# Remote sensing and fisheries: an introduction

Venetia Stuart[1]*, Trevor Platt[2], Shubha Sathyendranath[2], and Pravin P[3]

[1]Bedford Institute of Oceanography, Dartmouth, Nova Scotia B2Y 4A2, Canada
[2]Plymouth Marine Laboratory, Prospect Place, The Hoe, Plymouth PL1 3DH, UK
[3]Central Institute of Fisheries Technology, Kochi, India

*Corresponding Author: tel: +1 902 426 3817; fax: +1 902 426 9388; e-mail: vstuart@ioccg.org.

The international coordination project SAFARI (Societal Applications in Fisheries and Aquaculture using Remotely-sensed Imagery) organized a symposium on Remote Sensing and Fisheries in Kochi, India, 11–17 February 2010. The well-attended symposium highlighted various applications of remote sensing to fisheries and aquaculture and identified various steps that would further enhance the use of remote sensing for sustainable management of marine resources and stewardship of the oceans.

Keywords: fisheries, ocean colour, remote sensing, sea surface temperature.

## Introduction

The SAFARI Project (Societal Applications in Fisheries and Aquaculture using Remotely-sensed Imagery) was initiated in 2007 with funding from the Canadian Space Agency (CSA) for international coordination. SAFARI aims to accelerate the assimilation of earth observation into fisheries research and management on a global scale, one of the tasks of the intergovernmental Group on Earth Observations (GEO). Furthermore, SAFARI will stimulate the building of capacity at scientific and operational levels and facilitate the application of rapidly evolving satellite technology to fisheries management questions. Further information on the SAFARI Project can be found at www.geosafari.org.

The SAFARI International Symposium on Remote Sensing and Fisheries took place from 15 to 17 February 2010 in Kochi, India. It was the first symposium of its kind, and there were 157 registered participants from 30 countries, including seven keynote speakers (Emmanuel Chassot, Simon Jennings, Sailesh Nayak, Jeffrey Polovina, Sei-Ichi Saitoh, Kenneth Sherman, and Cara Wilson). India was a natural location for the event, given the strong contribution by the Indian Space Research Organization and the Ministry of Earth Sciences to the development of potential fishing zones (PFZs) using satellite data, and India's role in ensuring the continuous collection and dissemination of ocean-colour data by the recent launch of Oceansat-2 and its Ocean Colour Monitor-2 sensor. India continues to be at the forefront of ocean-colour research and the application of satellite data to fisheries-related problems.

In all, 42 oral presentations and 39 posters were presented during the symposium, covering the following themes and including the use of remote sensing in:

(i) harvesting of marine resources,
(ii) ecosystem-based fisheries management,
(iii) research and management of harmful algal blooms (HABs),
(iv) fisheries models,
(v) research on the effects of climate on fisheries, and
(vi) management of coastal zones and fisheries.

## Conclusions of the symposium based on presentations and discussions

Remote sensing of ocean properties provides us with a window into the ocean ecosystem on synoptic scales and has the potential to provide essential information for the governance of ocean ecosystems on global and regional scales. Various environmental properties that influence fish distribution, abundance, and migration and the application of remote sensing in monitoring these factors need to be studied in greater depth. The SAFARI Symposium on Remote Sensing and Fisheries provided a platform for deliberations on the latest developments in this field and highlighted case studies using earth observation data, with contributions from key fisheries systems around the world. The recommendations arising from the symposium (listed below in no order of priority) are anticipated to enhance the assimilation of earth observation data into fisheries research and management and to facilitate the application of remote sensing in fisheries and aquaculture.

(i) There is need to increase further both spatial and temporal resolution of satellite-borne sensors for earth observations and to incorporate the use of microwave-based sensors that can see through cloud cover to detect variables such as winds and sea surface roughness, to enhance the utility of remote sensing in fisheries and aquaculture.

(ii) The current ocean-colour sensors (SeaWiFS, MODIS-Aqua, and MERIS) are operating beyond their planned lifespan and need replacement with technologically advanced systems. The recently launched Indian sensor OCM-2 is important for covering potential gaps in data.

(iii) It is essential to maintain high-quality *in situ* observations of environmental and bio-optical variables for the development of conceptual models and validation of remote-sensing estimations and model performance.

(iv) The status of currently available algorithms for assessing chlorophyll *a* (Chl *a*) in optically complex coastal waters, inland waterbodies, and estuaries affected by coloured dissolved organic matter and suspended matter are being evaluated and their limitations addressed. Evaluation of errors and further improvements in the interpretation of ocean-colour data in coastal and inland waterbodies would be particularly useful for fisheries applications.

(v) Although remote sensing is of immense importance for providing reliable and accurate data at high spatial and temporal resolution, this must be complemented with work on (a) site-specific algorithms for retrieval of Chl *a*, total suspended sediments, and coloured dissolved organic matter from Case II waters (optically complex coastal and inland waters), (b) ocean general circulation models at sufficiently high resolution, (c) *in situ* measurements using coastal buoys and ships of opportunity, and (d) data-dissemination systems.

(vi) The use of remote sensing for the assessment of PFZs should be carried out in conjunction with a suitable strategy for ecosystem-based fisheries management, with a view to avoiding overfishing.

(vii) There is a need for continuous archiving of satellite remotely sensed data, such as sea surface temperature, chlorophyll, sea surface height, and surface winds. Near-real-time data should be made available at low or no cost to facilitate research and PFZ forecasting.

(viii) Efforts should be made to replicate and extend the success of PFZ advisories based on satellite remote sensing and information and communication technologies made available to the fishing communities in India and elsewhere. This will enhance the efficiency of harvesting operations based on precautionary and sustainable principles, reduce fuel consumption, and enhance socio-economic benefits.

(ix) Success of PFZ forecasts should be improved further by synergistic analysis of signatures of satellite-derived chlorophyll concentrations, sea surface temperature, sea surface height anomalies, and other parameters.

(x) Efforts should be made to inform fishing communities of the benefits of remote-sensing applications in fisheries and aquaculture through training and education.

(xi) The 64 large marine ecosystems (LMEs) of the world contribute goods and services worth an estimated US$12.6 trillion annually to the global economy, which includes 80% of the world fish catch. The primary production appropriated by current global fisheries has been estimated to be 17–112% higher than that appropriated by sustainable fisheries. There are indications that global primary production is declining in some parts, because of climate variability and change, which might be reflected in fish catches. The application of satellite remote-sensing technology to support management practices in recovering depleted marine fish stocks, restoring degraded habitats, controlling pollution, monitoring eutrophication and ocean acidification, conserving biodiversity, and adapting to climate change should be supported and encouraged by developing new methodologies for measuring the spatial and temporal environmental conditions of LMEs.

(xii) There is an urgent need to move towards open-access global time-series databases of remotely sensed data, *in situ* observations, and reliable catch estimates. It is also important for international collaboration to facilitate the development of models and to work towards better governance of our oceanic resources on global and regional levels.

(xiii) The fishing advisory TurtleWatch in the Pacific Ocean has been based on information obtained using electronic tags and complemented by satellite remotely sensed sea surface temperature, surface chlorophyll, sea surface height, and surface wind data. The success of this programme could be evaluated for adaptation in other areas affected by fishing-induced bycatch mortality of species at risk.

(xiv) The effectiveness of probabilistic models, such as Bayesian networks, could be refined further and validated to estimate primary production and fisheries potential from satellite remote sensing of ocean colour, sea surface temperature, and wind, in addition to *in situ* observations.

(xv) The composite-frontal-map approach combines the location, strength, and persistence of ocean thermal and colour fronts, observed over several days, into a single map via an automated clustering algorithm, and it allows intuitive interpretation of mesoscale structures. The use of frontal maps to study the distribution and management of commercial species and delimitation of biodiversity hotspots and marine protected areas should be explored further.

(xvi) Integrated systems for early warnings of emerging HABs and monitoring of HABs based on earth observation data, field observation, and modelling need to be refined further; sensor technologies and algorithms should be developed for species-specific detection and forecasts.

(xvii) Models based on remotely sensed estimates of phytoplankton biomass partitioned according to size, predator–prey ratios, and food chain length need to be refined further and validated for rapid estimation of potential fish production.

(xviii) Approaches based on simple successful models using remotely sensed water-quality properties, *in situ* observations, and GIS-based analysis should be adapted and popularized for site selection in coastal aquaculture.

(xix) The success achieved in correlating remotely sensed data to growth and recruitment of shrimp (*Pandalus borealis*) has demonstrated a new approach to the ecosystem-based management of the eastern Scotian Shelf shrimp fishery. Similar approaches can be applied to other fisheries for the determination of diagnostic indicators of stock health, partly based on remotely sensed data, and to formulate fishery management plans.

(xx) TOREDAS (Traceable and Operational Resource and Environment Data Acquisition System) is an important tool for sustainable fisheries management for fishers targeting Japanese common squid (*Todarodes pacificus*) and skipjack tuna (*Katsuwonus pelamis*) with PFZ forecasts and vessel monitoring systems. Similar approaches are possible and should be adopted, in other fishery systems.

(xxi) The use of remote sensing in monitoring climate change and the impacts of extreme weather events (i.e. tsunamis) is well documented. Remote-sensing applications in the forecasting and monitoring of such events, for disaster management and mitigation, can be cultivated further.

(xxii) The International Symposium on Remote Sensing and Fisheries was the first of its kind, had created strong interest, and urged that it be repeated at a future date.

This special issue in the *ICES Journal of Marine Science* represents a selection of papers presented at the symposium, complemented by additional contributed papers relevant to the topic of the symposium.

## Sponsors

The success of this symposium resulted from the hard work, dedication, efficiency, and hospitality of local organizers, particularly the members from the Central Institute of Fisheries Technology (CIFT) under the directorship of Dr B Meenakumari, as well as the many international and local sponsors (listed below).

### International

Canadian Space Agency (CSA)

Group on Earth Observations (GEO)

International Ocean Colour Coordinating Group (IOCCG)

Department of Fisheries and Oceans (DFO), Canada

Partnership for Observation of the Global Oceans (POGO)

Indian Ocean Global Ocean Observing System (IOGOOS)

National Centre for Earth Observation (NCEO), UK

Joint Research Centre, European Commission (JRC), Italy

UNESCO Intergovernmental Oceanographic Commission (IOC)

International Council for the Exploration of the Seas (ICES)

Societal Applications in Fisheries and Aquaculture using Remotely-sensed Imagery (SAFARI)

### National

Central Institute of Fisheries Technology (CIFT)

Indian Council of Agricultural Research

Indian National Centre for Ocean Information Services (INCOIS), India

Ministry of Earth Sciences (MoES), India

Indian Space Research Organization (ISRO), India

National Institute of Oceanography Regional Centre, Kochi (NIO−RC Kochi), India

Department of Animal Husbandry, Dairying and Fisheries (DAHD&F), India

National Fisheries Development Board (NFDB), India

Department of Science and Technology (DST), India

Society of Fisheries Technologists India (SOFTI), India

Central Institute of Freshwater Aquaculture (CIFA), ICAR, India

Central Institute of Fisheries Education (CIFE), ICAR, India

Central Marine Fisheries Research Institute (CMFRI), ICAR, India

Central Institute of Brackishwater Aquaculture (CIBA), ICAR, India

Marine Products Export Development Agency (MPEDA), India

Fishery Survey of India (FSI), India