Autumn 1996 ISSUE # 2

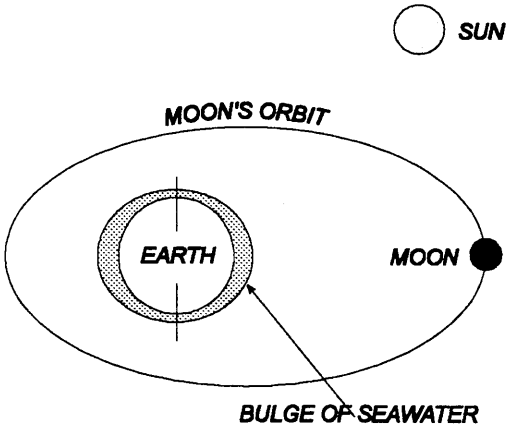
FUNDY ISSUES

TIDES OF CHANGE

Natural Processes in the Bay of Fundy

A Bay of Changes

In an age when we humans are responsible for so much appalling environmental degradation, it may be heartening to realize that we are not entirely to blame for every ecological upheaval. All ecosystems change continually, and alter in ways that are sometimes beneficial, but more often unfavourable, to human interests. When such changes occur rapidly and violently, for example in a volcanic eruption or tornado, their origins in natural processes are obvious. However, most natural changes happen at a pace barely noticeable on the scale of the human life span. Such gradual environmental changes complicate things for scientists trying to study the effects of human activities on the world around us. If the natural world is steadily changing already, regardless of any human activities, then it can be difficult to determine if we, or mother nature, are more reponsible for undesirable environmental changes that may be taking place. This is why many scientists are often so infuriatingly reluctant to point the finger in the aftermath of an ecological catastrophe. Often, they cannot readily determine whether the calamity was a direct result of something humans did, or merely the inevitable consequence of natural processes. They are slowly coming to the realization that in most cases the answer is — clearly both! As we shall see, Mother Nature may have to accept some of the responsibility for many of the unwelcome ecological changes that are now occurring in the Bay of Fundy.



The moon's pull and the earth's rotation create the moving bulges of seawater that we call tides. The continually varying positions of the moon, sun and earth cause the tidal range to have monthly, yearly or longer cycles.

The Bay is a unique coastal ecosystem, dominated and largely shaped by its surging tides that are the highest in the world. To our limited vision it seems a timeless and unchanging feature of our maritime landscape. In fact, it has been restlessly changing and steadily evolving since the area first formed at the rising of the Appalachian Mountains some 300 million years ago. This change has continued unabated since the massive glaciers retreated from Nova Scotia some 14,000 years ago. This allowed the land to gradually lift, once relieved of the immense weight of the ice, and the sea level to rise with the melting of huge volumes of polar ice. As a result, the depths of the Bay and of the adjacent Gulf of Maine have changed greatly during this period. Early on, Georges Bank, that rich shallow fishing ground

The
Gulf of Maine Council
on the Marine Environment

Clean Annapolis River Project

that angles across the the mouth of the Gulf of Maine, was a large island that severely restricted the flow of sea water into the Gulf and Bay of Fundy. The outer Bay was , at that point, like many other estuaries, with a more normal tidal amplitude of only 3 feet. Its upper reaches were little more than shallow lagoons largely cut off from the influence of the sea. During the subsequent centuries, the sea level rose, the surrounding land subsided, the protective outer islands submerged and the Bay opened itself more fully to the North Atlantic.

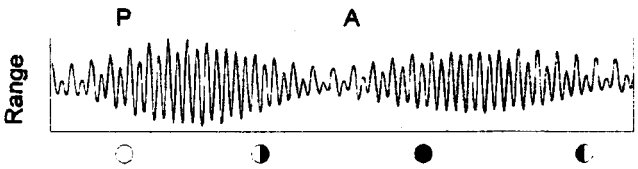
Oceanographers assure us that even today the sea level continues to rise between 15 and 30 centimetres each century. In addition, the range of the tide rushing into the Bay has gradually increased, until today the change in water depth between high and low tide can be a staggering 16 metres or more. Studies suggest that tidal range may still be increasing by 10-15 centimetres each century. Clearly, the watery forces that shape Fundy's shores and its ecosystems are steadily changing over time. To complicate things even further for scientists trying to understand what is going on, these steady long-term changes in the tides are taking place at the same time as much briefer regular cycles, ranging in duration from hours to decades. To understand these cyclic changes we must briefly consider the celestial forces that cause the tides.

"Mother Nature may have to accept some of the responsibility for many of the unwelcome ecological changes that are now occurring in the Bay of Fundy"

Fundy's Phenomenal Tides

Like tides everywhere, those of the Bay of Fundy result from the moon's gravity dragging two large bulges of seawater around the earth, one facing the moon and the other exactly opposite. As the moon makes its daily swing around the earth, the passing of these liquid bulges brings two high tides per day to a particular place. The fact that the moon's distance from earth varies and that the sun also contributes a slight gravitational pull in differing directions causes the actual heights of these bulges to vary at different times. The Bay of Fundy captures and shapes these watery bulges into the highest tides in the world. The funnel-like shape of the Bay and the gradual shallowing along its length causes an inevitable piling up of the water as it surges up the Bay. It can rise from less than 3.5 metres near the mouth to more than 16 metres at its inner end. However, what really makes for the record breaking tidal heights is the coming into play of the so called "bathtub effect". In effect, the great mass of seawater in both the Bay of Fundy and the adjacent Gulf of Maine sloshes back and forth like water in a giant bathtub. The size of this huge natural basin is such that this back and forth sloshing has almost the same duration as the twice daily pull of the moon. The two forces act together to cause an even greater rise in water level than that caused by the tide alone. However, the gravitational pull of the sun and moon also fluctuates cyclically over time and this also greatly influences tidal amplitude. The fact that the moon's monthly orbit about the earth and the earth's yearly orbit about the moon are not circular but rather elliptical means that the distances of the moon and the sun from the earth as well as their direction relative to each other change during each month and each year. These regular cyclical changes give rise to the twice monthly tidal fluctuations called spring (higher range) and neap (lower range) tides, as well as to less pronounced yearly fluctuations.

As if this was not complicated enough, the orbit of the moon about the earth also varies relative to the orbit of the earth about the sun. The resulting shift in the angle of the moon above and below the earth's equator during its monthly orbit thus slowly increases and then decreases in a cycle that takes 18.6 years to complete. This is called the "nodal cycle", in which tidal amplitude tends to increase for 9.3 years and then decrease during the next 9.3 years. This change can only be detect by sophisticated measuring techniques because of all the other daily, monthly and yearly cycles that are taking place at the same time. Oceanographers are, however, confident that the nodal cycle causes recurring variations in ocean currents, vertical mixing and water temperatures. These cyclical oceanographic changes in turn influence ecological processes and populations of marine organisms. For example, the size of fish catches in the Bay of Fundy and Gulf of Maine appear to fluctuate in an 18.6 year cycle. However, scientists are not yet sure why this happens. It could be that sea temperatures slowly become more, and then less, favourable for growth of fish larvae and juvenile fish. It could also be that the changes in current speed and rates of mixing of the water result in fluctuations in productivity of phytoplankton and zooplankton, and thus in the quantity of food available for the fish larvae. Clearly we need to know a lot more about the effects of such natural cycles on commercial fish populations. Only then can we make allowances for them in our efforts to better manage our use of these important living resources.



Phases of the Moon

Each month the tidal range changes with the phases of the moon, particularly when the moon is at its closest point to the earth (Perigee) and at its farthest point (Apogee).
[from Canadian Hydrographic ServiceTide Tables]

Malleable Mudscapes

It is inevitable that the turbulent currents pouring into the Bay each day are slowly reshaping its shorelines and bottom. The soft rocks of the inner Bay are constantly being worn down, releasing vast quantities of clay, silt and sand into the water giving it its characteristic muddy look. Much of this sediment has settled out as the familiar mud flats and salt marshes that are important to the ecology of the upper Bay. Even more of it has settled to the seafloor in various parts of the Bay. These mudflats, saltmarshes and submarine deposits are transitory things that owe their existence to subtle balances in the competing forces of the tides and currents that deposit sediments and those that erode them away. Slightly alter either the rate of deposition or the rate of erosion, and over time the mud layers will change, enlarging, shrinking or disappearing altogether. In Fundy, prevailing currents seem to be slowly carrying sediments to the northeast into the inner basins.

"Man's increasing ability to modify natural systems, particularly through engineering works, has far outstripped his ability to forecast the changes in complex ecosystems"

Scientists are making progress in understanding how factors such as size and type of particles, current speed, activities of animals and the growth of microscopic algae and saltmarsh grasses influence the deposition and erosion of muds. But they less confident about how the gradually rising sea level and increasing tidal amplitude will alter the distributions of the deposits in various parts of the Bay. They are also hard pressed to predict how the construction of a causeway or breakwater will change the distribution of mudflats and saltmarshes in an area, particularly against the backdrop of the natural changes. In the words of Graham Daborn of the Acadia Centre for estuarine research, "Man's increasing ability to modify natural systems, particularly through engineering works, has far outstripped his ability to forecast the changes in complex ecosystems". One thing is certain, however, and that is that the shorelines and bottom of the Bay will continue to change in response to the varying natural forces as well as to human activities. If, as a result, the depth and shape of the Bay change sufficiently, it is possible that the sloshing associated with the "bathtub effect" will gradually fall out of step with the tidal pulses and there will be a gradual decline in Fundy's monstrous tides. Because these powerful tidal forces so strongly shape Fundy's productivity and ecology, it is inevitable that such changes would profoundly alter its ecosystem.

Furrowing Floes and Howling Hurricanes

There are other natural phenomena that can also greatly change marine communities and thus obscure the effects of human activities. Winter ice and gales can be particularly damaging to marine organisms and their habitats. Thousands of years ago, glaciers scraped their way across Nova Scotia, crushing everything in their path. A similar thing, but on a far smaller scale, happens in winter on the Fundy mudflats. In some years, thick layers of ice form on the saltmarshes and mudflats of the estuaries. These glacial rafts float, move around and ground with the tides and currents. Flora, fauna and habitats are crushed and scraped by this grinding ice. The sediments may be deeply gouged or completely abraded away over large areas. Although the damage can be extensive and severe in some years, the recovery is usually rapid. By mid summer ice-scoured and untouched mudflats are usually indistinguishable in appearance and in numbers and types of animals.

Severe storms can have a far more devastating and lasting effect on the mudflats. We have a good idea of the ecological destruction that these storms can wreak, thanks to the fact that researchers from Acadia University have studied Minas Basin mudflats for decades. Thus they had a good idea of what particular intertidal areas looked like before a major storm roared through the region in 1975. Surveys shortly after, revealed that it had "caused significant erosion of the flats", with up to 8 centimetres of surface material completely removed. As for the animals, primarily clams and amphipods, "reductions as a result of the storm were catastrophic", with more than 90% of the populations destroyed. Windrows of dead clams and amphipods appeared on nearby beaches and saltmarshes. Because such large areas were devastated, recovery was

slow. A year later the animals were only 20% of their numbers before the storm; and even the following year numbers were still much depressed. Researchers ominously concluded that "recovery from major catastrophes may take a decade or more". Not all storms that pass through the Bay of Fundy are quite so devastating. Impact is influenced by the state of the tide when the storm strikes. The destructive "Saxby Gale" of October 1869, arrived at a time of very high tides and pushed the waters up to unprecedented levels. Tides in excess of 21 metres at the head of the Bay, destroyed miles of dykes, flooded thousands of acres of farmland and killed large number of cattle. Regrettably, in 1869 mudflat ecology was not a priority at Acadia University, or anywhere else, so we have no idea what "Saxby" did to local marine life and habitats. Chances are its effects were catastrophic and long-lasting.

The Challenge of Change

Geological processes, rising sea level, changing tidal amplitude, ice scour and hurricanes will continue to modify and shape the Bay of Fundy environment and influence its animal and plant communities. Change is, and always will be, a fundamental part of living nature. There is little that humans can do to prevent these natural changes from occurring. It is, nevertheless, important that we learn as much as possible about these processes so that we can better understand and anticipate their effects. Also, only by clearly understanding how ecosystems change naturally can we really determine if particular human activities are responsible for some of the undesirable changes that we see happening around us.

A good example of the confusion and uncertainty that can arise is provided by the recent groundfish crisis in the Northwest Atlantic. Some scientists have argued that the collapse was largely due to overfishing. Others are just as certain that it was a result of natural changes in ocean current patterns and water temperatures that were unfavourable for the fish stocks. If we had known more about these periodic changes in ocean currents and water temperatures and the effects they have on survival, growth and distribution of fish then we might have been in a better position to decide between the possible causes and to react accordingly. In science, as in life, forewarned is forearmed.

Further Reading

The postglacial evolution of the Minas Basin, N.S.; a sedimentological interpretation. C.L. Amos. Journal of Sedimentology and Petrology. Volume 48, pages 965-982. 1978.

A sea-level scenario for Minas Basin. J.S.B. Bleakney. Pages 123-125 In Effects of changes in sea level and tidal range on the Gulf of Maine - Bay of Fundy system. Edited by G.R. Daborn. Acadia Centre for Estuarine Research. Publication Number 1. 1986.

Relative sea-level rise and tidal development in the Fundy tidal system. D.B. Scott and D.A. Greenberg. Canadian Journal of Earth Science. Volume 20, pages 1554-1564. 1983.

Natural and anthropogenic changes in the Bay of Fundy - Gulf of Maine - Georges Bank System. G.R. Daborn and M.J. Dadswell, Pages 547-560 In Natural and Man-Made Hazards, edited by M.I. El-Sabh and T.S. Murty. D. Reidel Publishing Co. 1988.

The Fundy Issues Series is an initiative of the Bay of Fundy Ecosystem Project. These publications describe our present scientific understanding of some of the environmental issues confronting the Bay. We hope that they will enhance your understanding of the biological richness and complexity of this unique marine area. Such awareness may encourage you to help in protecting it for the use and enjoyment of all, particularly future generations who may also come to rely on its bounty and rare beauty. The origin, evolution and aims of the Bay of Fundy Ecosystem Project are described in the first issue of this series.

Written and produced by J.A. Percy
The Clean Annapolis River Project, P.O. Box 395, Annapolis Royal, Nova Scotia B0S 1A0
Tel: (902)532-7533 Fax: (902)678-1253 e-mail: shawboldt@fox.nstn.ns.ca

The Bay of Fundy Ecosystem Project is supported by Environment Canada, the Department of Fisheries and Oceans Canada and the Acadia Centre for Estuarine Research.

This publication is financially supported by the Gulf of Maine Council on the Marine Environment.