

**Potential Impacts of Tidal Power Developments
on Bird Populations in the Bay of Fundy**

Peter C. Smith

Biology Department

Acadia University

Wolfville, N.S. BOP 1X0

and

Peter W. Hicklin

Canadian Wildlife Service

P.O. Box 1590

Sackville, N.B. EOA 3C0

ABSTRACT

Migratory waterfowl, shorebirds, seabirds, and wintering bald eagles constitute the bird populations most likely to be affected by tidal power developments in the Bay of Fundy. The loss of salt marshes following changes in tidal range on either side of a tidal barrage may result in movements of waterfowl away from traditional feeding areas to other sites. Sandpipers (Scolopacidae) and plovers (Charadriidae) may be more severely affected in a number of ways. Those birds which would normally feed in the proposed headpond area (Cobequid Bay) would be displaced to other sites owing to the loss of the lower half of the existing intertidal zone which would remain permanently subtidal following barrage construction. Displaced birds would most likely be forced into the Southern Bight of Minas Basin where much larger numbers already forage during the autumn migration. The resulting increase in densities there may reduce the birds' ingestion and fat deposition rates as a result of increased competition. Furthermore, increased siltation in Minas Basin if a barrage were constructed might reduce prey abundance in the Southern Bight thus reducing birds' ability to deposit sufficient energy reserves for continuous migration to South America.

Shearwaters (Procellariidae), phalaropes (sub-family Phalaropodinae) and gulls and terns (Laridae) in Passamaquoddy Bay and off Brier Island near the mouth of the Bay of Fundy depend on tidal upwellings to concentrate prey near the water surface. Reductions in the velocity of tidal currents may affect these upwellings and thus the birds' ability to obtain food. Wintering bald eagles in the Shubenacadie River may suffer losses or displacement if construction of a tidal power barrage results in the river being frozen during January and February, thus eliminating access to the winter run of tomcod, Microgadus tomcid, the major winter food of eagles along the river.

Key words: waterfowl, shorebirds, seabirds, bald eagles, Minas Basin, Cobequid Bay, Shubenacadie River.

RÉSUMÉ

Les oiseaux aquatiques migrateurs, oiseaux du littoral, oiseaux marins et populations hivernantes de l'aigle à tête blanche Haliaeetus leucocephalus sont les populations d'oiseaux que touchera probablement le plus la mise en place d'une usine marémotrice dans la baie de Fundy. La disparition des marais salants résultant des modifications de l'amplitude des marées de part et d'autre de la digue de l'usine marémotrice, pourrait chasser les oiseaux aquatiques de leurs aires traditionnelles d'alimentation. Les bécasseaux (Scolopacidae) et les pluviers (Charadriidae) pourraient être plus sérieusement touchés, et de plusieurs façons. Ces oiseaux, qui normalement trouvent leur nourriture dans la partie amont de l'endiguement proposé (baie Cobequid), rechercheraient d'autres sites, en raison de la perte de la moitié inférieure de la zone intertidale actuelle, qui deviendrait définitivement subtidale après la construction du barrage. Les oiseaux ainsi chassés devront sans doute s'installer dans la baie sud du bassin des Mines, déjà fréquentée par des populations beaucoup plus nombreuses pendant la migration d'automne. L'augmentation résultante de la densité de peuplement pourrait réduire la quantité de nourriture ingérée par ces oiseaux, et provoquer une diminution de leur poids (une moindre accumulation de graisses), étant donné qu'ils devront en plus grand nombre aller en quête de nourriture. De plus, si l'on construit un barrage, l'envasement accru du bassin des Mines risque, dans la baie sud, de réduire l'abondance des proies que peuvent capturer ces oiseaux, donc d'empêcher ceux-ci d'accumuler suffisamment de réserves énergétiques pour effectuer leur migration continue vers l'Amérique du Sud.

Les puffins (Procellariidae), les phalaropes (sous-famille Phalaropodinae), ainsi que les goélands et sternes (Laridae) qui vivent dans la baie Passamaquoddy et au large de l'île Brier, près de l'embouchure de la baie de Fundy, trouvent au moment de la remontée des eaux froides avec le flux (upwellings) une grande concentration de nourriture, près de la surface de l'eau. La réduction de la vitesse des courants de marée pourrait diminuer l'"upwelling", et par conséquent la capacité des oiseaux à trouver leur nourriture.

Les populations de l'aigle à tête blanche hivernant dans le secteur de la rivière Shubenacadie risquent de diminuer ou d'être chassées, si la construction d'une centrale provoque l'englacement du cours d'eau en janvier et février, et par suite empêcher l'arrivée printanière de la petite morue Microgadus tomcod, qui est le principal aliment de l'aigle pendant l'hiver.

INTRODUCTION

In search for independence from fossil fuels governments in recent years have turned a favourable eye towards tidal power developments as a potential source of power generation. Especially in the past decade, serious attention has been given to the possibility of such developments in the Bay of Fundy (Fig. 1; Daborn, 1977), the Severn estuary and other areas in Britain (see Prater 1981 for summaries of various engineering schemes proposed in the U.K.).

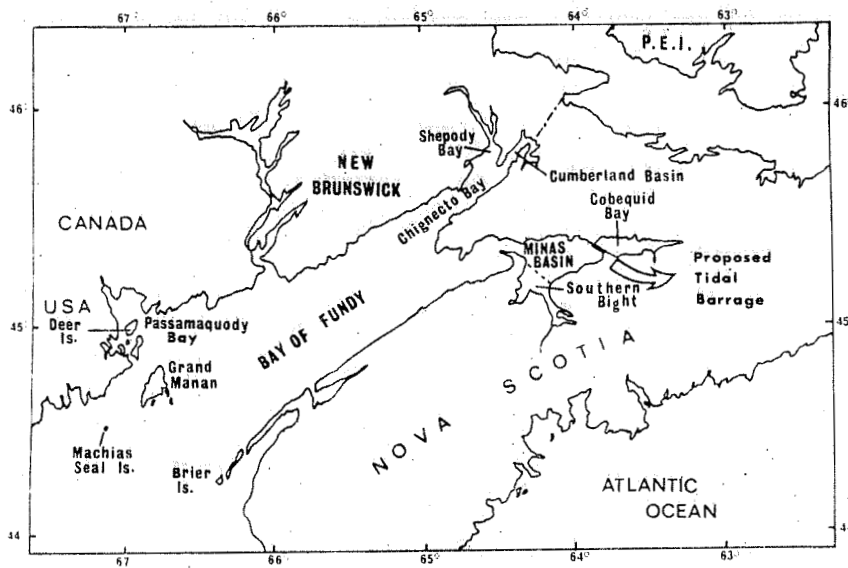


Fig. 1 The Bay of Fundy and location of proposed tidal barrage.

Birds make up part of the conspicuous fauna of coastal bays and estuaries. These include waterfowl (Anseriformes), gulls and shorebirds (Charadriiformes), alcids (Charadriiformes) and other seabirds (Procellariiformes). In order to judge the impacts of man-made developments on the populations, detailed studies are required to understand the relationships between various avian species and their habitats within marine and estuarine environments. Information is needed on 1) population levels of breeding, migrating and wintering species, 2) temporal and spatial distribution of each species, 3) food supply and the ecological requirements of major prey species, 4) feeding characteristics of birds and their inter- and intraspecific relationships, 5) effects of environmental variables and 6) mortality factors affecting populations. In Britain, many such studies have been undertaken independently of tidal power developments over a period of years and more recently as an integral part of environmental studies to measure the possible impacts of development on the estuarine avifauna (see Prater 1978, 1981). At the first workshop on the potential environmental implications of tidal developments in the Bay of Fundy in 1976 (Daborn 1977) the participants quickly became aware of the paucity of information on the ecology and dynamics of the Fundy system. This was especially true for the ornithologists who were keenly aware of the scarcity of information on avian populations in the Bay of Fundy and on the species' ecological requirements (Hughson 1977). Since 1976, research efforts have concentrated on studies of the feeding ecology of migrant shorebirds and seabirds. Much of the information gathered is as yet unpublished and many of the required studies either have not been undertaken or are not yet completed. Hence, to provide some basis for impact assessment we have to rely in large part on the findings of long-term studies in the U.K. and Europe.

In this paper, we examine the possible impacts of tidal power developments on birds, but emphasis is given to species which occur in the upper Bay of Fundy. There, shorebirds, numerically most important, are the focal group, but seabirds, colonial breeding birds, waterfowl and bald eagles are also considered.

SHOREBIRDS

Fundy is an internationally important staging area for migratory shorebirds where individuals of 22 species occur during late summer and fall. There, the birds deposit fat for migratory flight to Central and South American wintering grounds. For those species which concentrate their foraging activities on intertidal mudflats, the food utilized for the formation of fat consists largely of polychaetes and the burrowing amphipod Corophium volutator (Hicklin and Smith 1979). From mid-July to October sandpipers and plovers, which altogether probably number several millions, feed on marshes and mudflats when these are exposed and gather along open beaches to roost during high tides. By far the most numerous species is the semipalmated sandpiper, Calidris pusilla, which forms large flocks in Chignecto Bay and Minas Basin/Cobequid Bay in the latter part of July and early August (Fig. 2).

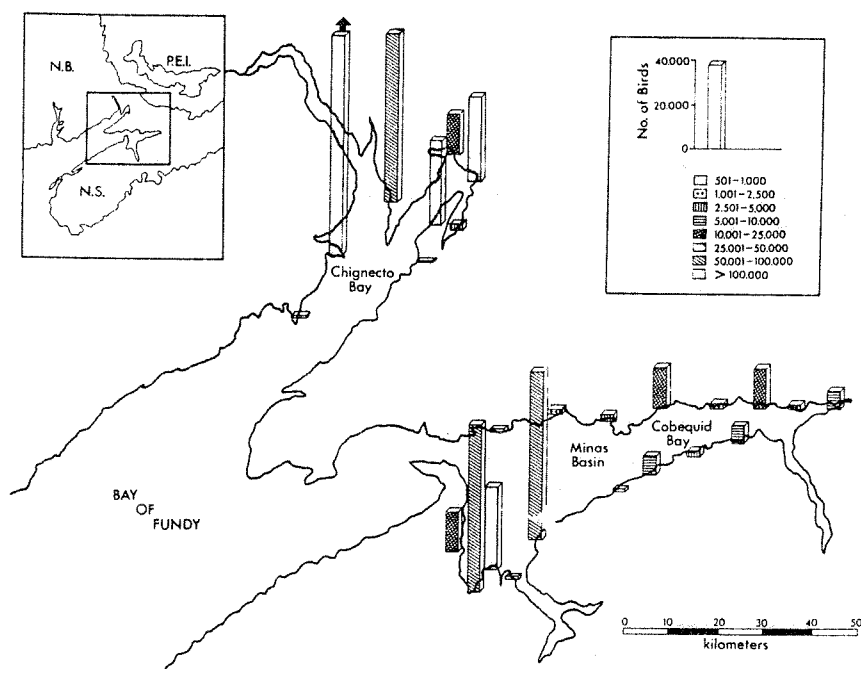


Fig. 2. Numbers of shorebirds in the Bay of Fundy based on aerial survey, 29 July, 1976.

One immediately apparent effect of barrage construction would be the reduction of shorebird numbers in the headpond (Cobequid Bay) owing to the loss of foraging area. One half or more (depending on slope) of the flats in the headpond area would be lost; the lower portion of the existing intertidal zone would remain subtidal following barrage construction under most operating regimes. Two other effects also seem probable, although the magnitude of these is much less clear:

1. Changes in tidal and current patterns in the Bay of Fundy following construction would cause concomitant changes in the sedimentation regime (Amos 1983). The nature of the sediments is crucial with respect to the distribution and abundance of invertebrate prey for birds. Availability of the invertebrates, in turn, affects the foraging distributions, densities, feeding success, rates of fat deposition, and length of stay (in Fundy) of the birds.
2. Birds displaced from the headpond area would move to and increase the densities of birds in other adjacent areas, thus increasing competition through both direct and indirect interactions.

As Cobequid Bay is receiving primary consideration for tidal power development, we will center our discussion of these points with respect to this site. Parallel effects would be expected at other potential sites in Fundy such as Cumberland Basin.

At the peak of migration on 29 July 1976, shorebirds in Cobequid Bay totalled about 65,000 birds and over the course of migration probably attain total numbers of 100,000 or more. With the loss of one half the present foraging area, an appreciable porportion would be displaced. The foraging sites nearest Cobequid Bay, on the seaward side of the barrage, are in the Southern Bight of Minas Basin. The Southern Bight is already the most important area for shorebirds in the Minas Basin-Cobequid Bay complex. Moreover, per unit area, the Starrs Point bar is among the most productive areas in Minas Basin yet studied (Boates 1980).

Our concern focuses upon changes in sediment regime on the Minas Basin side of a barrage built across Cobequid Bay (Amos 1984). We feel that some change would result although the magnitude of this cannot as yet be determined very precisely. The key relationships which exist here are those among the nature of the sediments, the invertebrates species inhabiting these and the birds which in turn prey upon the invertebrates. Certainly the close relationships which exist between substrate type (grain size) and invertebrates species composition and abundance have been well documented from studies conducted in North America and Europe (e.g. Meadows 1964, Longbottom 1970, Wolff 1973, Fenchel et al. 1975 and Scott and Crooker 1976). It is reasonable to assume, therefore, that changes in the sediment regime would lead to changes in the composition and abundances of prey species. Such changes in species composition would in turn affect the birds' ability to obtain food.

Irrespective of such changes, further effects can be predicted with regard to the displacement of birds to sites outside of Cobequid Bay. These effects are based on the premise that shorebird foraging dispersion is related to prey density and availability. This premise is based on our own studies in the Bay of Fundy (Boates 1980, Hicklin 1981, Hicklin and Smith 1984) and those of Zwartz (1980) in Holland and of Goss-Custard (1970, 1977a) in Britain. Furthermore, Zwartz (1980) has shown that, above critical densities of prey, foraging success is dependent on bird density. Hence, a number of interrelationships result. Displaced birds from one area would produce concomitant increases in bird density in other sites, thus depressing foraging efficiency in response to decreased prey abundance and greater competition and interaction. For instance, in the Wash, the feeding rate of red knots, Caladris canutus, decreased by 20% owing to a rise in frequency of aggressive encounters over food with increasing bird densities (Goss-Custard 1977b). Lowered foraging efficiency of the birds in Fundy would presumably reduce daily rates of fat deposition and thus require birds to remain longer in the area to achieve the level of fat reserves needed for the migration over the Atlantic Ocean to South America. All these effects are complicated by the arrival of additional birds (immatures and later migrants) and by loss of potential prey taken by fish (Gilmurray 1980). These interrelated effects could lead to decreased fat levels. Although mortality by starvation would not be expected in the Bay of Fundy, some mortality could occur during the long transoceanic flight to the wintering sites.

In such a situation, the question arises whether birds would stay in Fundy or move to other foraging areas outside the Bay. In British wintering studies, many birds did not move in hard weather and perished (see Prater 1978). Along the Atlantic seaboard of North America, many areas in the northeast (the Gulf of St. Lawrence, the Maritime Provinces and coastal New England) are used extensively by migrant shorebirds although total numbers are much less than those found in the Bay of Fundy. Work by McNeil and Cadieux (1972) and McNeil and Burton (1973) in the Magdalen Islands, Gulf of St. Lawrence, has shown that many migrant shorebirds which forage there during migration accumulate enough fat to reach the West Indies and the northern coast of South America, a distance of 3200 km. However, they also indicated that on average, the fat reserves of semipalmated sandpipers and other species could only provide sufficient energy for migration of about 2400 km. Hence, although many birds could undertake a non-stop flight from Magdalen Islands to the wintering grounds, "others would need to get fatter somewhere farther south in Nova Scotia or the New England states before undertaking an over-sea flight" (McNeil and Cadieux 1972). Reports of banded and marked birds dispersing from the Magdalens showed that of those subsequently seen in North America 62% occurred in the Bay of Fundy (McNeil and Burton 1973; computed from Table VI). Moreover, some semipalmated sandpipers recently banded and colour marked in Lubec, Maine, were seen in the upper Bay of Fundy during the same summer they were captured (T.A. May, pers. comm. and P.W. Hicklin, unpublished data). Those results suggest that these areas outside the Bay of Fundy cannot support large numbers of birds for the times required to put on necessary fat levels, and this further emphasizes the international importance of Fundy as a major staging area for North American shorebirds during the southward migration.

If the foraging grounds were indeed affected by tidal power developments as we have described and birds had to disperse to other areas, an important question remains. Where can the displaced birds move to in order to ensure successful migration further south? One obvious answer is that birds might adopt a coastal route along the United States to Florida and the West Indies. It remains uncertain whether sufficient habitat is available to support this large a population for few areas south of Massachusetts presently sustain notable concentrations of shorebirds in autumn.

Many small nearshore islands in the Maritime Provinces support small numbers of shorebirds in the fall. There are about 1400 such islands in Nova Scotia and perhaps these could absorb greater numbers of birds, thus helping to maintain the overseas migratory route. Unfortunately, little is known regarding the amounts of suitable and productive habitats available to shorebirds on these islands or on the numbers and species of migrants which might utilize them.

Some key questions have to be examined. How "traditional" are staging areas and migration patterns? How flexible are the responses of migrant shorebirds toward loss of habitat and changes in abundances of prey?

Taking into consideration the points outlined, we present two scenarios which we feel might result following the construction of a tidal barrage across the Minas Basin-Cobequid Bay system.

Increased use of areas near the headpond by migrant shorebirds following barrage construction

If substantial numbers of shorebirds were displaced from Cobequid Bay there is the possibility that the nearest foraging site, the Southern Bight of Minas Basin, could support more birds. However, the information presently available on the foraging distributions of birds in the Southern Bight suggests that the better foraging flats are presently saturated with the maximum number of birds they can support, at least during peak migration. The Starrs Point Flat which is the most productive area for shorebirds in the Minas Basin presently supports more birds and higher densities than surrounding mudflats (Boates 1980, Hicklin 1981). Nearby flats which in area are equal to or larger than the Starrs Point Flat, but which contain low densities of Corophium volutator, support densities of birds which are about 5% of the densities of foraging birds found at Starrs Point (Hicklin and Smith 1979, Hicklin 1981). Birds feeding on the less productive mudflats may have been displaced from the better foraging areas or indeed by high bird densities at Starrs Point. In these cases, the possibility that the Southern Bight can support substantially more birds is remote.

Increased use of the Southern Bight by shorebirds in relation to changing sedimentary patterns on the seaward side of a barrage

If large expanses of mudflat were lost in Cobequid Bay (as predicted) following tidal power development and serious disruptions of the

existing flats in Minas Basin developed, we believe that substantial reductions in the numbers of shorebirds would occur. In the Teesmouth estuary in Britain, the numbers of five species of wintering shorebirds declined substantially following reclamation developments (Prater 1978). If tidal power developments in the Bay of Fundy were to reduce invertebrate production significantly, such effects would be especially pronounced for later migrants and particularly immature birds because of lower prey abundance resulting from predation by earlier immigrants, especially adults, and perhaps by fish. The extent of mortality or displacement outside of Fundy cannot be predicted until some idea of the degree of possible change to the foraging areas is known. Presumably, some new equilibrium between bird numbers and the carrying capacity of the intertidal areas would be attained in the long term at a lower population size. However, here there is a problem. Because of the size of the Bay of Fundy and the scarcity of professional and volunteer observers to monitor regularly the numbers of birds at roosting and feeding areas, assessment of the possible change in numbers, if any, will be difficult. Because of the large numbers of some species, such as the semipalmated sandpiper, only broad estimates of numbers can be obtained and these can vary greatly between observers. Hence, unless reductions are substantial, the degree or occurrences of change will be difficult to ascertain.

Although attention is most often focused upon the most abundant species, the least numerous may be more affected. For example, recent work on the ubiquitous but less abundant least sandpiper, Calidris minutilla, suggests that it may be competitively excluded from the better foraging and roosting areas by the slightly larger semipalmated sandpiper (P. MacDonald, pers. comm.). Therefore, under periods of environmental change and stress, the least sandpiper may experience the greater loss.

WATERFOWL

Pearce and Smith (1974) briefly examined the potential influences on waterfowl of port and tidal power developments in the Bay of Fundy. Their discussion was based on ground and aerial surveys conducted in 1966-1973. Except for breeding colonies of common eiders, Somateria mollissima, in southwestern New Brunswick and a few pairs of black ducks, Anas rubripes, breeding in the higher marshes, most of the ducks and geese which utilize the Bay of Fundy are migrants. Dabbling ducks and Canada geese occupy the saltmarshes of the upper Bay of Fundy and the possible loss of these habitats was the chief concern of Pearce and Smith (1974). Since its publication, no systematic research has been conducted on waterfowl populations in the Bay of Fundy and little can be added other than that some distributional change might be predicted. No major deleterious changes at the population level are expected.

COLONIAL BREEDING BIRDS

Colonies of great blue herons, Ardea herodias, and double crested cormorants, Phalacrocorax auritus, in the Bay of Fundy are small compared

to the number and sizes of colonies elsewhere in the Maritimes. One notable exception is a colony of double crested cormorants on Manawagonish Island (2000 pairs). Any effects of tidal power developments are most likely to operate through changes in fish prey. Herring gulls, Larus argentatus, and great black backed gulls, Larus marinus, breed on numerous offshore islands in Fundy. It is doubtful that these would be affected by tidal power developments at all. The puffins, Fratercula arctica, razor-bills, Alca torda, and arctic terns, Sterna paradisaea, which nest on Machias Seal Island should not suffer any loss of breeding habitats. Since they probably feed outside the Bay of Fundy, presumably in the Gulf of Maine, it is difficult to envision any detrimental effects.

SHEARWATERS AND PHALAROPES

Large numbers of greater shearwaters, Puffinus gravis, and red phalaropes, Phalaropus fulicarius, congregate off Brier Island in the late summer and fall. Each species may occur there in numbers exceeding 20,000. red-necked phalaropes, Phalaropus lobatus, are even more abundant in fall near Deer Island in Passamaquoddy Bay. These birds forage on copepods and euphausiids in areas of upwelling tidal currents. It remains to be seen if these currents and food availability will be affected by barrage construction in the upper Bay of Fundy. If indeed current velocities are changed so that amphipods and copepods are no longer "pumped" up into the surficial layers, the loss of the food resource might force these migrants elsewhere.

BALD EAGLES

The Subenacadie River, which lies inside the proposed headpond in Cobequid Bay, is the most important known natural wintering area in Nova Scotia for bald eagles (Reid 1982). Maximum numbers recorded in the winters 1977-1982 ranged between 45 and 75 birds. Most are presumed to be of Nova Scotia origin but some may originate from Newfoundland and Labrador.

In winter, about 13-58% of the eagles known to be in Nova Scotia are observed along the river. The main attraction for these birds is the winter spawning run of tomcod, Microgadus tomcod, which also serves as an important food for 500-600 common mergansers, Mergus merganser.

The tides affect the Shubenacidae River up to 40 km above the mouth. The stretch of river most frequented by wintering eagles is 15-20 km from the mouth. Under the existing tidal regime this portion of the river presently remains relatively open in most winters. Since the river lies in the headpond area of the proposed tidal dam, it would very likely freeze completely in winter, thus eliminating this important wintering area for bald eagles and common mergansers. In addition, the tomcod run is likely to be affected by tidal changes. Can the eagles, displaced from this wintering area after barrage construction be supported elsewhere in coastal and inland Nova Scotia? Probably not all would survive, as some mortality may be expected there or upon movement down the seaboard.

Wintering sites which currently share smaller numbers of eagles may be able to support additional birds, but little is known of the carrying capacity of any of these areas.

GENERAL CONCLUSIONS

Although we know much more about the ecology and behaviour of some birds utilizing Fundy than we did in 1976, especially about shorebirds, seabirds and to some extent eagles, we are not much farther ahead with respect to assessing impacts. Many "ifs" and "buts" remain. We require more detailed information on the abundance, distribution and habitat use of many of the species we have discussed. Of the migrant sandpipers and plovers, much study has been devoted to the semipalmated sandpiper with less emphasis on other less abundant species. Fortunately, such studies are presently underway. Until more is known of engineering design and related changes in physical environment, a statement concerning impacts of Fundy tidal power on birds cannot be more precise than that made at present.

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QUESTIONS AND COMMENTS

D. Gordon: Your projection of the decline in bird populations and tide flat area agrees closely with our findings on changes in primary and secondary production. But do you think there will be a decline in bird populations if the barrage is built or will they just move to new areas?

P. Hicklin: My point is the length of time it takes the flats to readjust to the new tidal regime and resume maximum Corophium production levels. Throughout that period the birds will have difficulties and populations might decline or crash.

D. Gordon: Yes, but after a crash for 5 years or so, when the tide flats recover, will not the birds?

P. Hicklin: Perhaps but I think there is an element of risk.

Unknown: I assume in the past few years there has been some annual variation in the production and availability of Corophium. Has this ever manifested itself in the birds?

P. Hicklin: I never felt that this was really noticeable except one time after there had been a severe storm at Mary's Point the birds became very aggressive and this may have been in response to unavailability of food. In terms of your original question abundances of birds and benthos seems to have been uniformly high.

1. The first part of the document discusses the importance of maintaining accurate records of all transactions. It emphasizes that proper record-keeping is essential for the success of any business and for the protection of the interests of all parties involved.

2. The second part of the document outlines the various methods and techniques used to collect and analyze data. It provides a detailed description of the procedures followed and the results obtained from the study.

3. Discussion and Conclusions

The findings of the study indicate that there is a significant correlation between the variables studied. The data suggests that the factors mentioned in the study have a direct impact on the outcome. The results are consistent with the theoretical framework proposed at the beginning of the document.

In conclusion, the study has provided valuable insights into the relationship between the variables. The findings suggest that further research is needed to explore the underlying mechanisms and to test the generalizability of the results. The authors hope that this study will contribute to the existing knowledge in the field.