SciencePages

Mapping Animal Distribution and Changes in the Ocean

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Stretched across the sea floor like beads on a string, acoustic receiver stations detect tagged animals up to half a kilometre away (1). The Halifax Line, extending over 100 nautical miles offshore from Halifax to the edge of the Scotian Shelf, is the longest acoustic receiver line in the world gathering data on animal movements and ocean conditions more frequently and with greater accuracy than current wide-spread methods like sampling and monitoring from research vessels (2).*

How much do we know about the oceans?

To guarantee the many benefits Canadians draw from the marine environment, we must understand how plants and animals, including humans, are interconnected (3), and sustainably manage human activities in a way that maintains ocean resources and ecosystems.

Management at the ecosystem level is challenging given our present state of knowledge—perhaps two-thirds of marine species globally have yet to be described by science (4) with Canada's biggest gaps occurring in the deep oceans outside of our Exclusive Economic Zone and in the Arctic.

Historically, humans have been unable to reach all parts of the ocean. In recent years, tremendous technological advances have been made and there is no area of the ocean we cannot sample; though, it can be costly and dangerous, which has limited exploration and mapping to less than five per cent of the global oceans (5). The deep ocean, including some regions of Canadian waters, is almost entirely uncharted, which limits our understanding of important environmental and ecological processes that can inform management.

Establishing and maintaining sustainable commercial fisheries

Seafood is one of Canada's largest food commodity exports—about 85 per cent of wild-caught seafood is exported globally each year. In 2012, this generated $3.6-billion in export revenue (6). In the same year, the landed-value of wild-caught seafood was more than $2.1-billion (6). To maintain this annual revenue and the employment that depends on it, it's critical to map the movements and natural mortality of valued species, and document their interactions with other species in marine ecosystems. Animal movements and interactions can be mapped with animal tracking studies whereby free-ranging fishes and marine mammals are fitted with sophisticated electronic tags that show geographical locations, behaviour (e.g., feeding vs. travelling), habitat use and survival.

Canadian technology; global applications

The Halifax Line is part of a global ocean-tracking infrastructure that uses Canadian-made technologies to document the location and movements of marine animals around the world. Acoustic transmitter tags (also Canadian-made) are implanted or externally attached to fishes (e.g., sharks, cod, salmon, sturgeon), invertebrates (e.g., lobsters), or marine mammals (e.g., seals) to provide data on geographical movements and ocean conditions for up 20 years, depending on the size of the tag.

Fleets of autonomous ocean-patrolling robots, called gliders, upload information from fixed receiver stations to laboratories via satellite. Gliders also carry their own receivers

Environmental conditions provide clues to population fluxuations

Case Study: Adaptive Pacific Salmon Management in a Changing Environment

The smallest transmitters (an astonishing 5 mm) allow researchers to tag juvenile sockeye salmon (smolts) as they encounter environmental stressors like unfavorable temperatures and disease organisms on their journey between the Fraser River and the Pacific Ocean (10).

A recent study looking at the relationship between parental stress and offspring survival found that highly stressed parents produce offspring that swim faster and may, on average, have a higher probability of surviving (10). At the population level, this advantage will be offset by the lower overall probability of survival (and thus reproduction) of stressed parents (10).

This and other tracking studies are helping to explain the causes of the population collapse in salmon returns to the Fraser River in 2009, when over nine million salmon went "missing." It's also helping to inform Canadian salmon policy in light of the recommendations from the Cohen Commission (10,11), which was charged with investigating the cause of the collapse.

to detect tagged marine animals and gather data on ocean temperature, salinity, depth and dissolved oxygen, providing information more accurately, frequently and cost effectively than other methods (i.e. ship surveys) (2,8). Other novel multi-functional tools are the animals themselves. Larger animals can be outfitted with dual tag-receiver units, which maps their interactions with other tagged animals while also carrying sensors to document the environmental conditions they are experiencing (9).

Biodiversity hotspots and commercial fisheries

Tracking studies have been essential to identify biodiversity "hotspots." These are ocean regions where animals frequently congregate, rich in plant and animal resources, and providing both food and shelter. Some "hotspots," especially those in the open sea, occur in different places in different years. Others are fixed and highly predictable.

Deep sea, cold-water corals are not commercially harvested, but are vital habitat for some species, including the commercially important redfish off Canada's west coast. Redfish dive down to the corals and lay their eggs. After hatching, the corals provide a nursery to the young fish before they move into open waters (7). Protecting the coral ecosystem is necessary to maintain healthy redfish stocks that sustain the commercial fisheries. Understanding important interactions like this enables effective management of valued species.

Grey seals, tagged on Sable Island and in the Gulf of St. Lawrence, routinely arrive independently at common feeding grounds off the coast of Nova Scotia to form large feeding groups (12). The seals congregate in the areas where their prey gather (and their prey's prey gather), creating a biodiversity hotspot on the Scotian Shelf. These areas are also of interest for expanding industries including oil and gas, aquaculture and fiber optics (12). By understanding the biological importance of these areas, we can devise strategies for our new developments while protecting ecologically and commercially important species.

Special tracking tags provide more than just geographical location

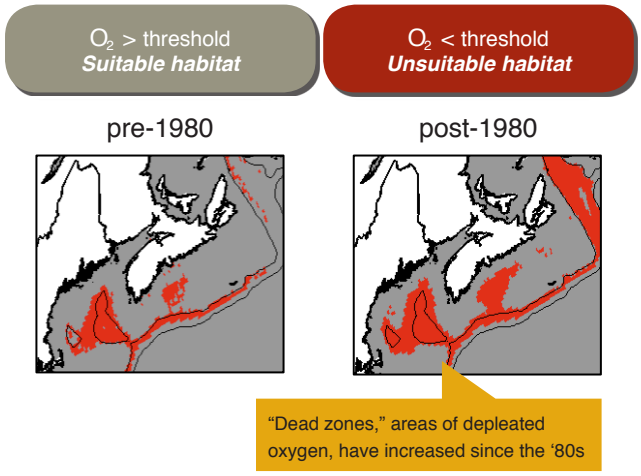
Understanding environmental effects on animal survival

Ocean Acidification

Carbon dioxide is absorbed by the ocean where it forms carbonic acid, which lowers the pH and acidifies the water. This makes calcium-based compounds (necessary for shell growth) less available to animals like corals and shellfish (13). A large portion of the Canadian fisheries economy is derived from shellfish (14), meanwhile Canada's oceans are becoming more acidic (15, 16). We're only beginning to understand the location and extent of acidification, and how organisms respond to it, in large measure because of limited ocean sampling. Sensors and sampling instruments carried by animals like seals are increasingly being used to expand (sampling) coverage.

Excess Nutrients

Excess nutrients are released into the ocean from sewage, industrial waste or agricultural runoff (17). The excess nutrients promote excessive plant growth. As the plants die and sink to the bottom, they decompose—a process that uses up the oxygen in the water sometimes leading to areas with no oxygen, called "dead zones" (17).



Case Study: Gulf of St. Lawrence Dead Zones and Commercial Cod

The Gulf of St. Lawrence now contains dead zones that affect commercial cod stocks (18,19). Researchers in Norway (20) and Canada (21,22) have found that cod avoid areas with low oxygen. Canada has recently implemented wastewater treatment regulations to reduce the amount of untreated sewage discharged into waterways (23). By monitoring movements and habitat used of tagged cod, tracking studies can also inform the effectiveness of management and industrial regulations.

Case Study: Porbeagle sharks vs. American eels

American eels grow in Canadian continental waters and then leave them for their spawning migration at the onset of their maturing phase. Eels are a commercially valuable species—juveniles sell for over $2,000 per pound to stock aquaculture sites in Asia. A 2012 tracking study to map eel migration from Canadian freshwaters to their spawning areas in the Sargasso Sea revealed some "fishy" data when some eel tags suddenly recorded a sustained rise in temperature in the Gulf of St. Lawrence. Comparisons of the recorded temperatures and dive patterns of the tag to what we knew of warm bodied fishes revealed Porbeagle sharks in the Gulf of St. Lawrence may exert predation pressure on the already endangered eels (24). Unravelling these mysteries helps scientists and policy-makers gain a better understanding of critical interactions (animal-animal, animal-environment) beneath the waves to manage marine and aquatic resources more effectively.

A global database

Transboundary issues such as biodiversity loss, climate change, and ocean acidification require global partnerships and integrated data management. Along with its leadership in animal tags and ocean monitoring technologies, Canada is pioneering the development of a central global database to organize, share, and effectively manage the vast information that is being collected from its tagging programs (8). Developing global networks that allow for the sharing of data, equipment, and technologies will build more powerful, effective, and cost-efficient solutions to our shared ocean challenges (8).

* The Halifax Line is operated and maintained by the Ocean Tracking Network in Halifax, Nova Scotia. The Ocean Tracking Network (OTN; oceantrackingnetwork.org) is a global research and technology-development platform funded by the Canada Foundation for Innovation, the Natural Sciences and Engineering Council, and the Social Sciences and Humanities Research Council. The OTN provides acoustic-receiver infrastructure for the tracking and monitoring of marine and aquatic animals globally.

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