Applications of remote sensing in fisheries and aquaculture

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Collectively, human society is responsible for the well being of the oceans. Various commercial conflicting interests are concerned that range from fisheries, aquaculture, and mineral extraction to tourism and transportation. Non-commercial issues, such as maintaining a healthy state of biodiversity, are also to play.

Internationally, and intergovernmentally, a consensus has been reached that, in meeting the responsibility for stewardship of the oceans, an ecosystem-based approach should be followed. The implication is that management decisions should be made in such a way that the integrity of the ocean ecosystem, its structure and vital function, should not be compromised. Ecosystem-based management is the new paradigm.

But it is far from simple to restate the new principle in operational terms. Here, the primary requirement is for information about the ocean and its ecosystem. First, we need to know the spatial structure. Next, we need to know how the ocean changes in the short term (response to weather), medium term (response to seasonality) and long term (response to climate change). The green plants in the ocean (the phytoplankton) are mostly microscopic and they respond to short-term changes in the environment more rapidly than do the plants on the land. Ideally, we need our information about the ocean to be updated daily if we are to understand the mechanisms underlying ecosystem response to change.

Photo: Meena Kumari, Central Institute for Fisheries Technology, Kochi, India

Local fish market in Nagapattinam, Tamilnadu, India

Earth observation (EO) by remote sensing is the only way in which we could hope to collect the information required on the appropriate timescales at the spatial scale of the ocean. And fortunately, there is a technology available (visible spectral radiometry, often called ocean-colour remote sensing) that enables us to produce maps of the quantitative distribution of plant biomass, indexed as the concentration of chlorophyll, over the broad swath of the ocean. Chlorophyll is a pigment found in all green plants, including the microscopic ones living in the sea: it provides the means by which the ecosystem can interface with its energy source, the sun. When we look at an image of the distribution of chlorophyll in the ocean, we are really looking at a map of connectivity of the marine ecosystem to the source of its sustenance. It is the most fundamental information we could have about the marine ecosystem.

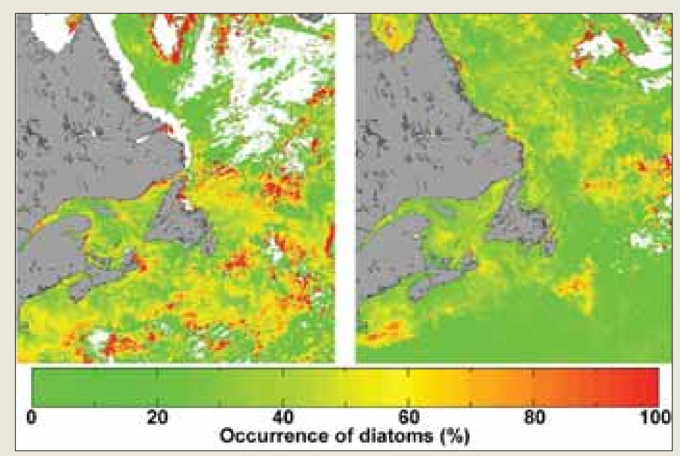
If information is the essential requirement, and if EO is the method to acquire it, what is the best way to apply it? One of the important applications is in the construction of ecological indicators. These are a suite of objective, quantitative indices intended collectively to capture in a few numbers the condition of the ecosystem at a given time and place. The idea is to condense the potentially-bewildering detailed information into an economical set of quantitative indices that should be more simple to assimilate. When the indicators are evaluated in a serial manner, they afford the possibility of detecting, and quantifying, ecosystem changes in response to perturbations such as pollution, over-fishing or climate change. EO has many qualities advantageous in this regard: it can give excellent spatial resolution, high repeat frequency and is very cost-effective. We can expect therefore that EO will be an important contributor to the development of an optimal set of ecological indicators for operational use in the ocean.

Ecosystem seasonality provides a good example. In temperate latitudes, a pronounced peak in chlorophyll concentration in spring is typical. It is such an important event in the ecological year that many species of fish and invertebrates, including those of economic interest to fisheries, time their reproduction to take advantage of it. At a particular location, the timing of this peak in particular years will vary by a few weeks depending on the weather. These fluctuations may have profound effect on the survival of the offspring, to the extent that the success or failure of the year class in a particular year maybe determined by them.

Images of chlorophyll distribution obtained by EO may also be used directly in fishing. It is often found that local concentrations of fish are related to typical oceanographic structures that can be recognized by EO. In India, artisanal fishermen are supplied regularly with analysis of EO imagery as an aid to their work. The intent here is not to overexploit a stock that might already be under heavy fishing pressure. Rather, the purpose is to help the fishermen complete their work with a minimum of searching time and a corresponding saving in fuel.

An important refinement of the interpretation of data from EO of ocean colour is to determine the quality as well as the quantity of plant biomass in the ocean. In the simplest case, all the chlorophyll is treated as a single pool of biomass. But in fact, there is a very large number of species of phytoplankton in the sea, representing several major taxonomic groups. These have different roles in the chemical cycles of the ocean, and also different values as potential food sources for organisms that feed on them. One of the contemporary goals of ocean-colour science is to be able to determine the presence and abundance of these different groups by EO. A major advance in this direction is the algorithm that detects the presence of the important group of phytoplankton known as the diatoms.

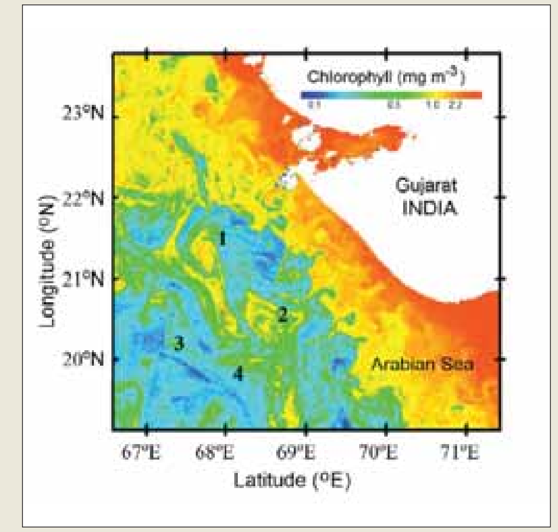
Diatoms



These satellite-derived maps show the probability of the occurrence of diatoms in the Northwest Atlantic Ocean during spring (16-30 April, left) and summer (1-15 July, right) of 1999

Source: Shubha Sathyendranath and Emmanuel Devred, Bedford Institute of Oceanography, Canada

Chlorophyll image of northwestern India



This chlorophyll image of northwestern India on 29 February 2006 was generated from the Indian OCM sensor. Oceanic features such as cyclonic eddies (1 and 2 on the image) and fronts (3 and 4) are known to be productive sites, and are hence relevant for fishery exploration

Source: R.M. Dwivedi, Indian Space Research Organisation, India

A specialized application for identification of phytoplankton using EO is in the aquaculture sector. Here, the occurrence of blooms of certain phytoplankton is antagonistic to the industry. Such outbreaks are referred to as Harmful Algal Blooms (HAB). Some species of phytoplankton are dangerous for culture of salmonids because the cells tend to clog the gills of the fish. Others produce toxins which may accumulate in the tissue of bivalve molluscs that feed on them. Consumption of shellfish containing these toxins may be fatal to people.

Sometimes, phytoplankton that are otherwise not dangerous may become so because, having reached high abundances through vigorous growth under favourable conditions, they may die and decay when conditions become unfavourable, consuming oxygen such that the environment may be rendered disadvantageous for aquacultured species. It is clear that the aquaculture industry can benefit from the information provided by EO to determine the onset, extent and fate of phytoplankton blooms.

The fishery for cultured pearls is also vulnerable to environmental conditions, in this case to the effect of excessive sediment deposition over the oyster beds. Fortunately, the movement of sediments by coastal currents can be monitored by EO, alerting growers to the potential threats following storms or heavy rains.

The ocean ecosystem is not everywhere the same. Rather, it is organized into a suite of more-or-less autonomous subsystems loosely connected to each other. We may call these systems ecological provinces. Informed stewardship of the ocean requires that we understand the organization into provinces and that we can observe its seasonal modification in real time. Here again, EO proves to be a very useful tool.

Coastal sediments

A true-colour image of northwestern Australia, captured by the MODIS ocean colour sensor on 2 July 2003. Commercial oyster farms are located in the clear waters around Broome and the Buccaneer Archipelago. High sediment loads, clearly visible in King Sound, are detrimental to the pearling industry and can be monitored using MODIS data

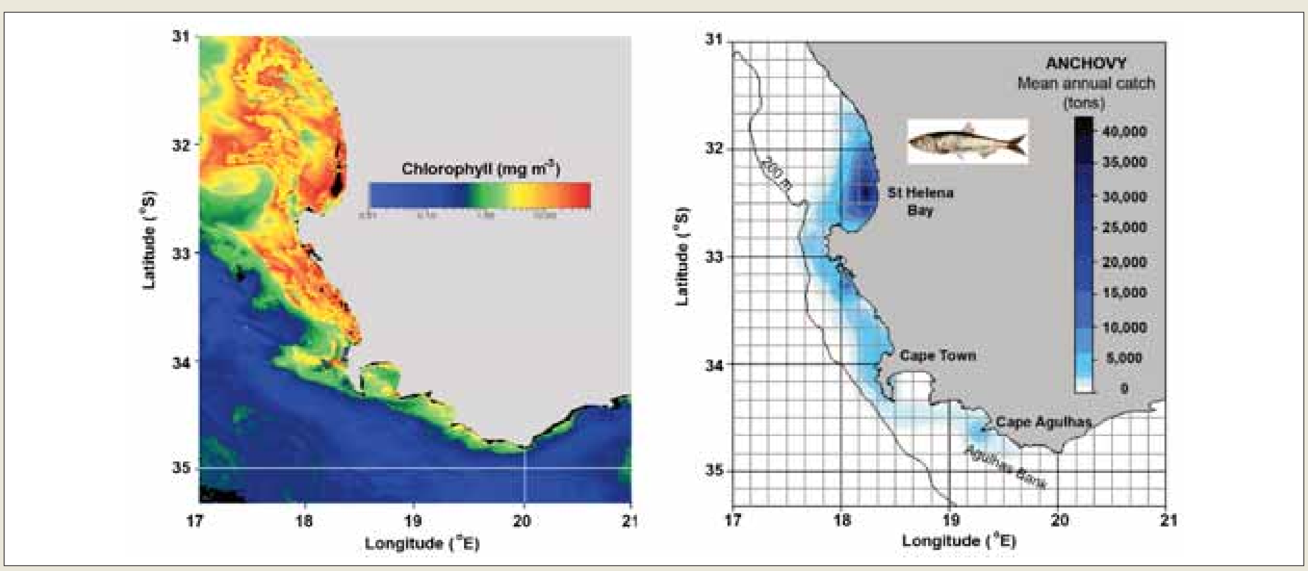
Source: MODIS Science Team, NASA/GSFC and the Remote Sensing and Satellite Research Group, Curtin University, Australia

Generally, we find that the ecological organization is controlled by physical forces, such as currents and wind patterns. In turn, it is frequently found that the spatial extent of fishing stocks is related to the spatial patterns depicted in a partition of the ocean into ecological provinces. An excellent example is found in the Benguela ecosystem off the west coast of South Africa, which is driven by strong south-easterly winds that induce upwelling of cold nutrient-rich water. This strong coastal upwelling leads to high levels of primary productivity, which in turn supports the large commercial fisheries in the area.

From the examples presented, it is clear that there is enormous potential for EO to benefit society through application to fisheries and aquaculture. However, such applications are still in their infancy. To encourage and coordinate, at the international level, the pursuit of excellence in this field, the Canadian Space Agency has agreed to fund the Societal Applications in Fisheries and Aquaculture using Remotely-sensed Imagery (SAFARI) programme in the context of GEO Task AG 06-02. This programme will host an international coordination workshop; highlight excellent demonstration projects of EO in fisheries; produce a monograph on the state of the art, develop an outreach component to increase awareness of the value of EO in the fisheries and aquaculture sector, and convene an international symposium on this timely topic.

All things considered, there is a promising and exciting future for the application of EO to fisheries and aquaculture, extending the ways that society can benefit from investment in EO capacity.

Benguela upwelling



On the left is an example of a three-day composite chlorophyll image from the Benguela upwelling region off the coast of South Africa captured by the MODIS ocean colour sensor. High chlorophyll concentrations along the coast are indicated in red/yellow, while areas of low chlorophyll are indicated in blue. The image on the right shows the distribution of the mean annual catch of anchovy

Left image: MODIS Science Team, NASA/GSFC. Right image: Kobus Agenbag, Marine and Coastal Management, South Africa