there is a predominant surface flow from New Brunswick to P.E.I. along most of the N.B. shoreline, with a compensating flow along the bottom from P.E.I. to N.B. (Fig. 10). This type of flow apparently is able to concentrate sand sized sediments near the P.E.I. shore. The SPM values (Kranck, pers. comm., 1987) are low, depend on the state of the tide, and are generally below 10 mg/1.

The volume of material fed into the coastal zone from weathering and surface erosion is small due to the limited size and relief of the various drainage basins. However, fluvial erosion of the unresistant sandstones and shales is a source of sand-sized sediments (a small amount due to low discharges) which contribute to the littoral sand transport. Because the tidal range is small (<2 m), concentration of wave energy is confined to a narrow vertical band, leading to rapid erosion of unresistant rock exposures (Owens, 1975, Reinson, 1977). This process contributes approximately 100,000 m to 200,000 m^3 per annum into the littoral zone, primarily in the fall season, when northeasterly winds favor wave generation of sufficient magnitude (McCann, et al., 1977).

Development of sea ice, which usually begins by mid December in the more confined areas, limits the action of wave processes by preventing wave generation for up to 5 months per year. The development of an ice foot or stranded ice floes on the beach can absorb wave energy or prevent waves from sorting and transporting littoral sediments.

Meteorological effects, either local or due to the propagation of storm surges, are important as they can cause sea level changes greater than those generated by tides and allowing waves to be effective above the normal limit of wave action (Owens, 1975).

It seems then that Northumberland Strait is a fairly active sedimentary regime, characterized by high variability due to strong and variable winds and, in places, strong tidal currents. Sediment effects due to dredging would be quite local; however, effects which alter the morphology of the littoral zone (say inside the 5 m line), such as the construction of shore fast structures, should be discouraged. Ice seems to protect the beaches from the attack of waves for a significant fraction of the year. It does seem as an important agent of coastal erosion along the Northumberland Strait.

5. Invertebrates

5.0 Introduction

Herewith is a brief review of the issues concerning the proposed Northumberland Strait Crossing Project as it impacts on the invertebrate stocks in the area. Due to the nature of the subcommittee meeting, there is some redundancy of concerns with other presentations. As mentioned previously, quantification of the perceived issues is beyond the reach of the meeting.

5.1 Background

- The main species of concern are as follows:

Primary:	Homarus americanus	lobster
	Placopecten magellanicus	scallop
Secondary:	Mercenaria mercenaria	quahaugs
	(Recreational fishery)	
	Mya arenaria	soft shell clams
	Spisula solidissima	bar clams
	Mytilus edulus	blue mussel
	Crassostrea virginica	oyster
Tertiary:	Food Web Benthos & Plankton	
	Marine Plants and Phytoplankton	

- There is a dearth of information concerning:
  a) Population dynamics and production of invertebrate stocks, and
  b) Overall primary and secondary productivity of area
     i.e., food web dynamics, turnover of nutrients, algal production, zooplankton production, secondary production of pelagic and benthic

species, and detrital processing. See section 3.2 for details and references.

- The area is considered to be physically dynamic in terms of water movement via tides and currents, but little is known about the biological dynamics.

5.2 Issues

1) Is it possible to obtain a realistic baseline data set with which to differentiate between the natural variability of the area and the impact of the project? To this end, what spatial boundaries are considered significant (1 km, 10 km, 20 km, entire Strait considered as a conduit) as well as the short- and long-range temporal boundaries?

2) Would the fixed link affect the larval population dynamics of invertebrate stocks in a positive, negative or neutral fashion? In particular, the Tormentine scallop and lobster fisheries?

   The effects which could be observed include:

   - Significant changes in distribution. What larval retention mechanisms are operational and will they be altered during and after construction?

   - Survival/mortality eventually influencing recruitment processes. (Effects of silt, ice regime, etc. Would effects be significantly different from natural large storm event?

   - Changes in benthic substrate (silt, etc.) that may disrupt natural settling/attachment processes for scallops

3) Would the dynamics and productivity of food webs be perturbed to the point of altering the population dynamics of invertebrate stocks?

4) Behavioral modifications due to sublethal toxicological effects, such as noise, light, silt which may alter:

   - adult lobster migrations
   - trapability of lobsters
   - fishing mortality
   - mating behavior

5) Ice climate and regime changes, whether it manifests itself as time of formation, amount of cover, duration and disappearance, may impact on the following:

   - habitat destruction due to scouring
   - dynamics and productivity of food webs
   - degree days of physiological growing period, in particular, lobsters, eventually altering moulting period, which may ultimiately modify the fishing season and trapability
   - basic life cycle modifications, recruitment processes

6) Does the "greenhouse effect" come into consideration within the context of the project, with the predicted increase in ocean water levels and water temperature. What is the temporal scale to consider? Would the NSCP modify the predictions? If so, in what direction?

7) The creation of artificial reef habitat from brdige piers may or may not result in a real increase in habitat for lobster. Are the lobster habitat limited in the vicinity? In this regard, the results of Scarratt's work in Egmont Bay may be applicable but perhaps inconclusive. Productivity of marine plants - periphyton, etc., would probably increase and alter the food web dynamics and general productivity of the area.

8) What is the resistance of the Tormentine scallop bed to disturbance? Preliminary unpublished data suggest it may have lower growth rates than other areas. Does this imply lower production and low resiliency to environmental perturbations? What are the larval retention mechanisms operational which maintain the population structure? Would an increased mixing area caused by the pier placement alter the bed size and production?

5.3 Summary

These are some of the more salient issues concerning the invertebrate stocks. However, because of the close connection between biological/physical oceanography and the natural population dynamics of the species of concern, it is difficult to address these issues independently from a purely biological point of view. The problems of "predictions" based upon predictions are again exemplified by the above issues.

6.0 Finfish

6.1 Herring

6.1.1 Introduction

One of the goals of DFO policy for the management of fish habitat is to maintain the current productive capacity of fish habitats. The principle of "no net loss" established by the department is fundamental to the habitat conservation goal. This principle, no doubt, applies to the proposed N.B./P.E.I. crossing.

6.1.2 Background Information

The fisheries of Atlantic herring have been the mainstay of many fishermen in the Gulf of St. Lawrence since the time of settlement.

As in the case of lobster, issues of herring fisheries are politically sensitive. Inshore herring fishermen have been the most outspoken group. One example showing their determination is the continued difficult experience following the construction of the Canso Causeway in 1956. Over the past 35 years they repeatedly raised the issue, asking the department for action. The publicity surrounding the impact of the Canso Causeway on fisheries in the early 1960's probably influenced the decision of halting the N.B./P.E.I. bridge causeway construction which started in 1965. The present bridge alternative is similar in many respects to the 1960's proposal except that the earlier proposal was a bridge/causeway combination. The present selected alternative replaces the causeway portions at each abutment with elevated approaches.

6.1.3 Catch Statistics

Most herring catch in the Gulf is presently taken by gillnets (mostly fixed nets for spring fishery, and drift nets for fall fishery). Herring catch and effort in the vicinity of the proposed bridge site (Fish. Dist. 78 and 80) is relatively small (Table 1; see Fig. 11 for Fishery Districts). Almost all catch in the two districts is taken in May, June, and July (Table -2). Average catch for the period 1973-85 is only 10.9% of the total gillnet catch of 4T NAFO Div. (Table 1).

However, there is an increasing trend in the fishing activity in this area in the past 3-4 years, particularly after the development of the lucrative Japanese market for herring roe. (Figure 12).

6.1.4 Herring Stock Interrelations

The stock structure of Atlantic herring in the Gulf of St. Lawrence is rather complex. A number of studies have provided indication of interrelations to various degrees between herring stocks within 4T Div. and between 4T and other areas, particularly 4Vn and 3P (Winters and Beckett, 1978; Stobo person. comm. Parsons, 1972; Messieh and Longmuir, 1978; Iles and Sinclair, 1982; Sinclair and Tremblay, 1984; Messieh and Tibbo, 1971; Ware and Henriksen, 1978; Lambert, 1987; Kornfield et al. 1982).

The composite picture is that several stocks (management units) collectively belong to two spawning populations; spring and fall. The stocks inhabit the southern Gulf of St. Lawrence. More recently, a summer spawning component believed to be separate from the two spawning populations was identified. Available information indicates that each stock has a separate spawning ground.

Migration of herring stocks is extensive at some stages of their life history. Feeding and overwintering areas support a mixture of stocks which migrate far from their native spawning grounds. Circumstantial evidence indicates that the movement of adults is more in open waters than in shallower waters and bays. In contrast, juvenile herring (post-larval and pre-recruits) movement tends to be in shallower waters. In occasional research cruises, juvenile herring were located and collected from Northumberland Strait on both sides of the proposed bridge site (Fig. 13).

In considering the possible effects of the proposed bridge, it is reasonable to look at the Northumberland Strait as: (1) a habitat of some local herring stocks of relatively small importance, and (2) as a migratory passage for other herring stocks moving from/to spawning, feeding, overwintering, and nursery areas. The question of the bridge interference with this migration is open to discussion. There are no studies elsewhere to indicate whether or not a bridge of this nature would deter fish migration.

6.1.5 Herring Spawning Beds

There are several spawning stocks within at least two spawning populations in the Gulf of St. Lawrence. Surveys of the spawning beds by SCUBA diving were carried out in the Gulf since 1980 (Messieh et al. 1985). The relative importance of the spawning components and the intensity of the spawning beds have changed over the years (Messieh 1987a). Historically, the spring-spawning beds around Magdalen Islands and the spring-spawning and fall-spawning beds of Chaleur Bay were the major contributors to herring production in the Gulf. The Magdalen Is. spawning grounds have collapsed since the mid 1970's. At present, the spring-spawning beds in Escuminac area are the largest followed by those in Caraquet, North Pt., P.E.I. and other smaller beds scattered along the Northumberland Strait (Figure 14). The fall-spawning beds in Fisherman's Bank are now the largest in the Gulf followed by those in Caraquet/Shippegan, and others of a lesser magnitude in Northumberland Strait.

In the past 2 years, a minor spawning bed was identified near Murray Corner, about 10 km west of Journaine Island (approach to the proposed bridge at New Brunswick side). The bed is in shallow area (about 20 ft). The substrate consisted of bedrock and rubble covered with vegetation.

Within the Gulf herring stock complex, spawning starts in April and extends until late September (Figure 15). The multiplicity of spawning beds has its ecological significance for the survival of herring. It reflects both the plasticity of the herring species and the abrupt environmental changes characteristic of the Magdalen Shallows (Messieh 1987a, and b).

Taking into consideration the small magnitude of the spawning beds in the vicinity of the bridge construction, a possible loss of any spawning beds would have a little effect on the fishery. There was some discussion on possible enhancement of herring spawning by using the underwater caissons of the bridge supports as artificial substrate for herring spawn. This idea is a novel concept and there is no guarantee that herring spawn on artificial substrate. Depth of spawning beds is critical, and because the tops of underwater caissons are not of the same depth, this could create a problem. Moreover, herring are known for their homing behavior i.e. adults returning to their native spawning beds. There is no information on how long it takes - if at all possible - for a herring stock to be established on an artificial substrate.

Little is known about the exact locations of the nursery grounds or the migratory route of juvenile to adult stages. From scattered data collected over the years from research cruises, there is indication that the nursery areas are near shore, in estuaries and embayments in areas including Northumberland Strait. In recent inshore cruises (D. Clay, person. comm.) juvenile herring were caught in several places in Northumberland Strait including areas near Pictou, N.S. and Woods Island, P.E.I.

6.1.6 Effect of Temperature on The Timing of Spawning

Annual variability in mean arrival time of herring on the spawning grounds seems to be primarily a function of temperature (Messieh 1978, 1987a; Lambert, 1987). Warm spring results in earlier spawn, and cold spring in a delayed spawn (Figure 16).

On the assumption that temperature during spring would change due to the bridge structure and change in ice dynamics, the timing of herring arrival on the spawning grounds could be affected. In such cases, spawning would be a few days earlier if temperature increases or a few days late if temperature decreases. This situation, however, should not be of much concern. During herring spawning, sudden changes in subsurface and near bottom temperatures over short periods of time were often encountered (Messieh and Rosenthal, 1986, Figure 17). Moreover, expected variations in temperature due to ice formation/breakage would be of a lesser degree than the natural inter-annual variations of temperature during spawning (Table 3).

6.1.7 Effect of Dredging on Herring Spawning and Feeding

Some data on the impact of dredge spoils on herring fisheries were collected during a study on the Miramichi channelization project carried out in 1979-81 (Messieh et al. 1981). The influence of suspended sediments on herring eggs was investigated. Eggs were artificially fertilized and two types of experiments were performed. In one experiment, glass slides with attached eggs were covered with layers of fine sediments (median particle size 4.0-4.5u) to varying depths. In the second experiment, eggs were suspended in water containing various concentrations of suspended sediments.

Results showed that settled sediments of the size used in these experiments are lethal to herring eggs if the eggs are blanketed. To survive, at least a portion of the egg must project above the sediment layer. Results also showed that sediment deposited onto developing eggs causes increased egg mortality due to smothering effect preventing circulation of clean oxygenated water around the eggs. Hatching success does not seem to be influenced by concentrations of suspended solids, but the mean size of hatched larvae was inversely dependent on the suspended sediment concentration. A decrease in larval hatching size would decrease their feeding and growth rate and their chance for survival. Experiments were performed on the effect of suspended sediments on herring larvae and juveniles (Messieh et al. 1981). Results showed that suspended solid concentrations of a few parts per million affect deleteriously the feeding success of herring larvae, and this could result in stunted growth and subsequent increased mortalities. Avoidance behavior experiments showed that juveniles avoid sediments at concentrations in the parts per million range. The results suggest that juvenile herring, and possibly adult fish, may avoid high concentrations in the field. Thus, individual fixed gillnets subject to high suspended solids may face reduced catches because herring avoid such areas.

The problem of suspended sediments would be expected during the construction of bridge supports and dredging. Turbidity would increase on both sides of the bridge, but more southward dispersion would be expected due to the direction of residual currents and prevailing winds.

6.1.8 Summary and Conclusion

The Gulf of St. Lawrence comprises a complex of herring stocks which are all interrelated. On the spawning grounds, stocks are presumably discrete, but a mixing among stocks occurs during feeding, nursing, and overwintering. Spawning beds in the vicinity of the proposed bridge are minor and gillnet intensity on these beds is relatively small. However, in the past 3 years there is an increasing trend for herring fishing in this area due to changing market demands.

In evaluating possible effects of the bridge on herring fishery, the Northumberland Strait area should be looked at as a habitat not only for spawning beds of local stocks, but also as a migratory passage for other major herring stocks. The ice formation/breakage by the bridge during winter and spring could change the local temperatures and thus may change the timing of spawning. However, the expected changes in temperature would be of a lesser magnitude than those resulting from storms and wind-driven currents during spawning or from the interannual variations in spring temperatures.

Increased suspended solids during dredging and construction activities would be expected. Turbidity would particularly affect larval and juvenile herring. However, it is conceivable that such effect would be temporary, and would cease shortly after the construction is completed. With respect to the effect of the bridge passways on the migration of adult herring, there are no data to indicate whether a bridge of this nature would or would not deter herring migration. As a regulatory measure, an exclusive non-fishing zone on both sides of the bridge should be established.

Monitoring the fishery prior, during and post construction is important for the evaluation of the impact. Methods of evaluating the proper parameters should be developed, taking into consideration the large natural interannual variability of recruitment which is a biological characteristic of herring populations.

6.2 White Hake

The white hake fishery based at Cape Tormentine, N.B., exploits a spawning stock in Baie Verte, N.S. In the mid 1970's the fishery landed 200-400 t in the 4-6 week period (June-July) between the scallop and lobster seasons. The current fishery is landing only ±5 t per year, this decrease is due to overfishing. A similar fishery exists in River John, N.S., in July-August and later (August) in Lismore/Arisaig, N.S. Whether these are the same group of fish migrating or a continuous west-east substock that is exploited as various groups of fishermen have 'available' time between more financially lucrative invertebrate seasons is unknown.

6.3 Gaspereau

6.3.1 Introduction

Many rivers in the Gulf Region support populations of anadromous gaspereau which contribute to substantial commercial fisheries in May and June. Those fisheries may harvest either alewife (*Alosa pseudoharengus*) or blueback herring (*Alosa aestivalis*) although in most cases the catch is mixed. Annual harvest from Gulf rivers is in the range of 3000 to 5000 tonnes.

6.3.2 Fisheries

Some gaspereau fishing is conducted along the coast, using both trap nets and gillnets. Catch probably consists of mixed gaspereau stocks from various rivers. Most of this coastal catch is used as bait for the lobster fishery. The most intensive gaspereau fisheries are located within the spawning rivers and therefore harvest discrete stocks. Important discrete stock fisheries occur on the Miramichi River, the Margaree River and in Pictou Harbour.

6.3.2.1 Miramichi River

The Miramichi River fishery is currently restricted to 36 traps nets which are permitted to fish only from mid-May to mid-June. Much of the catch is used as lobster bait, but some is salted and exported for human consumption. As much as 1000 tonnes per year are sold as "over-the-side sales" to the Soviets.

In response to reduced catches compared with historic levels, (Table 4) the Department of Fisheries and Oceans initiated studies of the Miramichi gaspereau fishery in the early 1980's. Annual stock assessments (Alexander and Vromans 1983, 1984, 1985a, 1986a, 1987a, 1988a) suggest that both alewife and blueback herring are over-exploited. Results also show that alewives typically arrive in the fishing area two weeks earlier than bluebacks, and bluebacks continue to arrive after fishing ceases. In some years such as 1985, late arrival of fish may influence the relative exploitation rates of the two species and very late arrival could severely reduce catch. Run-timing was also shown to be influenced by the age of fish with the older fish arriving early.

It is worth noting that prior to the initiation of a major dredging project by Public Works Canada on the Miramichi River in 1981, an environmental screening had concluded that the potential conflict rating between dredging and gaspereau was low - this proved not to be correct. Compensation, in the order of 1/4 million dollars, was paid to fishermen for both direct and indirect impacts. Indirect impacts included additional work required to clean silted nets and reductions in catch. In calculating the value of reduced catch, the Monitoring Committee used DFO stock assessment data even though the data collection had not been intended to serve that purpose. The Monitoring Committee recommended that advance provisions should be made for collection of data on potentially vulnerable species and that monitoring and compensation protocols should be designed and included as an intergral part of any development program.

6.3.2.2 Margaree River

Gaspereau fishing on the Margaree River, Cape Breton, Nova Scotia utilizes a unique form of mechanical tip trap operated from the river bank. Although historical peaks in catch are not as great on the Margaree compared to the Miramichi, the mean is similar (Table 4). Value is higher, however, as nearly all fish from the Margaree are salted and exported (Haiti) for human consumption. The success of this fishery is considered critical to the economy of the Margaree River Valley.

The Margaree River fishery was also been assessed by DFO since the 1980's (Alexander 1984; Alexander and Vromans 1985b, 1986b, 1987b, 1988b) and results again show that the stock has been over-exploited. In contrast to the Miramchi, this stock was shown to be about 99% dependent on alewife only. The fishery is therefore less resilient than on the Miramichi. It is interesting to note that many gaspereau fishermen on the Margaree believe that construction of the Canso causeway resulted in a visible decline in runs to the river.

6.3.2.3 Pictou

In the 1980's, a new gaspereau fishery developed using trap nets set in Pictou harbour. This fishery is not as well documented as the Miramichi or the Margaree, but is similar in annual landings. The fishery is known to harvest mixed stocks of alewife and blueback herring and has been the subject of increased study by the Nova Scotia Department of Fisheries in recent years (R. Crawford, pers. comm.). There is speculation that opening of the West River causeway in 1984 could have resulted in a decline in those gaspereau populations. New environmental perturbation could confuse these studies.

6.3.2.4 Others

Many smaller gaspereau fisheries exist on rivers such as the Kouchibouguac River, Wallace River, River Phillip, and others. In some cases, these too provide a major source of income to individual fishermen.

6.3.3 Potential for Impact

The extent to which gaspereau fisheries will be impacted, if at all, by the Northumberland Strait Crossing project is largely unknown. Some coastal traps could be affected directly or indirectly by ship activities and dredging, as on the Miramichi. Advance data collections should be planned to assess potential for impacts.

Recoveries of gaspereau tagged in the Margaree River in 1987 and 1988 (Alexander, unpublished) suggest that many adult fish migrate through the Strait. These adult fish are not thought likely to be impacted directly by construction of a fixed link, but the possibility of indirect effects is greater. If ice-out is delayed in the spring, there could be an effect on the time of the spawning migration which could then influence the fisheries.

There is also some potential for both direct and indirect impacts of the fixed link on juvenile gaspereau. Underyearling gaspereau immigrate from rivers largely in September and October, although some may be earlier. Their rearing areas and behaviour in the marine environment have not been studies. It is assumed, however, that gaspereau at that stage of development are highly susceptible to disturbance. Disturbance could be caused by such activities as regular ferry operation. Further research is necessary and effects monitoring for gaspereau should be considered. Continuation of current DFO gaspereau stock assessments will be useful in this regard, but monitoring should not be limited to those assessments.

7.0 Summary

The overview presentation provided a background on the Northumberland Crossing project, its historical perspective, and ways in which the current environmental review process differed from the usual process. There were three particular concerns highlighted.

1) Background studies were carried out with little coordination and little opportunity for DFO to influence terms of reference.

2) The Risk Scoping Matrix approach used in the Generic Initial Environmental Evaluation was considered subjective, methodologically flawed, and unverified, and was employed despite objections from Science Branch staff.

3) The key analysis of ice dynamics was based on a questionable model, excluded consideration of significant variables and interactions, and relied on weak data bases. Nonetheless, model results were used generally without qualification by consultants preparing reports on other aspects of the potential impacts of the project.

The environmental evaluations considered neither intra-project cumulative impacts nor potential positive environmental effects. These were considered serious deficiencies. It was also stressed that a tunnel, rather than a bridge, would be nearly environmentally neutral, at least for DFO's concerns, and should be the department's very strongly preferred option. The actual process also had compromised the Science Branch's ability to ensure high quality evaluation of potential impacts of the project, through inadequate input to terms of reference, inadequate influence on consultant's approaches to their tasks, and unrealistic deadlines for reviews.

The Ecosystems Dynamics review focused on two key issues:

1) Serious data gaps in our knowledge of productivity, phytoplankton and zoo-plankton dynamics and ecology, and even life history dynamics of commercial species in the Northumberland Strait.

2) The large, but generally unquantified variation in the ecosystem components, against which impacts of a structure will be impossible to measure.

Two biological features were highlighted in the talk and subsequent discussion:

1) The established correlation between lobster larvae and landings 4 years later is the only biological feature quantified adequately to be possibly used as a tool for measuring environmental change. To use the relationship, however, requires that urgent priority be given to restarting the larval survey, and to testing current predictive power of the relationship on an unimpacted area.

2) Primary production appeared to be highest between ice floes rather than later in the spring. This has potential but unknown implications for ecosystem consequences of effects of a bridge on ice dynamics. This feature was not considered in any of the environmental studies done for PWC.

It was also noted that the lack of long-term, well focused research on effects of the physical environment on the marine ecosystem makes the Branch unable to provide meaningful predictions of impacts, and unable to provide defensible advice on whether an observed change in the system is likely to be the consequence of any specific undertaking.

The Physical Oceanography review echoed the emphasis on natural variability and its implications for the ability to predict impacts and attribute subsequent changes to impacts of projects. Four aspects of the physical environment were highlighted as possibly affected by a bridge: tidal dynamics, sea ice, water movements and mixing, and sediment transport. In each area, there are important first-order analyses of possible bridge impacts which have not been done. As these analyses are based on physical processes, they are possible with current tools and do not require additional data collection. Particular importance was given to the need for analyses of residual currents, mean flows, and potential resonances between tidal periods and pier spacing across the Strait. None of the features have been considered in consultant studies but may have important implications for the impacts of a bridge; for example, by introducing nonlinearities to interactions thus far treated as simply linear. The ice analysis in the Bercha report was also noted as lacking qualified peer review; and it was felt that expert opinion should be sought from appropriate experts on ice structure and dynamics, possibly at the Ice Research facility of NRC, in St. John's.

The presentation on invertebrates focused on the many unknowns and unanswerables which preclude prediction of impacts on invertebrates. The concerns were generally the same as covered under Ecosystem Dynamics, with discussion also bringing out doubts about suggestions the project would actually result in creation of new or improved habitat. The possibility that the greenhouse effect would further complicate attributing changes to project impacts was also felt reasonable.

In the consideration of finfish, it was felt that herring were most vulnerable to impact of bridge construction. Although the number of separate spawning beds and complex stock/substock structure of herring give the stock as a whole resiliency to local impacts, a spawning bed eradicated during construction might not be recolonized for decades. The paucity of knowledge of distribution and movement patterns of larval and juvenile herring also leaves the branch unable to evaluate the potential for disruption of the life history cycle by bridge construction, or effects of the bridge on the physical environment. Because of the importance of the infrequent very strong year-class to support commercial herring fisheries, the opinion in the GIEE that loss of a single year-class of herring would be a small impact is unacceptable. Evaluating impacts of a bridge on gaspereau is essentially impossible, because of the lack of knowledge of distribution and movements of juvenile gaspereau once they leave estuaries. It is unlikely that a bridge will impact on the locally spawning hake stock severely, and the very high fishing mortality would make it nearly impossible to detect an impact were one to occur. No other fish stocks are thought to frequent the area in numbers large enough for concern.

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Table 1. Fishing effort and catch-per-unit-effort of inshore spring herring fishery in the southern Gulf, 1973-83.

District	65,66,67 Caraquet		73,75 Escuminac		78,80 Shediac		71 Pictou		82,92 North PEI		Total	
Year	C/E	E	C/E	E	C/E	E	C/E	E	C/E	E	C/E	E
1973	3.25	669	2.01	1471	0.85	354	-	-	0.95	184	2.09	2678
1974	2.15	492	1.58	1436	0.45	764	-	-	0.36	427	1.23	3119
1975	0.82	238	1.60	1035	0.71	189	-	-	0.99	345	1.29	1807
1976	1.52	356	1.83	1218	0.24	453	-	-	0.49	183	1.34	2210
1977	3.91	67	2.28	546	0.92	140	-	-	0.54	155	1.89	908
1978	4.33	121	2.67	1204	1.22	321	-	-	0.96	377	2.22	2023
1979	1.90	223	1.68	1657	0.59	415	-	-	1.36	275	1.49	2570
1980	2.56	217	1.17	1174	0.63	796	-	-	0.92	236	1.09	2423
1981	0.75	381	0.87	1089	1.19	418	6.81	12	0.82	578	0.92	2478
1982	1.49	509	2.33	687	1.28	612	9.46	6	1.61	455	1.73	2269
1983	1.51	704	2.60	1308	0.96	910	0.63	74	1.76	661	1.79	3657
1984	1.33	217	2.92	657	0.62	132	-	-	0.44	256	1.90	2404
1985	1.20	505	2.95	815	1.52	614	0.92	2	0.76	390	1.81	2326

E = Number of successful fishing trips; C/E = catch (mt) per successful trip.

Table 2. Fishing effort and catch-per-unit-effort of inshore herring fishery in Shediac (Fish. Dist. 78, 80), 1973-83.

Year	April		May		June		July		August		September		October		November		All Year	
	C/E	E	C/E	E	C/E	E	C/E	E	C/E	E	C/E	E	C/E	E	C/E	E	C/E	E
1973	-	-	1.55	2	0.85	352	0.98	237	-	-	-	-	-	-	-	-	1.09	532
1974	0.40	1	0.41	582	0.69	182	0.26	214	-	-	-	-	-	-	-	-	0.49	906
1975	-	-	0.83	111	0.54	78	0.22	49	0.09	-	-	-	-	-	-	-	0.78	187
1976	0.96	55	0.23	443	0.85	10	0.33	38	-	-	-	-	-	-	-	-	0.53	489
1977	-	-	1.12	101	0.41	39	0.20	14	-	-	-	-	2.46	50	-	-	1.28	204
1978	0.67	9	1.12	307	3.40	14	1.19	52	-	-	-	-	-	-	-	-	1.18	382
1979	1.0	35	0.59	401	0.53	14	2.55	18	-	-	0.06	1	-	-	-	-	0.70	469
1980	0.70	24	0.64	691	0.57	105	0.65	37	-	-	-	-	-	-	-	-	0.63	857
1981	0.84	18	1.17	330	1.25	88	1.02	64	-	-	-	-	-	-	-	-	1.15	500
1982	1.24	43	1.42	314	1.14	298	1.25	27	-	-	-	-	-	-	-	-	1.28	682
1983	-	-	0.99	628	0.89	282	1.23	31	-	-	-	-	-	-	-	-	0.97	941

E = Number of successful fishing trips; C/E = catch (mt) per successful trip.

Table C.3. Meterological data from the Madgalen Islands, southern Gulf of St. Lawrence, showing prevailing wind direction, speed, and number of days with wind speed >63 km/h and air temperature during April for the period 1958-80.

Year	Prevailing wind direction	Mean wind speed (km/h)	Days with speed 63 km/h	Mean temperature (°C)
1949	N	30.4	-	0.4
1950	SE	33.3	-	0.4
1951	NE	35.7	-	4.1
1952	M	M	-	1.2
1953	M	M	-	3.2
1954	M	M	-	-0.6
1955	M	M	-	0.3
1956	M	M	-	0.6
1957	M	M	-	-
1958	S	38.3	13	2.6
1959	M	M	M	1.0
1960	M	M	M	0.3
1961	M	M	M	-0.1
1962	NW	31.2	8	1.0
1963	N	35.8	9	-0.6
1964	M	M	M	-0.2
1965	M	M	M	-0.6
1966	M	M	M	0.7
1967	N	28.4	4	-2.0
1968[a]	WNW	32.5	6	1.8
1969	WNW	28.7	3	0.1
1970	N	31.0	7	0.2
1971	S	29.8	7	1.2
1972	NW	26.8	2	-1.8
1973	E	27.0	1	0.0
1974	WNW	28.7	3	0.1
1975	NW	29.2	7	-0.7
1976	SE	27.6	3	0.7
1977	NW	34.0	7	-0.3
1978	NNW	30.9	4	-0.9
1979	S	26.2	2	1.1
1980	E	30.1	9	2.0

M = Missing data.

[a]In 1969 onward, wind data observations changed to the 16 point system.

Table 4. Annual catch (tonnes) of alewife (Alosa pseudoharengus) and blueback herring (Alosa aestivalis) on the Miramichi River, New Brunswick and the Margaree River, Nova Scotia.

Year	Catch (tonnes) Miramichi River	Margaree River
1950	4,952	713
1951	8,014	755
1952	11,381	964
1953	8,026	638
1954	4,649	1,275
1955	3,413	1,163
1956	3,009	859
1957	884	58
1958	816	395
1959	1,596	496
1960	716	531
1961	161	423
1962	733	558
1963	543	551
1964	119	640
1965	425	875
1966	746	320
1967	532	185
1968	436	188
1969	175	251
1970	874	408
1971	469	620
1972	468	965
1973	967	1,113
1974	271	1,681
1975	141	1,238
1976	406	497
1977	2,240	1,202
1978	1,434	1,713
1979	3,343	1,776
1980	3,767	1,069
1981	1,410	1,369
1982	1,278	1,445
1983	1,088	580
1984	665	883
1985	1,857	1,223
1986	1,154	545
1987	2,145	1,259

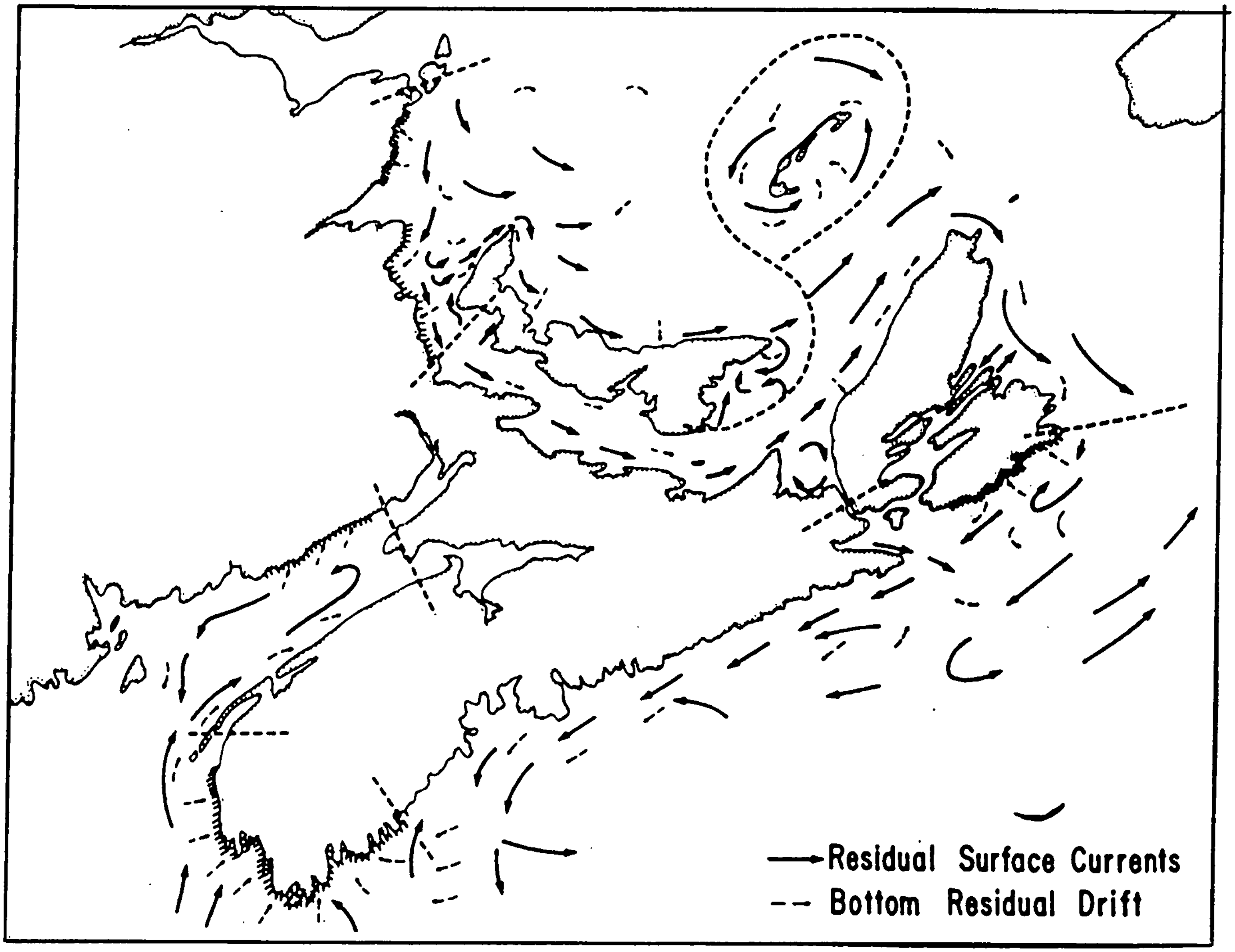

Figure 1. Surface and bottom residual current around the Maritimes during summer and fall as determined from drift bottles (from Dadswell 1979).

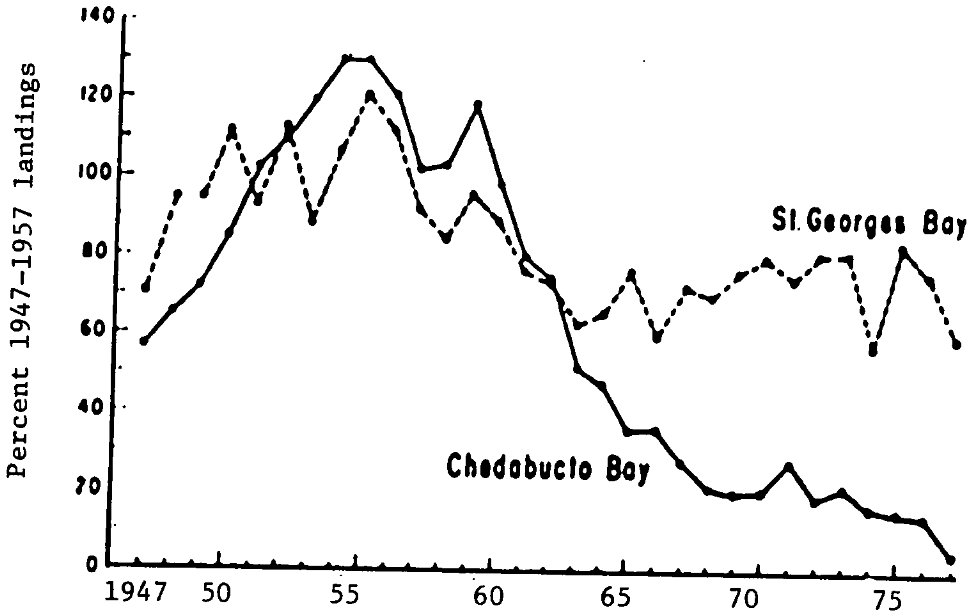

Figure 2. Lobster landings in districts 13 and 3 (St. Georges Bay) and districts 8, 9, 14 and 15 (Chedabucto Bay) between 1947 and 1977 expressed as a percent of the 1947-57 mean landing (from Dadswell 1979).

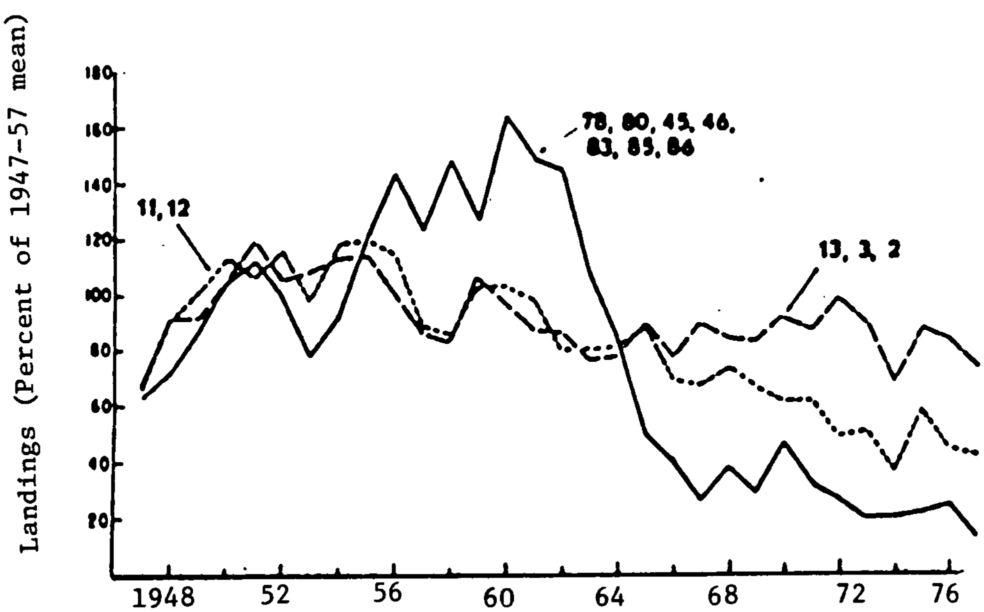

Figure 3. Lobster landings in districts along the Northumberland Strait expressed as percent of mean 1947-57 landing (from Dadswell 1979).

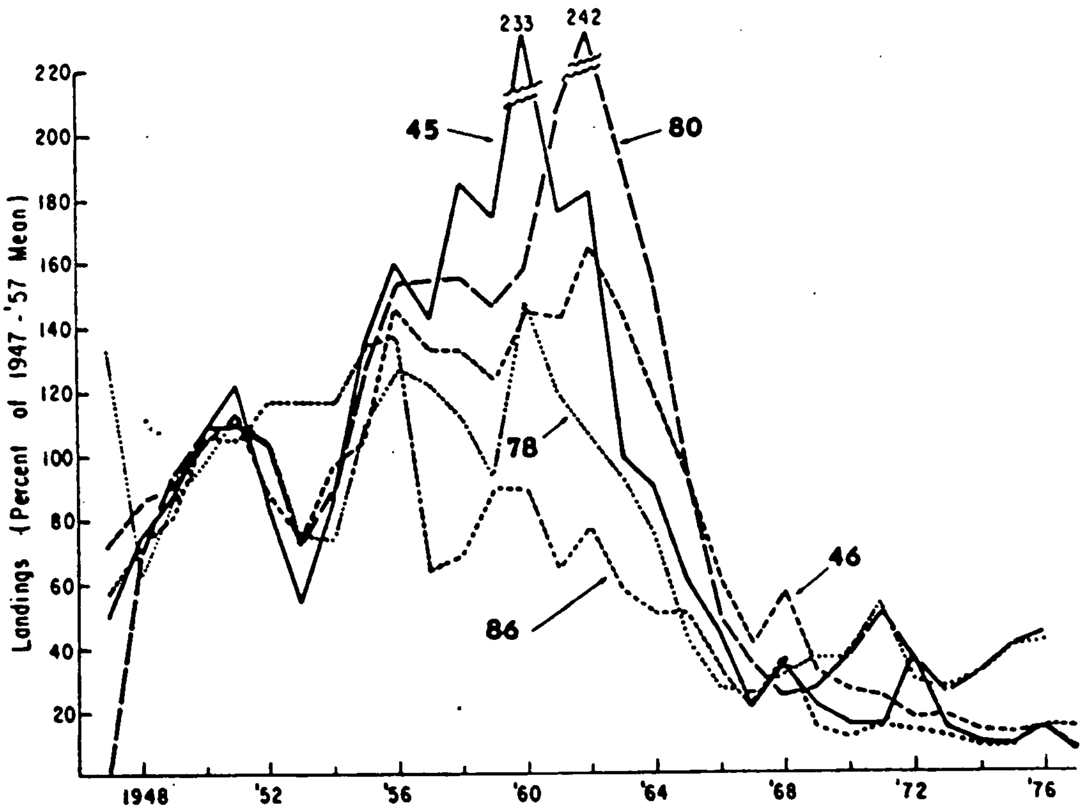

Figure 4. Lobster landings in districts in the middle of Northumberland Strait between 1947 and 1977 as a percent of the 1947-57 mean landing (from Dadswell 1979).

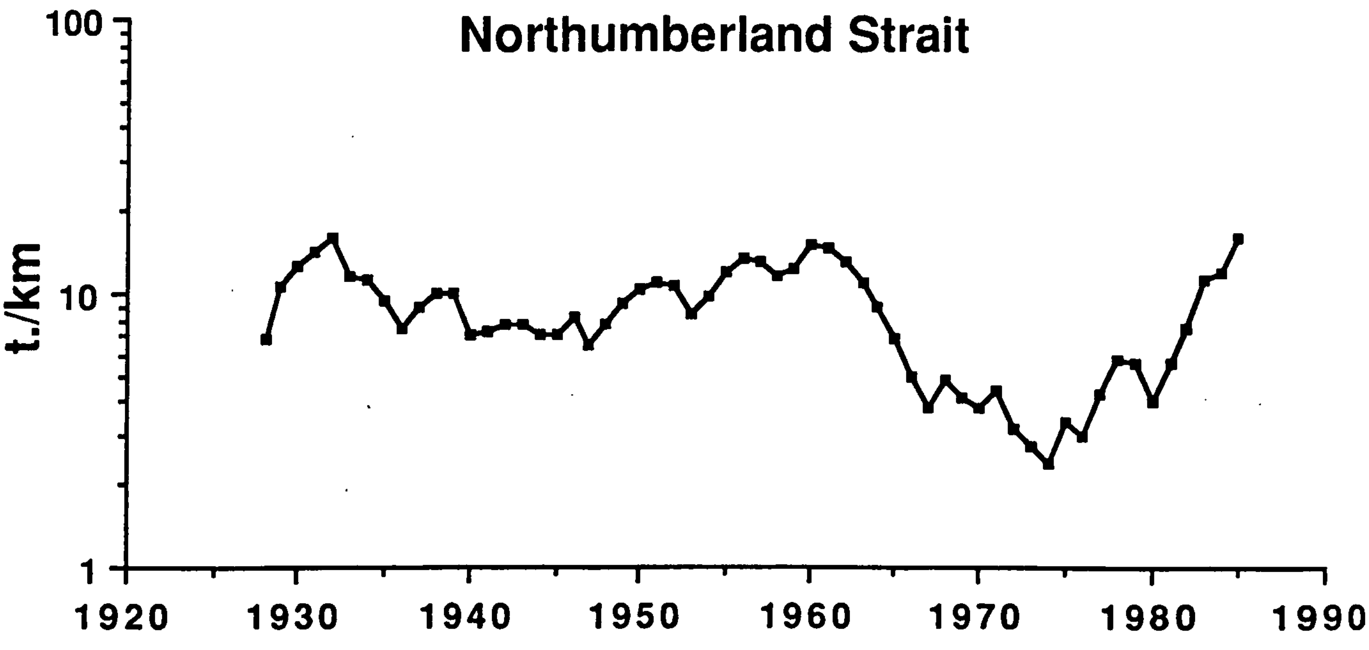

Figure 5. Lobster landings as tons/km of shoreline for districts along Northumberland Strait from 1928 to 1985. Data summarized by G. Harding (unpublished).

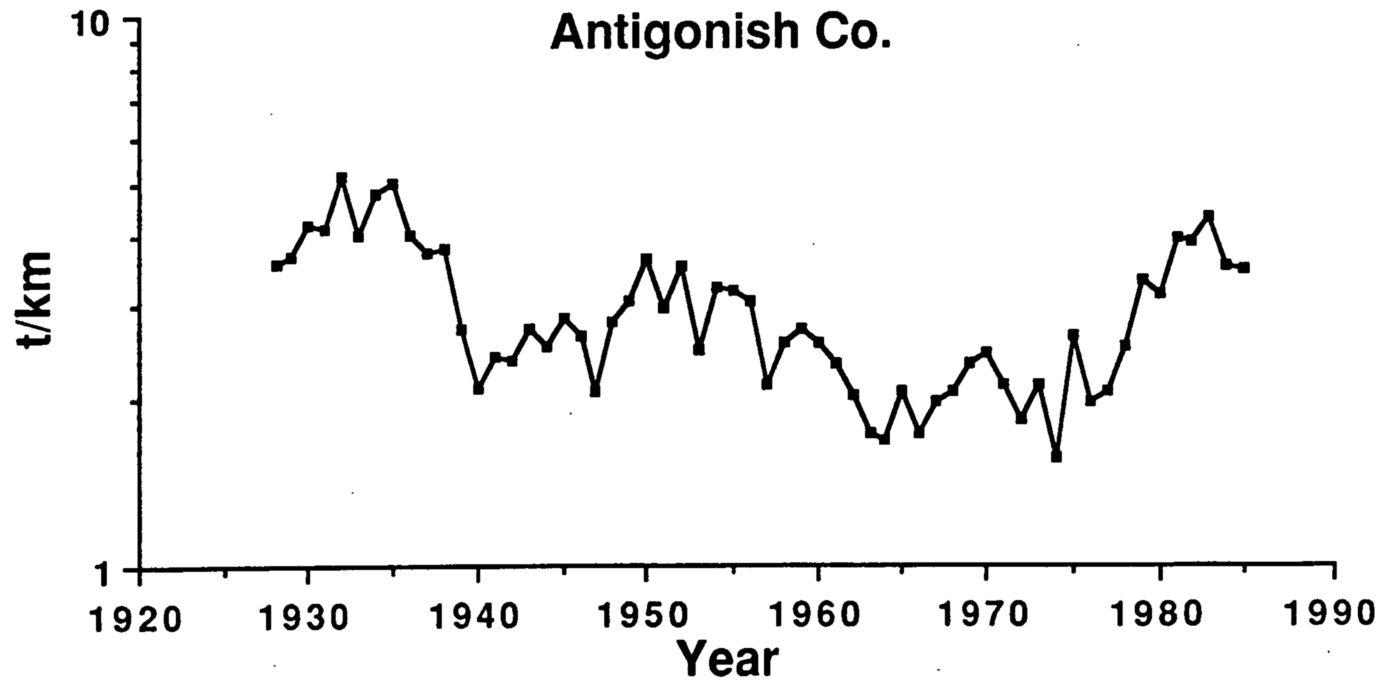

Figure 6. Lobster landings as tons/km of shoreline for Georges Bay (district 3, Antigonish Co. only) from 1928 to 1985. Data summarized by G. Harding (unpublished).

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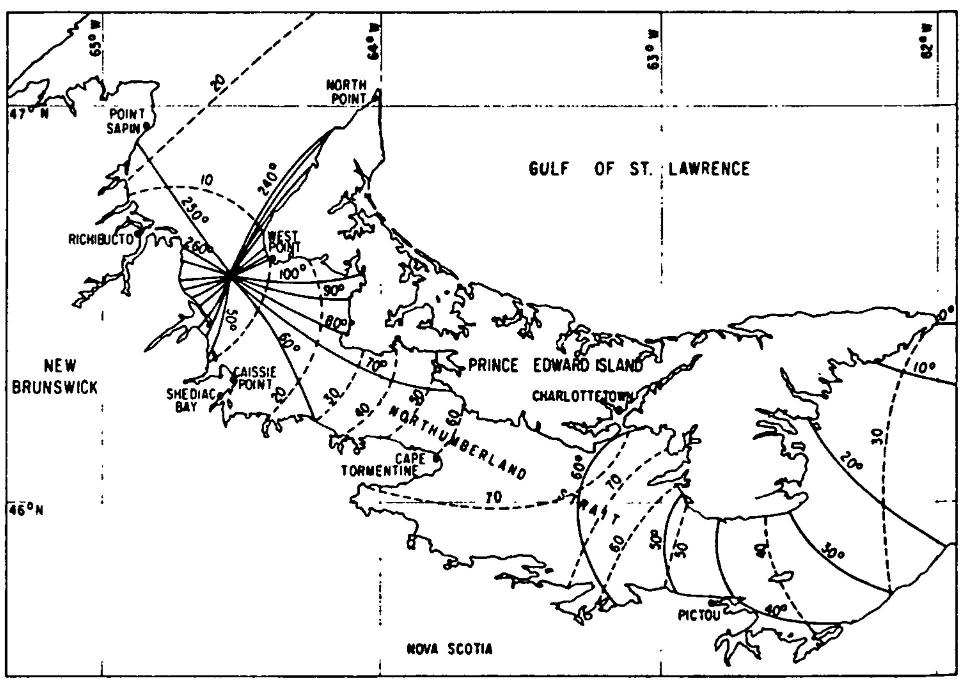

Fig. 7. Cotidal chart of the major lunar semidiurnal component of the tide, M_2, in the Strait of Northumberland. The continuous lines mark lines of equal phase lags; the phase lag indicated is measured from Greenwich mean time ($Z = 0$); 360° of phase of M_2 are equivalent to 12.42 h. The dashed lines are contours of equal vertical displacements in cm.

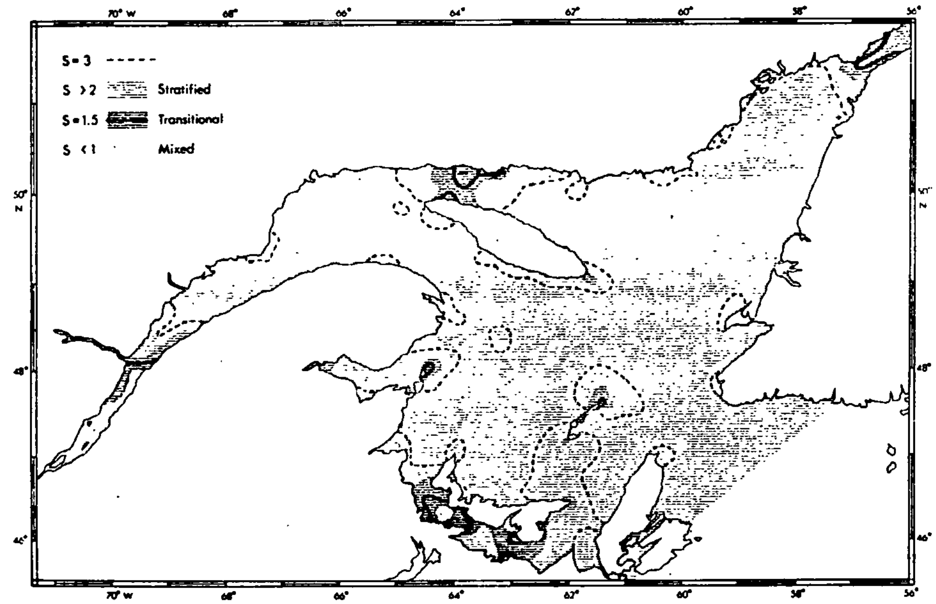

Figure 8.
Contours of the stratification parameter S with bold line (S = 1.5) identifying frontal regions.

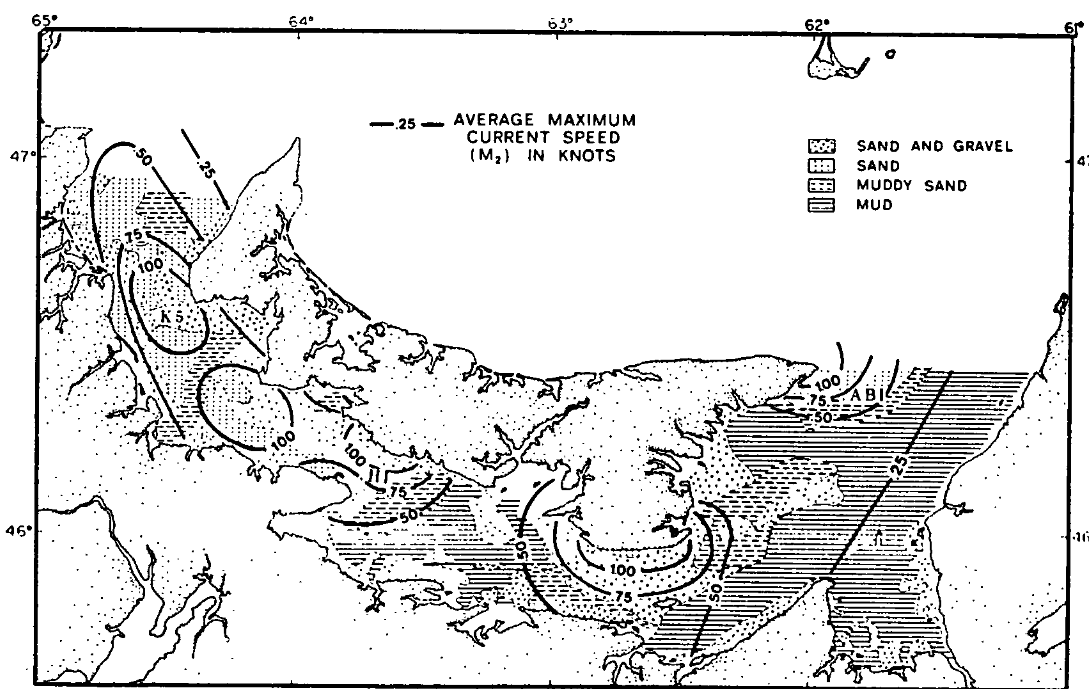

FIG. 9.—Distribution of average maximum speed of tidal streams (amplitude of M_2 measured 7m below the surface) and bottom sediment facies in Northumberland Strait. (Current after Farquharson, 1962) 1 knot = 52 cm/sec.

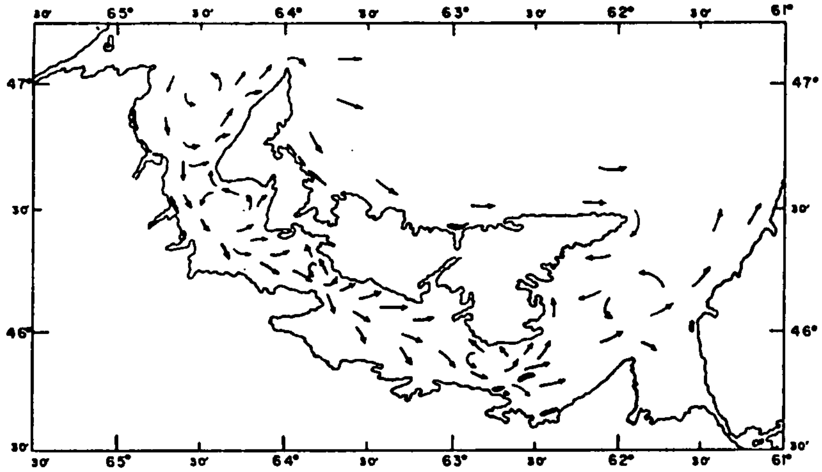

Figure 10. The inferred non-tidal drift in Northumberland Strait.

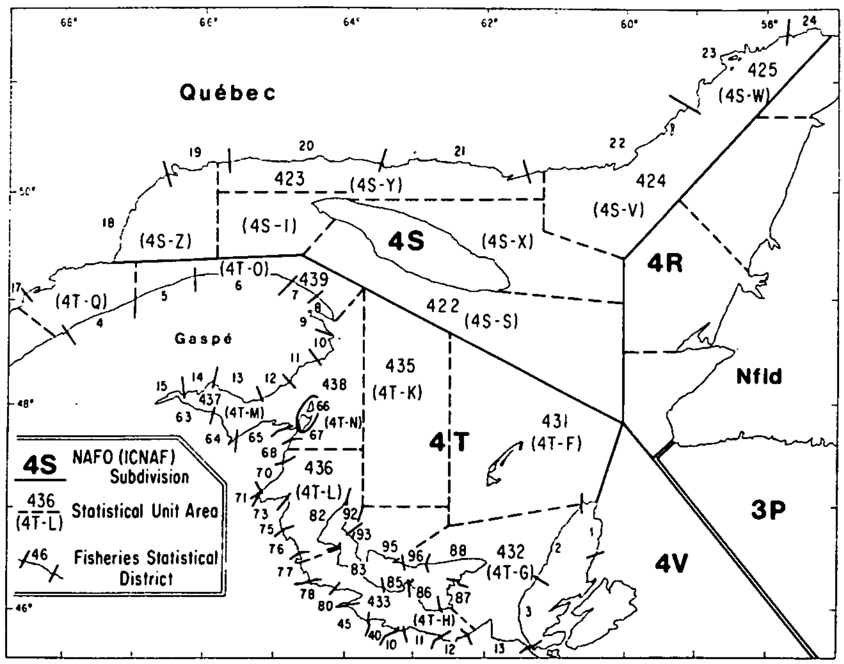

Figure 11. Map of the Gulf of St. Lawrence showing the Fishery Districts in NAFO Division 4T and Subdivision 4Vn.

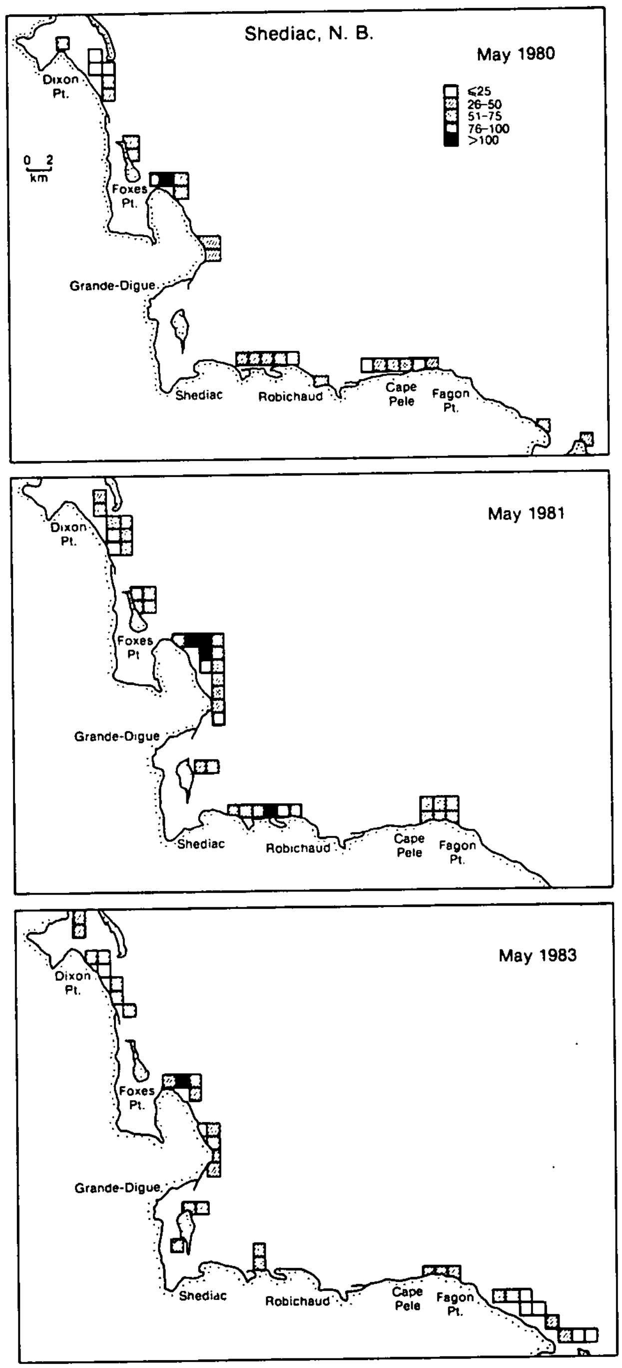

Figure 12. Gillnet distribution in Fishery Districts 78 and 80 located by aerial photographic surveys in spring 1980, 1981, and 1983.

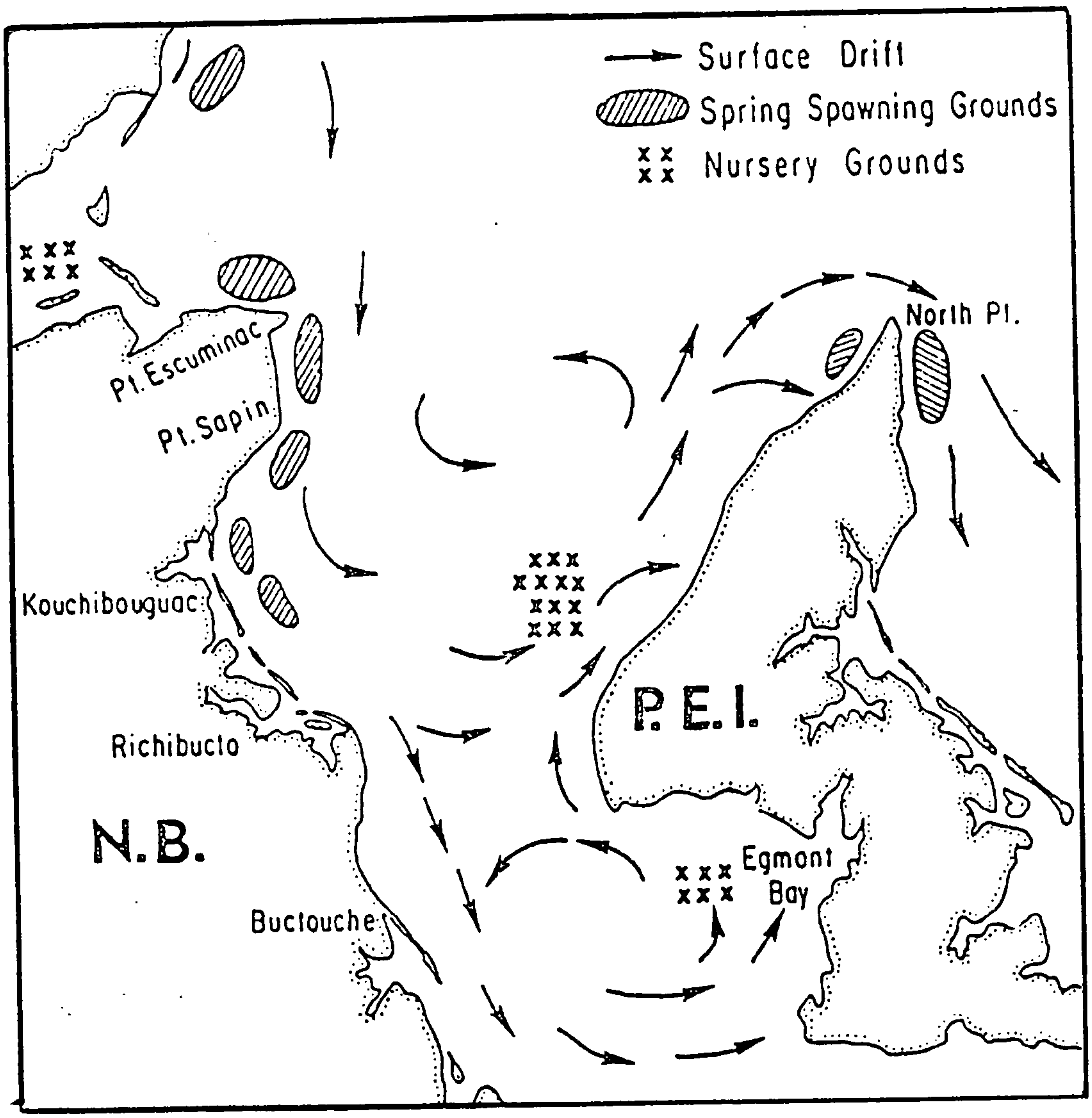

Figure 13. Herring spawning beds, nursery areas and surface drift in northern Northumberland Strait.

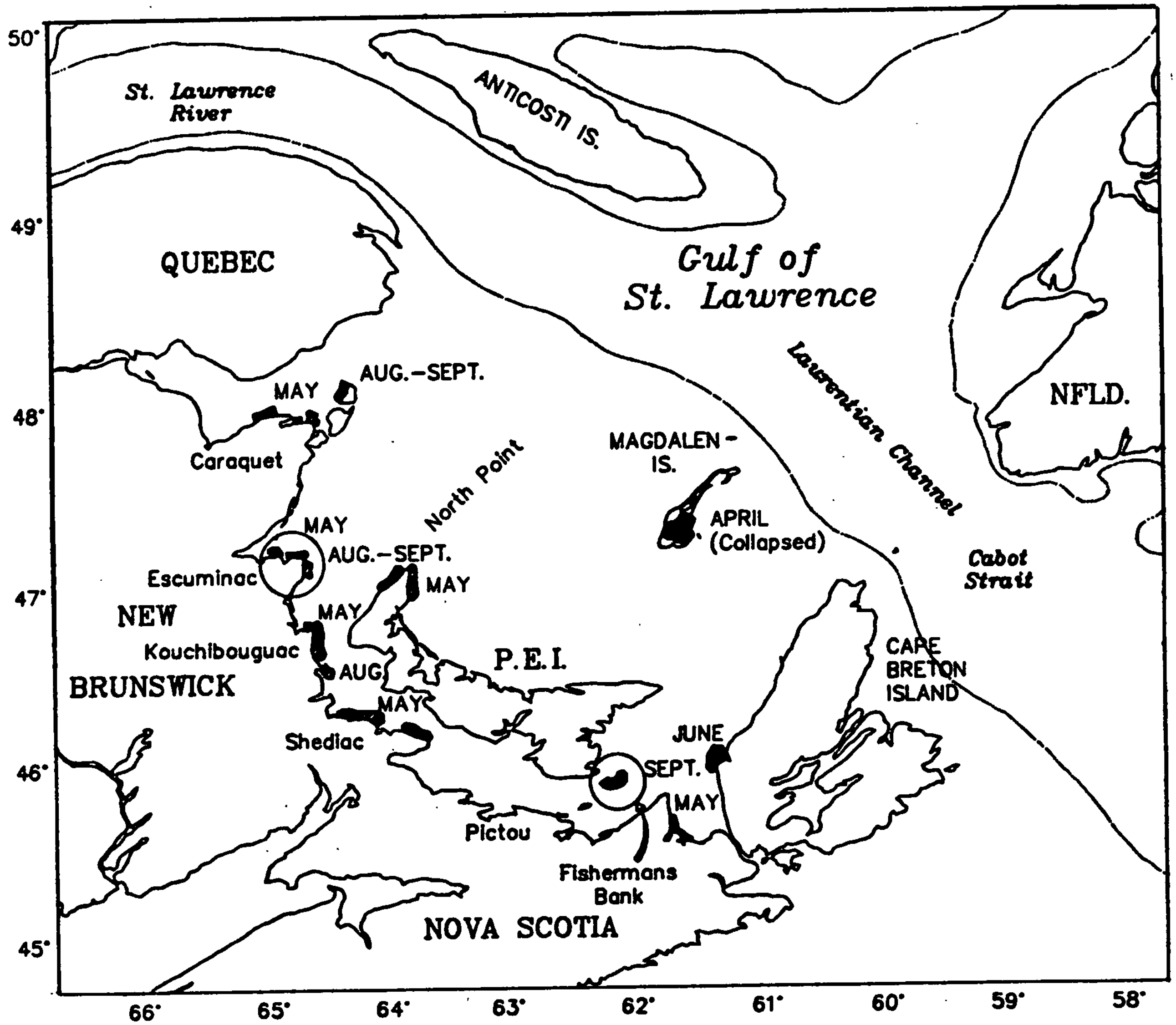

Figure 14. Herring spawning beds and feeding areas in the Gulf of St. Lawrence (Division 4T).

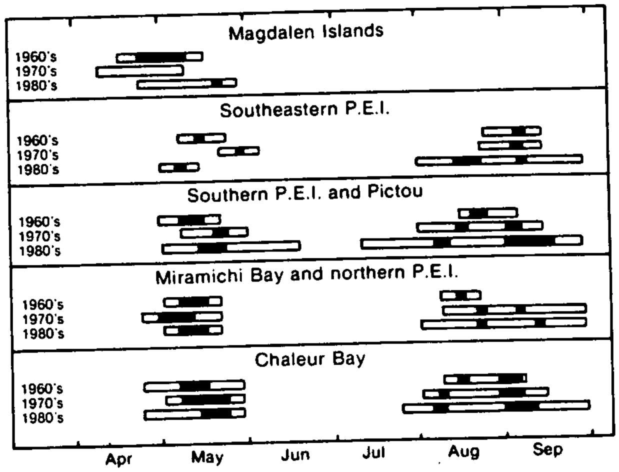

Figure 15. Time and duration of spring and autumn spawning herring populations in the southern Gulf of St. Lawrence in the past three decades. Bar = ripe and running herring taken. Solid bar = At least 50% of herring ripe and running.

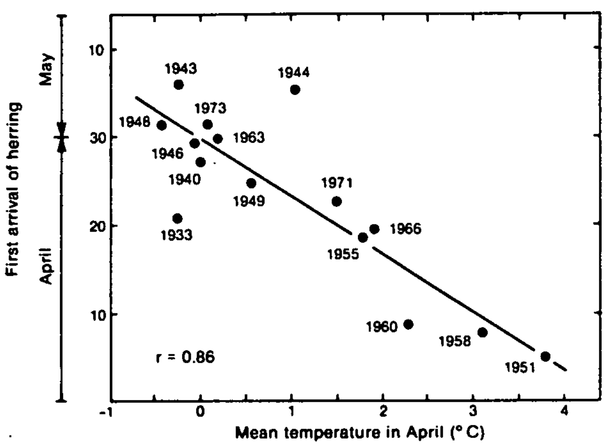

Figure 16. Relationship between the time of first arrival of spring spawners and surface temperatures on the spawning grounds at Magdalen Islands from sporadic observations during 1933-1973.

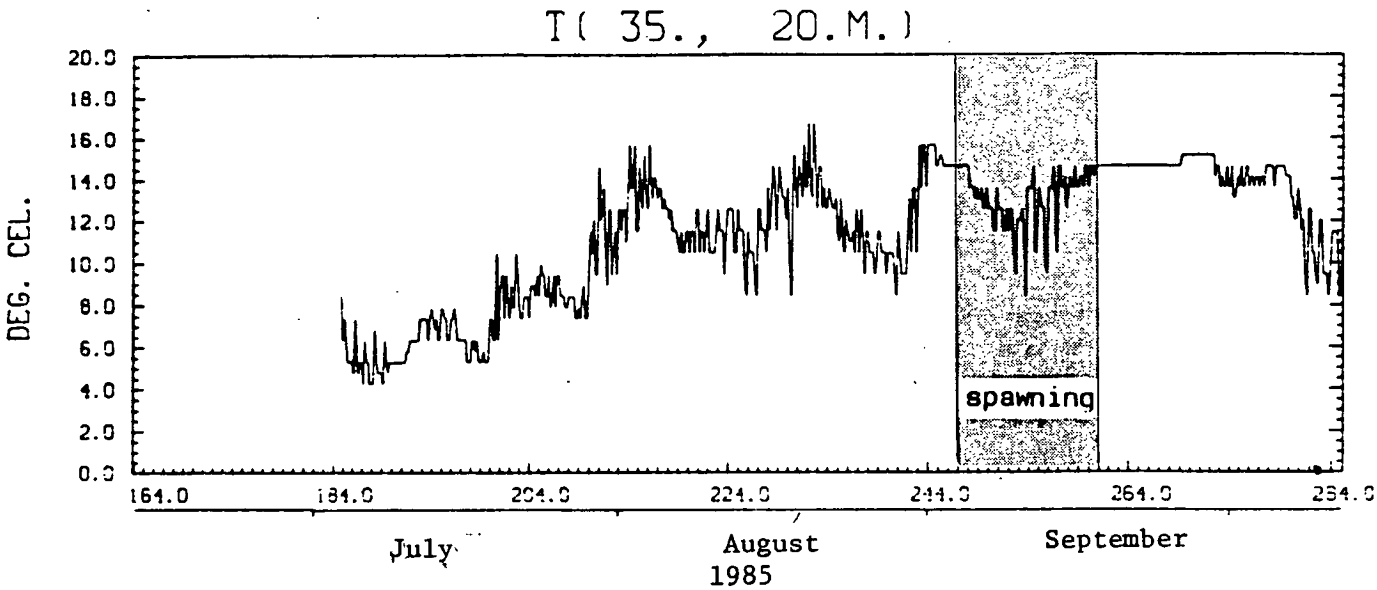

Figure 17. Ryan thermograph record showing daily variations in temperature at 20 m depth taken during herring spawning surveys on Fisherman's Bank.