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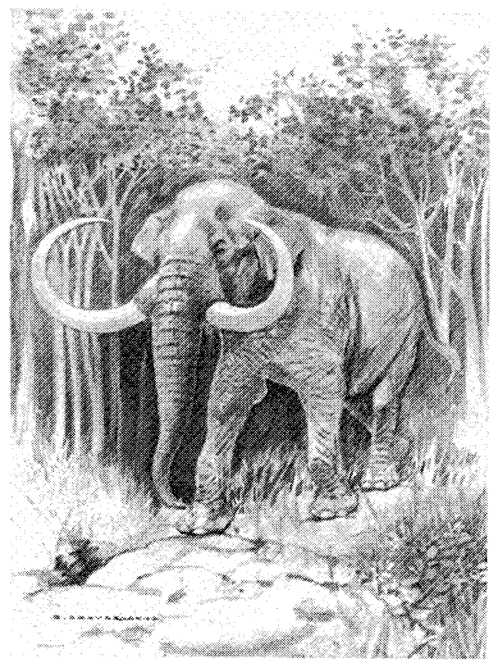
FUNDY ISSUES

Fundy in Flux

The Challenge of Understanding Change in the Sea.

Unchanging Change?

Lumbering mastodons once roamed its rolling hills, caribou herds grazed its grassy valleys and noisy flocks of waterfowl crowded its lush, fringing salt marshes. Today cod and halibut roam its sunken hills and valleys, and migrating whales sweep past 60 metres overhead. Gone are the mastodons and caribou, save for a few fossils. The migrating flocks now wing over surging swells, oblivious to their ancestral refuge hidden in the depths. Obviously something has changed on Georges Bank and in the Gulf of Maine/Bay of Fundy during the 12,000 years between then and now! We cannot escape such change in our world; it is everywhere, within and around us. Some 2,500 years ago a Greek Philosopher, Heraclitus, declared that "Change alone is unchanging"; a thought that rings even more true today. We live in a world of bewildering alterations in social, economic and environmental conditions that are often linked in complex ways. For example, industrial plants built near a village increase economic opportunities, attract new residents, stimulate residential development, and expand social activities and institutions. Inevitably, the quality of air, water and landscape, and the abundance and variety of wildlife also change, often for the worse. Clearly, economics, sociology and ecology are all part and parcel of these changes. Here, we are mostly concerned about environmental changes, particularly those involving the Bay of Fundy, but the other two aspects are seldom far away. If change is so inevitable and has always been with us, then why should we worry about it now? Partly because Herodotus didn't get it exactly right; certainly change is inevitable, but the



Mastodons once roamed the fishing banks of the Gulf of Maine.

FMESP Fundy Marine Ecosystem Science Project

BoFEP Bay of Fundy Ecosystem Partnership

rate at which change happens can vary greatly. No one would dispute that the pace of social, economic and environmental change has increased sharply during the past century or so, and it still quickens with each passing year. Alarmingly, many of the environmental changes now seem to be caused by human activities; and most of them are not ones that we are particularly happy about. Indeed, some threaten our social and economic well being and that of our children and grandchildren. Thus we have good cause to worry about change.

"Perhaps the most worrisome thing about these changes is that scientists aren't really sure why they are happening and what is causing them".

The Bay of Fundy is not immune to change. Over the past several decades it has altered in many worrisome ways. In the outer Bay, seabirds, such as phalaropes, petrels and puffins are not as numerous as they once were. Some species have also noticeably changed where and how they search for food. Male and juvenile North Atlantic right whales don't congregate on Banquereau Bank anymore, but instead in the outer Bay of Fundy where the females and calves had traditionally gathered. Local populations of commercially valuable groundfish, such as cod, halibut and haddock, have collapsed and their ecological place seemingly taken by cartilaginous species, such as dogfish and skate. Something unusual may also be happening to the mud flats surrounding the Bay's inner basins. In Chignecto Bay the sediments may be becoming finer and more watery, while in the adjacent Minas Basin they seem to be getting sandier and drier. These seemingly small changes, if real and continuing, may have huge implications for migrating shorebirds, such as the semipalmated sandpiper, which depend on the swarms of burrowing crustaceans that can only thrive in mud with a very precise consistency. (For more about this see Fundy Issues Number 3, *Sandpipers and Sediments: Shorebirds of the Bay of Fundy* and Number 13, *Keystone Corophium: Master of the Mudflats*). Perhaps the most worrisome thing about these changes is that scientists aren't really sure why they are happening and what is causing them, or whether they simply reflect a natural change in the marine environment. Suspicions about causes abound: blockage of rivers by causeways, global warming because of greenhouse gases, increased ultraviolet radiation from a thinning ozone layer, long-term oceanographic or tidal cycles, pollution, or careless harvesting of marine resources by humans. Lots of suspects, but few smoking guns!

Characterizing Change

We know that our natural environment is changing, but what exactly is the nature of that change and how do we detect and measure it. We have all heard garrulous elders claim that winters were much tougher when they were kids, and there sure used to be a lot more snow! Others fondly recall catching monstrous sturgeon in the local river where there aren't any now. Scientists are never sure how to treat such reminiscences; there are no numbers, no specific dates and no multiple observations. They are also wary about the vagaries of memory and the subtle allure of embellishment. Thus they lump such informal personal observations into a catchall category of "anecdotal" information, from the Greek for "things unpublished". Scientists are trained to be obsessive about documenting the source of every statement. They are at ease with facts gleaned from learned journals, but uncomfortable with an observation supported only by "my neighbour told me that he remembers….". Not that they don't believe it, but it isn't a sound reference that other scientists could easily check. Perhaps even more importantly, there are no numbers to use in a graph, table or equation. However, some scientists have come to recognize that this sort of "anecdotal information" might be useful in identifying and understanding certain types of ecological change. They are thus seeking innovative ways of incorporating it into their thinking.

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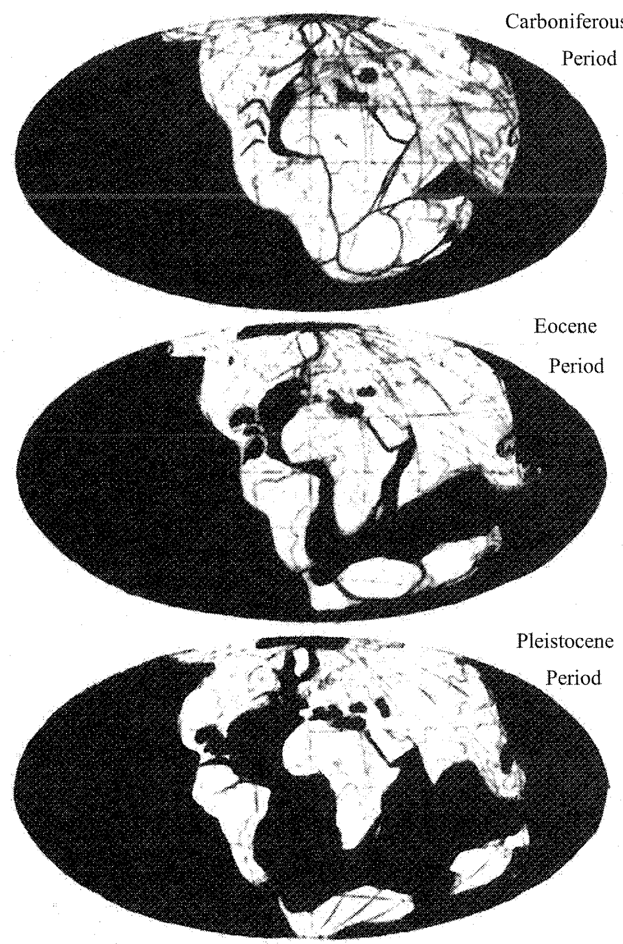
There are now efforts being made to record many of these "stories" about environmental conditions in the past from old-timers who have spent a lifetime on the shores of Fundy, before it is too late. An excellent example is the book "*Voices of the Bay: Reflections on Changing Times Along Fundy Shores*" (See Further Reading), a fascinating collection of interviews with dozens of residents of New Brunswick's Fundy Coast.

"We can do little to alter most of these great, slow geological upheavals. But if we are aware that they are happening then there may be things we can do now to avoid unwelcome surprises in the future."

The Pace of Change

When we think about changes in our environment we have to consider the length of time involved. Some changes, such as the flooding or erosion of a shoreline during a storm surge, occur within minutes to hours. Others, such as filling in of a channel by sediments may take years or decades, and be just within the memory of long-term residents. Other changes involve the geological time scale, and are quite imperceptible to us in a lifetime. These include momentous changes such as continental drift, fluctuating sea level and the uplift and weathering of mountain chains. We have to rely on indirect evidence to convince ourselves that such changes have indeed taken place and that they are almost certainly continuing right now. We can do little to alter most of these great, slow geological upheavals. But if we are aware that they are happening, then there may be things we can do now to avoid unwelcome surprises in the future. For instance, if sea level is indeed rising, shouldn't we think about restricting building in vulnerable, low-lying coastal areas? We should also be aware that these gradual natural changes form a constant, slowly changing backdrop to the more pressing environmental emergencies that we may be able to halt, reverse or modify.

The Bay of Fundy has seen very dramatic changes in the past few thousands to few millions of years. This reassuringly stable piece of geography around which we dwell is, in fact, only a brief interlude in a long geological saga. It has gone from a landscape totally foreign and unrecognizable to us and is heading towards a future one almost certainly equally as strange. Between 600 and 350 million years ago, the continental masses of North and South America, Europe and Africa drifted together, squeezing out the original Atlantic Ocean, to form a supercontinent, Pangaea. Thus, some 200 million years ago Nova Scotia was a small fragment wedged tightly between North America and Africa, much nearer to the the equator. Then, 190 million years



Some 200 million years ago Nova Scotia was located nearer the equator, wedged between North America and Africa, in a supercontinent named Pangaea (top). Gradually the continents drifted apart to their present locations.

ago the drift reversed and the Atlantic Ocean reappeared. As the continents separated, rift valleys formed, extending from Nova Scotia to South Carolina. Most of these quickly filled with the sediments eroding from the continents. The Bay of Fundy is a remnant of one of these ancient rifts. Continental movement is still going on today, a few centimetres each year at most. Geologists tell us that 15 to 20 million years ago the Gulf of Maine was only a shallow, submerged gradual seaward slope, with no deep basins, banks or steep-sided channels. This flat coastal seafloor slowly emerged as dry land. It is not certain whether this was because the land rose or the sea fell; perhaps both. Great rivers, draining the nearby highlands, soon eroded this newly exposed coastal plain, carving out the sediments and softer rocks to form deep valleys and steep-sided gullies. Two million years ago vast, thousand-metre thick glaciers expanded across much of northern North America. Grinding over the region, they carved out even more of the softer rocks and sediments to form the deep inner Basins of the Gulf. These glaciers receded about 13,000 years ago and seawater flooded into the newly sculpted basins and gullies. With the heavy ice burden removed, the land rose and the sea fell 60 metres below its present level on the shore. The harder, resistant rocks of Georges and Browns Banks emerged from the sea as extensions of Cape Cod and Nova Scotia, respectively. These two encircling capes almost cut off the deep basins within the Gulf of Maine from the Atlantic Ocean. There remained only a deep entrance through the present day Northeast Channel and another shallower, narrower passage across the present Tantramar marsh to the Gulf of St Lawrence, effectively making Nova Scotia an island. This sheltered body of water is known as the DeGeer Sea in honour of Baron Gerard DeGeer, a Swedish Geomorphologist. It was a very different Bay of Fundy than the one we know now; no massive tides, no tidal bores, no surging currents and probably very different plants and animals. It was then that the mammoths and caribou grazed upon Georges Bank. Steadily rising sea level has long since sunk Georges and Browns banks under 60 metres of seawater, deprived Nova Scotia of its island status and opened wide the Gulf of Maine to the influence of the Atlantic Ocean. The sea level is still rising today and thus the geography and hydrography of the Gulf will continue to slowly change.

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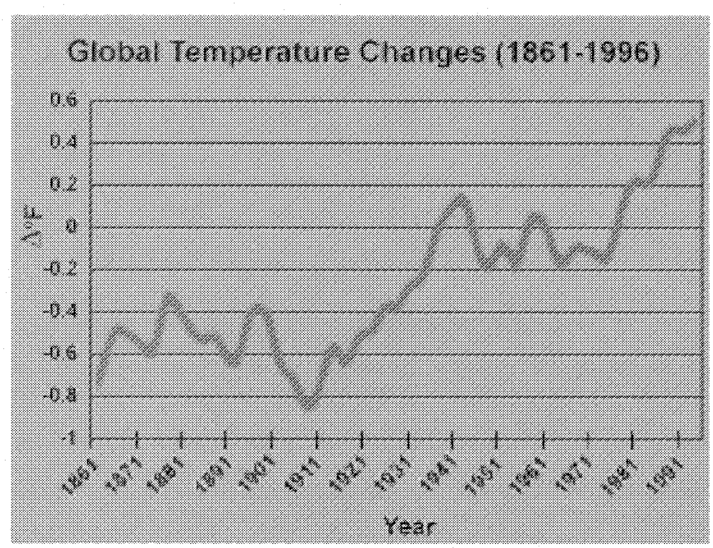
Cycles of Change

Many changes in nature are really cycles and if you wait long enough things will eventually "come around again". Some of these cyclical changes involve the physical environment, such as the annual fluctuations in air and sea temperature with season. Others are clearly biological, such as the periodic rise and fall in seabird populations or fish stocks. Some cycles, particularly many of the physical ones, are precise, regular and predictable while biological ones are often seemingly random, complicated and unpredictable. Cycles, such as tidal ones, repeat themselves within a matter of hours, while others, such as fluctuations in animal populations or in



Global temperature change is one of the background "natural" environmental fluctuations that ecologists have to consider in studying ecological changes.
Intergovernmental Panel on Climate Change, 1995

climatic and oceanographic conditions may take years, decades or even centuries. Some cycles are even longer and often we might not even recognize them as such; rather they seem to be a continuous one-way change. Rising and falling sea level, global temperature fluctuations and glacial growth and retreat, occurring over periods of thousands if not millions of years, are examples of this sort of phenomenon. Going one step further, geological cycles of continental drift and mountain building may take hundreds of millions of years. The key point is that virtually all features of the environment are changing constantly, on many different time scales, without any help or hindrance from man. This sometimes makes it difficult for researchers to tease out the environmental changes that can legitimately be attributed to human activities from the great cacophony of "background noise" of constant natural change. Short-term, predictable cycles can often be accounted for fairly easily. It's the longer-term, unpredictable and poorly known ones that present a real challenge.

Is it a natural change or did we cause it?

The Hand of Man or Nature?

One of the challenges we face is to determine which environmental changes result from human activities and which are caused by natural processes. Scientists use the term "anthropogenic" (from the Greek Anthropos for human being) for changes in which the hand of man is clearly evident. However, all too often man and nature work hand in hand to cause a particular ecological change, although it is seldom clear who is most responsible. In the last few centuries environmental changes have been occurring at an accelerated pace. This is clearly linked to an exploding human population, man's growing technological prowess and his continuing efforts to adapt the environment to his own needs. We use the term "impact" for an environmental change caused by some human activity. It implies that there is a definite cause and effect between what man has done and how nature has reacted. Thus, the accumulation of mud below the causeway across the Avon River is an environmental impact of blocking the river. In complex, natural systems most "causes" usually result in many different environmental impacts. We tend to focus on the one or two that are particularly obvious or of special concern to us. But there are usually many others that are less obvious, but just as ecologically important. Sometimes we simply aren't aware of some of the impacts that we perhaps ought to be concerned about. For example, we should be asking - "Where did all the mud go before we built the causeway on the Avon River? Does the fact that it is no longer going there have any lasting effects on other parts of the Bay that may only become apparent much later?" Unfortunately we don't know enough about the intricate connections between mud erosion and accumulation, shifting water currents and the complex lifestyles of the animals and plants that dwell in muddy places to answer these questions completely. Most of our "interferences" with the natural world cause a mixture of such known, poorly known and totally unknown "impacts". We should be very wary of promoters, developers and engineers who glibly assure us that the ecological consequences of their projects are negligible and there is nothing to worry about.

Is the change permanent or reversible?

Another important point to think about is whether an environmental change is permanent (irreversible) or can be easily undone (reversible). Driving a bulldozer through a woodlot, or towing a trawl through a kelp bed greatly disrupts large areas of each habitat. But nature is usually resilient and in time the vegetation regenerates and the scars on the landscape heal. In time both areas return essentially to the way they were. However, if the assaults are repeated monthly or yearly, then the habitats may never have a chance to recover and they remain degraded and desolate as long as the activity continues, and often beyond. In some particular situations, even a single major assault may permanently alter the environment. The ecosystem never reverts completely to its original state. For example, some scientists feel that even if causeways are now removed it is unlikely that many of the affected rivers and estuaries would ever revert completely to their former ecological state.

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Combining Changes

Scientists are particularly concerned about the "cumulative" effects of human activities. Often, when we consider the effects of an activity, such as the filling of an area of salt marsh to create a building lot, we limit our thinking to that one specific project. We conclude that it is only a small area of marsh and its loss will not greatly alter the diversity or productivity of the greater coastal ecosystem. But there are many such "little" projects going on all around our coastlines. Many widely scattered fragments of salt marsh are being filled and buried. Undersized highway culverts, shut off the tidal exchange the marsh needs to survive and thus slowly strangle other little pieces. Other marshes are slumping and eroding because new wharves or other such structures have changed the flow of the passing tidal currents. Unfortunately, nobody is keeping tabs on all of the "insignificant little bits" that are being lost, so we are unaware of what is happening to the overall coastal ecosystem. It is all of these little losses added together that is the "cumulative effect" of all these different activities. If they are summed, the total impact may be as great, if not greater, than that of a single large project affecting hundreds of acres of marsh. A project of such magnitude would be minutely assessed and the environmental costs carefully considered. And yet, we think nothing about frittering away an equivalent area in small, "insignificant" bits and causing an ecological "death by a thousand cuts"!

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Scientists worry too about "synergistic effects". These also involve the combined impacts of several human activities. However, cumulative effects are additive; in other words if one project causes 2 units of environmental damage and another nearby one causes 3 units of damage, then the total damage of both projects is 5 units. In contrast, synergistic effects reinforce each other, almost as if the damages were being multiplied rather than simply added. Thus, in our example the two units of damage and 3 units of damage would cause a total of 6 units of environmental damage. Examples of this are somewhat obscured by the complexity of biological and ecological processes, but they do occur and are of real concern. A very simplistic example would involve a chemical that becomes more poisonous to marine organisms as the temperature increases. Assume that on a particular estuary a chemical company is dumping this particular substance in amounts just sufficient to make fish and other animals slightly sick, but not kill them. However, a nuclear power plant is built nearby and it draws water from the estuary to cool its reactor and returns heated water to the estuary, raising its temperature by only a few degrees. Separately, there might not be any obvious environmental effects of chemical release or water warming. However, the slight rise in temperature is just enough to make the chemical lethal to fish and large numbers die and wash ashore. This oversimplifies a complex situation, but it illustrates the principle and shows why both "synergistic" and "cumulative" effects are worrisome to ecologists.

Checking on Change

We have already seen that scientists are wary about accepting "anecdotal" reports of change and much prefer concrete, measured and repeatable observations. Many different scientific methods and tools can used to measure environmental change. Some techniques can detect changes in the environment, while others monitor the populations of animals or plants living there. In recent decades there have been tremendous advances in the development of new scientific tools to measure ecological change. Remote sensing techniques, such as satellite imagery, broaden our vision of the world immeasurably. Computerized analytical techniques enable us to quickly process and make sense of the huge amount of information that the increasingly sophisticated new monitoring tools are producing. Consider a few examples of the many new and exciting techniques. Until recently scientists' ability to "see" the seafloor was limited. They bounced sound waves off the bottom with echo sounders to get a very crude picture of the shape of the seafloor. But such depth traces were limited to a narrow line right under the track of the vessel and gave a distorted, two-dimensional view of the sea floor. To study the bottom in more detail they lowered grabs or corers to bring up samples of sediments. But these were taken at widely scattered points and there was uncertainty about what lay between them. Underwater still and video cameras, and manned submersibles give a slightly better view of portions of the seafloor, but the coverage is still sparse. Since the early 1990s a more sophisticated survey method has enabled scientists to map large areas of the seafloor in remarkable detail. This new multibeam "swath" technology is discussed in Fundy Issues Number 5, *Dredging Fundy's Depths: Seabed Mining in the Bay of Fundy.* The survey ship sweeps a wide track on the seabed with sound waves of many different frequencies (hence multibeam) and collects the returning echoes with an array of sensors. Computers process the incoming information and generate a three-dimensional map of a wide strip of the seafloor on both sides of the ship's track. By running along a series of parallel tracks the survey vessel can quickly and completely map a very large area. The result is an incredibly detailed picture of the seafloor, almost comparable in quality to an aerial photograph. Details such as boulders and sand waves, biological structures such as mussel reefs and kelp beds, as well as the tracks produced by the dredges and trawls of fishing vessels, are all clearly visible. In fact, this powerful new tool is showing us for the first time the extent of the disturbance that commercial fishing gear is causing to seafloor habitats. By mapping the same areas every few years scientists will be able to see major environmental changes resulting from natural processes or human activities. Gordon Fader and his colleagues at the Bedford Institute of Oceanography have been in the forefront in using this technique off the coast of Atlantic Canada. Areas of the Scotian shelf and the Bay of Fundy have already been mapped, providing a baseline against which to monitor any future changes in seafloor habitats.

"for a monitoring project to have any real value it must be continued for a long period. Only then can we sort out the real trends of environmental change from the random variations and natural cycles."

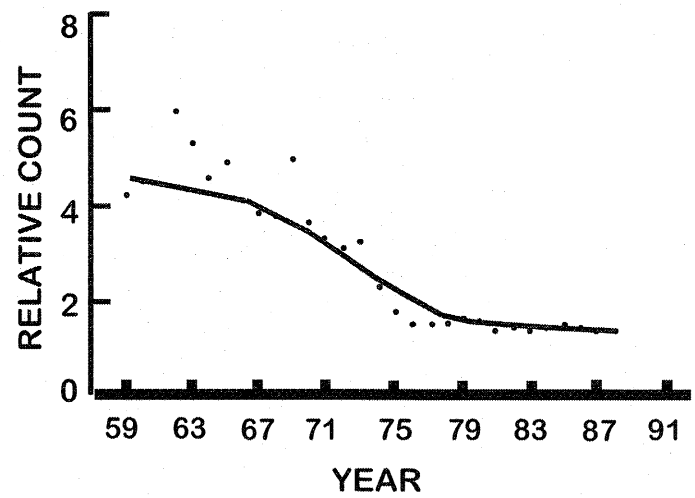
An important new computer tool that is revolutionizing the way that we can look at complex environmental information is GIS (Geographical Information System). GIS programs permit a researcher to store a particular type of sample measurement, such as the percentage of sand in bottom sediments, in a data file in which each sample is linked to the specific point on a digitized map where it was collected. Other measurements, such the abundance of clams, salinity or water depth, are also each stored in their own data file and similarly linked to points on the same map. Each of these files can then be used to produce a "layer" on the map showing the distribution of its particular feature. Many different information layers can be superimposed over each other on the digital map, much as clear plastic overlays with information drawn on them can be piled up on a map to show the geographic distribution of the various measurements in relation to one another. But unlike the plastic layers, the computerized ones can not only be easily displayed, but much more importantly they can also be manipulated in a great many complex ways to produce new layers of information that would be difficult if not impossible to obtain in any other way. By periodically collecting the same type of information over large areas with remote sensing techniques, a GIS can be used to quickly detect changes in many different environmental features. For example, scientists at the US National Marine fisheries Service in Boothbay Harbor, Maine periodically survey the size and condition of coastal eelgrass bed by aerial photography. By scanning the information into computers and then using a GIS they are able to closely monitor changes in the extent and condition of the ecologically valuable eelgrass beds along much of the State's complex coastline. A similar approach could be used to monitor ecological changes in the vulnerable salt marshes of Fundy. Sometimes by using a GIS to analyze a particular environmental change at different times in different places it may even be possible to determine the cause.

"An inevitable fact of evolution is that species become extinct and are replaced by more resilient ones better adapted to the changing environment. However, scientists worry that nowadays species are fast disappearing largely because of human activities."

Monitoring Change
Biodiversity and Bird Counts

Detecting changes in the abundance and condition of other living things, particularly animals, may not be quite as straightforward. Nevertheless, it is becoming ever more urgent that we develop new approaches and new tools to monitor the status of our diverse wildlife populations. An inevitable fact of evolution is that species become extinct and are replaced by more resilient ones better adapted to the changing environment. However, scientists worry that nowadays species are fast disappearing largely because of human activities. Steady degradation of habitats in much of the world is leading to a decrease in the "biodiversity" or variety of species in many areas. The degree of biodiversity differs according to habitat. Coral reefs, home to an astonishing variety of fish and invertebrates, have an extraordinarily high biodiversity. In contrast, few species live in arctic tundra ponds or in hot springs, and biodiversity is exceptionally low. Most habitats fall between these extremes. High or low biodiversity is thus not necessarily an indicator of the health of a particular habitat. However, ecologists have found that as habitats degrade the number of species usually declines. In extreme situations almost all animals and plants may be killed or driven out, leaving only a few hardy opportunists. Thus, it is not just the level of biodiversity that is of interest in habitat monitoring, but rather large changes in the biodiversity index over a period of time. To monitor habitat health using the biodiversity index, many different species have to be sampled, identified and counted periodically. This is a complex, labour intensive task given the numbers of plants and animals living in most habitats. Often, only a few "indicator" species are counted to keep the task manageable. A sudden rise or fall in the abundance of any of the "indicators" alerts us to possible undesirable changes in the habitat. One of the most often cited examples of this approach was the sudden decline in the number of raptors, such as hawks and eagles, across much of North America in the 1960s. Careful study revealed that the widely used pesticide DDT was accumulating in their food chain and causing thinning of eggshells and a decrease in successful hatching. Curtailment of DDT use has allowed raptor numbers to rebound.

However, the problem with monitoring environmental change by watching animal or plant populations is deciding which ones to count. There are thousands of species in and around the Bay of Fundy from which to choose. Presumably, a team of ecologists could come up with a selection of representative species from key habitats to monitor. Some groups such as the Environmental Monitoring and Assessment Network (EMAN) are striving to do just that. However, species are more often selected for monitoring because of their particular interest to those doing the counting. Many are monitored because of their value to humans, not because they are good indicators. Thus, the Department of Fisheries and Oceans (DFO) monitors populations of commercial species of fish and shellfish by recording the amounts fishermen are catching and by doing survey cruises. The problem with this sort of monitoring is that it is difficult to know whether fluctuations in the populations are caused by a change in the environment, by the fishing itself or by both. For an example we have only to consider the ongoing arguments among scientists as to whether the recent collapse of groundfish stocks was a result of overfishing, predation by seals, changes in water temperature, ocean currents or something else entirely. Some populations are monitored for their potentially harmful effects. For example, DFO regularly monitors phytoplankton to keep an eye out for the poisonous species that cause "red tide" and other dangerous algal blooms. Birds may be the best monitored of all species, for a number of very good reasons. The Canadian Wildlife Service (CWS) and groups such as Ducks Unlimited carefully track the abundance of waterfowl, such as ducks and geese. to ensure the continuity of the species as well as the lucrative hunt. Many waterfowl and shorebirds have wide-ranging migrations. Most of these are protected by international wildlife treaties that require monitoring of their status in countries throughout their range. Thus, CWS keeps track of the populations of shorebirds such as semipalmated sandpipers that feed heavily in the Bay of Fundy during migration. However, perhaps the most remarkable monitoring effort involving the greatest variety of birds over the largest area is that carried out by amateur birders strictly as a hobby. Each year a number of different bird counts, such as the Christmas Bird Count, the North American Feeder Watch program, the Breeding Bird Survey and other similar well-organized efforts draw upon a huge network of birders to estimate bird populations. Some counts have been going on for many decades and provide valuable information about the trends in numbers of many bird species throughout North America.



Counts of birds such as semipalmated sandpipers over many years can provide information about population trends.

— Data from North American Breeding Bird Survey

> ***"for a monitoring project to have any real value it must be continued for a long period. Only then can we sort out the real trends of environmental change from the random variations and natural cycles."***

Monitoring change
Looking back to the future

Measuring water temperature, gauging sea level and counting birds are good ways for studying present or future changes. But what about changes that took place ten, a hundred, a thousand or even a million years ago? How do we go about studying them? We can get some idea about changes that have occurred within this generation by collecting "anecdotal" information, provided we allow for the vagaries of memory. We can also get useful information from samples or records that were collected long ago for a variety of reasons. Thus, old photographs may provide hints about changes in the geography of shorelines or coastal wetland during the past century. Scientists have estimated amounts of chemicals, such as lead, in the environment a hundred or more years ago by analyzing samples of tissue from animals or plants preserved in museums. However, to look any further back in time we can sometimes use "proxy" data, or substitute information that is linked to a feature of interest that can't be directly measured. We are familiar with counting the rings of trees to determine their age. The tree's rings can also serve as proxy data for information about local environmental conditions during each year of its long life. The relative widths of the rings record good and bad years for tree growth. Thus, they may provide a long continuous record of the occurrence of hot or cool or wet or dry summers. Gail Chmura, a scientist at McGill University, is using a comparable method to study how the salt marshes of Fundy have changed over the past few centuries. In a manner similar to analyzing tree rings, she studies the thin layers of fine sediments that have been deposited annually on the marshes. A specially designed corer is pushed deep into the sediment to freeze a long cylinder of soft mud that can then be removed for study. Thin layers can be pared off this mud "sausage" and used in various types of analyses. The "age" of the core at various depths can be determined by examining particular radioisotopes, preserved pollen grains or various other "event markers". It is possible to estimate the rate at which the sediment was deposited at different times in the marsh's long history and thus learn much about how it grew. It has also been possible to measure substances, such as lead, at various depths in the mud and determine how the amount in the environment has changed over the centuries. By comparing results from many different areas, Gail is hoping to be able to learn a great deal about the history of Fundy's salt marshes and the nearby coastal ecosystem. Many researchers are using other types of "proxy" data to glimpse even further back into the Bay's long turbulent history. Understanding natural processes and their cycles or trends that have already taken place on the earth is essential to anticipating how they might influence our environment far into the future.

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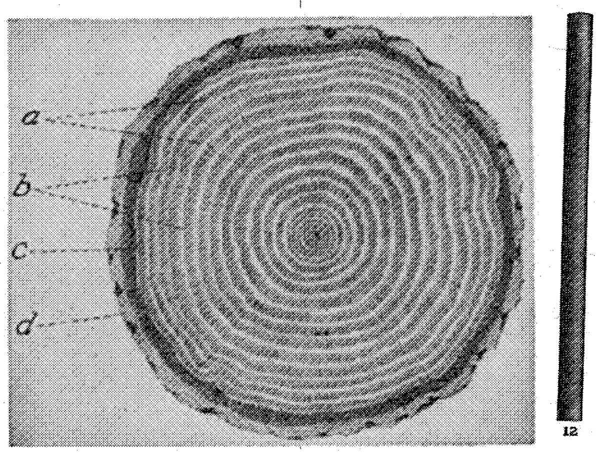

Information stored in the rings of a tree (left) and in the layers of a core of sediment from a marsh (right) can be used to study changes in the environment over time.

One important lesson that we have learned from studying proxy data, monitoring populations and measuring environmental changes is that for a monitoring project to have any real value it must be continued for a long period. Only then can we sort out the real trends of environmental change from the random variations and natural cycles. Counting sea gulls for a couple of years is probably not going to tell us whether their population is rising or falling. But with several decades of data, such as that provided by the Christmas Bird Count, we can get a real sense of what is happening to the birds and whether we ought to be concerned. In order for such long-term monitoring to work it has to have reliable funding and good organization. This usually means the active involvement of well-established institutions with a long-life span, good archival facilities and skilled people, such as academic institutions, museums or government agencies. Trained volunteers may still do much of the field-work. For example, bird count data are collated, stored and made available by Cornell University. Similarly, the Canadian Wildlife Service compiles information about shorebird and seabird abundance and DFO accumulates information on fish stocks and oceanographic conditions. Some scientists advocate the establishment of dedicated marine archival identification centres and the creation of tissue banks for the long-term storage of representative marine biological samples. We cannot even guess what people might want to measure in the future in their response to unforeseen environmental problems. Preserving representative samples of tissues from many species might give them the material needed to better monitor changes in the amounts of contaminants in the environment.

"It is critically important in comparing measurements collected in different areas or at different times that all the researchers use the same methods of sampling, measuring and recording information."

Long-term monitoring of environmental conditions and biological diversity over large areas has to be a co-operative venture involving many partners, and sometimes many nations. The decline in habitat quality and biological diversity is a worldwide problem of growing international concern. In 1992 the United Nations completed a Convention on Biological Diversity that obliges countries, including Canada, to ensure the conservation and sustainable use of their biological diversity. The Convention defines biodiversity in a broad sense to include not just species, but genetic groups, such as races or varieties, and ecological communities, such as salt marshes or kelp beds. Article 7b of the Convention requires routine monitoring of biological diversity. In complying with this, Canada prepared a Canadian Biodiversity Strategy in 1995. As part of the strategy, Environment Canada established the Ecological Monitoring and Assessment Network (EMAN) to promote the long-term monitoring of biological diversity in many different habitats, from forest to seafloor. EMAN comprises a network of representative study sites in different terrestrial and marine ecological zones across Canada. Similar regional sites are grouped into Ecological Science Co-operatives consisting of groups and organizations conducting long-term research and monitoring programs in the region. EMAN monitors the rate and magnitude of ecological changes at its study sites and tries to determine whether the changes are cycles or trends in environmental conditions. It also examines the causes and consequences of environmental change. Another of its important tasks is to develop "protocols" or detailed instructions on how to measure different environmental features. It is critically important in comparing measurements collected in different areas or at different times that all the researchers use the same methods of sampling, measuring and recording information. Because biodiversity encompasses such diverse things as microscopic phytoplankton and hundred-tonne whales, a correspondingly wide variety of different sampling "protocols" are needed. A large number of agencies, institutions and groups monitor a wide range of species and ecological processes in various parts of Canada. Many, such as Parks Canada's Breeding Bird Survey, the Biological Survey of Canada of the Canadian Museum of Nature and the Atlantic Co-operative Wildlife Ecology Research Network (ACWERN) are partners in EMAN. Clearly we are now developing not just the technological tools and expertise, but also some of the institutional structures that can help us to better monitor our environment over the long term, and thus enable us to react to ecological change in a timely manner.

"Any changes we cause must not detract from the ability of those future generations to share in the many benefits of the natural world (economic, environmental, recreational, educational, aesthetic and spiritual) that we now value."

Coping with Change

Herodotus warned us that change is the only thing that is constant in our world. How then should we respond to the "inevitable" environmental changes that are taking place all around us? We certainly shouldn't feel complacent or helpless. We know enough about some of the large-scale changes, such as sea level rise and global warming, to learn to adapt to them, even if we can't halt them. We have also seen that human activities cause great, often disastrous, environmental changes. Earlier generations bear a heavy responsibility for a lengthy list of assaults on the environment whose effects we have inherited and very much regret today. Their indiscriminate hunting drove the passenger pigeon and great auk to extinction. They little dreamt that anything they did could wipe out such remarkable natural abundance. But they were wrong, and we are all the poorer for it. The list of past environmental disasters is a distressingly long one. But at least our forefathers could justifiably plead ignorance of some of the environmental consequences of their actions. They had neither the knowledge nor the tools to measure or predict the ruinous effects. We, however, have no such defense. Our steadily advancing science and technology is providing us with the tools to monitor many of these environmental changes and to predict the ecological consequences of our actions. We have the ability to anticipate the adverse impacts of our activities on the environment. We therefore have to accept full responsibility for the consequences. We can reasonably be held accountable by future generations for our actions or inaction. Any changes we cause must not detract from the ability of those future generations to partake in the many benefits of the natural world (economic, environmental, recreational, educational, aesthetic and spiritual) that we now value. We must plan to adapt ourselves to those changes we can't influence and carefully and thoughtfully manage the ones that we can. Building upon the pronouncement of Herodotus, our watchword as responsible stewards of the environment must be "Change is inevitable, but not intractable".

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Further Reading

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The Fundy Issues Series is an initiative of the Bay of Fundy Ecosystem Partnership. 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 and the problems confronting it. Such awareness may encourage you to help in protecting it for the use and enjoyment of all, so that future generations may also share and appreciate its bounty and rare beauty.

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