Satellite Remote Sensing in Support of Fisheries Management in Global Oceans

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Abstract The world's oceans are dynamic: environmental conditions and ecosystems in marine environments fluctuate spatially and temporally on multiple scales. Spatially, the ocean varies with water depth, ocean currents, and oceanic fronts. This abiotic and biotic variability makes managing resources in the dynamic ocean environment extremely difficult, and as a result, fisheries management often serves as one of the textbook examples of an unstructured or 'wicked' environmental problem. This chapter provides an overview of the role satellite remote sensing can play in ocean and fisheries management. Currently, there are very few applications available that enable managers to use satellite earth observations in a scientifically robust but straightforward manner. The chapter recommends collaboration between researchers, scientists, data analysts and conservation practitioners to develop accessible tools, all the while ensuring such approaches are scientifically robust and defensible and are directly meeting the needs of the management community. Continued support and resources for satellite earth observations, distribution, integration, and management-relevant science are needed to maximize the return on this investment in support of sustainable fisheries.

1 Fisheries Management in a Dynamic Ocean: Overview

The world's oceans are dynamic: environmental conditions and ecosystems in marine environments fluctuate spatially and temporally on multiple scales (Hazen et al. 2013). For example, sea surface temperature fluctuates temporally daily, seasonally, and in multi-year cycles such as the El Nino, Southern Oscillation (ENSO) cycle. Spatially, the ocean varies with water depth, ocean currents, and oceanic fronts. Other abiotic conditions like currents, eddy structure, and salinity thresholds also fluctuate in both predictable and non-predictable ways. Biotic conditions in the ocean are just as complex (Haury et al. 1978). Habitat associations

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of species or assemblages vary in space and time, as ocean conditions change, and biotic patterns, such as migration or persistent movement pathways, i.e., corridors, are far more dynamic than in terrestrial systems (Hazen et al. 2012). This abiotic and biotic variability makes managing resources in the dynamic ocean environment extremely difficult, and as a result, fisheries management often serves as one of the textbook examples of an unstructured or 'wicked' environmental problem (Balint et al. 2011; Hisschemöller and Hoppe 1995).

In the US, ocean fisheries management is legislated by several legislative instruments with the Magnuson Stevens Act as the primary law governing marine fisheries. The Magnuson–Stevens Act was originally enacted as the Fishery Conservation and Management Act of 1976. Two major recent sets of amendments to the law were the Sustainable Fisheries Act of 1996 and the Magnuson–Stevens Fishery Conservation and Management Reauthorization Act (MSFCMA) of 2006. The MSFCMA and other relevant policies mandate a management approach that balances the often conflicting objectives of economic viability with ecological sustainability, i.e., fisheries managers are tasked with protecting target and nontarget species and stocks, protecting essential habitats as well as supporting viable fishing economies.

Globally, fisheries management is often a part of a larger ecosystem-based management framework; a transition from single-species, stock assessments, or management plan to ecosystem approaches which requires the ability to monitor the ocean conditions and variability that drive many biotic and abiotic processes (Scheurell and Williams 2005; Wells et al. 2008). The vast temporal and spatial scales of the global oceans, the limited ability to collect ocean data directly, and the move to manage ocean systems rather than ocean species has led to the reliance on advancing technology in satellite remote sensing (SRS) data (Collie et al. 2013). Hereafter, the term SRS will be used to signify Earth observation (EO) in the previous chapters.

2 Current Status of Ocean SRS: The Fisheries Management Context

Traditional approaches to collect oceanographic data relied on ship board equipment and observer driven measurements. However, since the early 1970s, fisheries scientists have implemented airborne remote sensing (ARS) using balloons, helicopters, and airplanes to study oceans from above (reviewed in Santos 2000; Klemas 2013). In some areas, ARS relies on naked-eye observations from flown transects over ocean waters. Although the human eye and airborne sensors have a wide spatial range and high resolution, ARS is limited by human skill and endurance as well as by water depth and both water and atmospheric visibility (Klemas 2013). The addition of airborne sensors like cameras, low-light-televisions, infrared cameras, and LiDAR (Light Detection and Ranging) has made ARS more reliable, but they are still limited temporally and spatially (Klemas 2013; Rose et al. 2000).

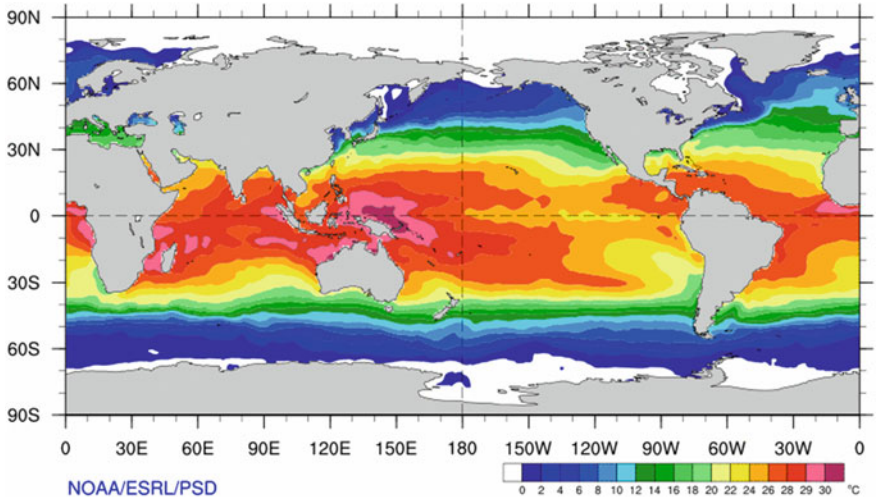

Fig. 1 This image shows the global weekly average SSTs, January 30 2011–February 5 2011. *Image credit* Earth System Research Laboratory Physical Sciences Division. Public domain

With rapid increases in satellite technology and data storage in recent years, SRS has become an essential element of fisheries management due to its ability to collect data at regular intervals for long time periods across the entire globe (Chassot et al. 2011; Pettorelli et al. 2014). The scale and scope of SRS data allow for the implementation of near-real-time ecosystem and forecast models that can be applied to ocean management. To contextualize the application of SRS technology to fisheries management, we describe some of the most common SRS data used in fisheries.

Sea surface temperature: Sea surface temperature (SST) is a measure of the energy from the molecules at the top layer of the ocean and was one of the first satellite-sensed ocean variables applied to fisheries. Thermal infrared sensors that measure SST, when there is no cloud cover have been deployed for over four decades (Klemas 2013). SST can be used to detect oceanic fronts and large-scale climatic fluctuations. Maps of SST are directly relevant to fisheries because of the temperature preferences of individual fish species. Satellite platforms use different bands sensitive to the thermal infrared, allowing precise, daily measurement of SST over the world's oceans (Fig. 1). Currently, the most common data source for SST is the NASA-deployed MODIS sensor.

Ocean color: The color in most of the world's oceans is in the visible light region (wavelengths of 400–700 nm) and varies with the concentration of chlorophyll and primary ocean producers, phytoplankton. When more phytoplankton are present, the concentration of plant pigments increases and the greener the water becomes. Subtle changes in ocean color signify various types and quantities of marine phytoplankton. Changes in ocean color signify changes in chlorophyll concentrations and can be used to infer biological productivity (Fig. 2). Ocean color

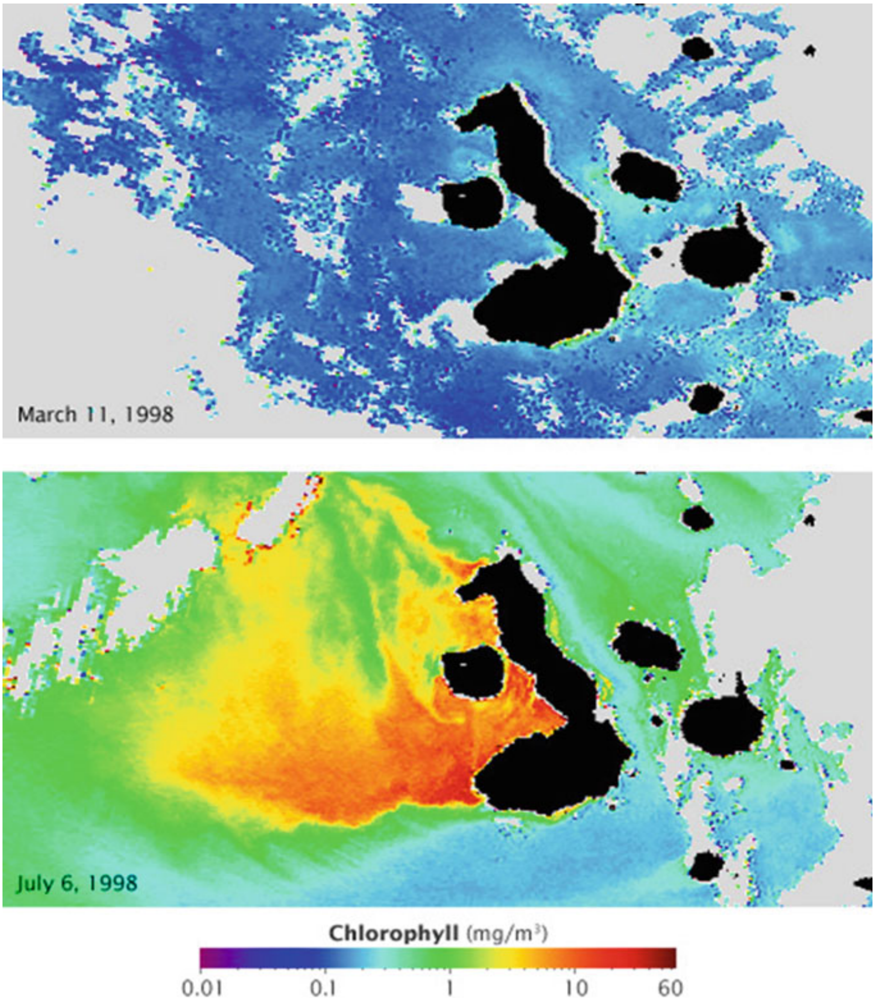

Fig. 2 Chlorophyll concentration during El Niño (*top*) and La Niña (*lower*) where *blue* represents low concentrations, while *yellow*, *orange* and *red* indicate high concentrations. *Image credit* GSFC Ocean Color team and GeoEye, NASA Earth Observatory. Public domain

data is also useful for detecting terrestrial runoff and tracking oil spills (Wilson, IOCCG). Currently, the most commonly used satellite sensors for ocean color include Nimbus-7, SeaWiFS, and MODIS.

Sea surface salinity: Salinity in the ocean is defined as the grams of salt per 1000 grams of water. Since salt dissolves in sea water creating increased reflectivity and decreased emissivity. Salinity can be determined using microwave radiometers when accounting for SST. Salinity varies due to evaporation and precipitation over the ocean as well as river runoff and ice melt. Along with SST, it is a major driver of

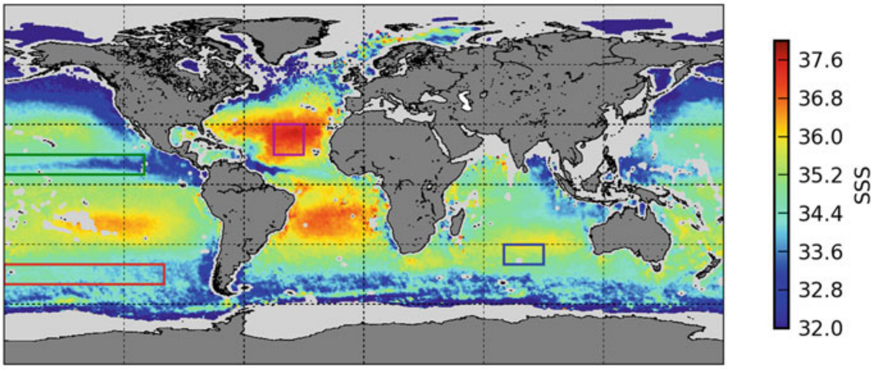

Fig. 3 A map of surface salinity levels recorded between August and September, 2010 and 2011. *Image credit* SMOS GLOSCAL Cal/Val project. Public domain

abiotic processes like ocean circulation (Fig. 3). The most commonly used salinity sensors are the European SMOS and the NASA-launched Aquarius/SAC-D.

Ocean currents: Because of the complexity, the range of temporal and spatial scales and the dependence on local conditions, satellite remote sensing is an ideal tool to measure ocean currents. Currents are responsible for water exchange between different parts of the ocean. Satellite sensors are not capable of measuring ocean currents directly. However, remotely sensed data are used to assess current velocity with a variety of methods and products including Ocean Surface Current Analyses Realtime (OSCAR; http://www.oscar.noaa.gov, http://podaac.jpl.nasa.gov), as well as Mercator/SURCOUF (Larnicol et al. 2006; http://www.mercator-ocean.fr), and the Centre de Topographie des Océans et de l'Hydrosphère (CTOH; Sudre and Morrow 2008; http://ctoh.legos.obs-mip.fr). These products provide global surface current data directly calculated from satellite altimetry and ocean vector winds. The current sensors for ocean currents include Jason-2/OSTM and QuikSCAT.

Sea surface height: Just as bathymetry measures the relief or topography of the ocean floor, sea surface height measures the topography of the ocean surface. In the context of fisheries, sea surface height is often used to calculate anomalies, which are related to eddy structure and strength and other important features in understanding fish species and community distributions (Fig. 3). Sea surface height data is available from Topex/Poseidon and Jason-1 and currently from Jason-2, Ocean Surface Topography Mission.

3 Utility of SRS in Fisheries Management

The formidable challenges of fisheries management, i.e., the concurrent objectives of harvesting and protecting living marine resources have been a joint focus of the National Oceanic and Atmospheric Administration (NOAA) and the National

Aeronautics and Space Administration (NASA) for decades. For example, NOAA and NASA sponsored a 2006 workshop, "Integrating Satellite Data Into Ecosystem-Based Management of Living Marine Resources," to identify specific ways to incorporate Earth science satellite observations, data, and associated models into NOAA fisheries management (EOS 2006). A similar workshop was convened in 1996 (Boehlert and Schumaker 1997). The interest in capitalizing on SRS to support fisheries management and the larger goals of ecosystem-based management continues to expand and develop. Here, we describe some of the key areas of SRS application in fisheries management.

3.1 Identifying Ocean Features and Regions

Ocean features such as ocean currents, eddies, and fronts often serve as aggregating features for fisheries target species. The spatial and temporal scale of many of these features makes them difficult to study with traditional, shipboard, or ARS methods. SRS, in contrast, has the capacity to monitor these dynamic ocean features on broad scales as it can combine thousands of daily, global satellite images using a number of different data integration methods.

Detecting ocean fronts is often central to identifying important fishing areas and there are several methods that use SRS data to do so including gradient measurement and histogram-based methods (Chassot et al. 2011). The gradient method can detect fronts on a scale >4 km using time-averaged data although it can be limited when the SRS data are noisy. A more widely used approach is the histogram-based method (Kahru et al. 1995; Chassot et al. 2011), which uses single image analyses and can detect mesoscale circulation patterns such as eddies, which are often important for fish recruitment processes and tracking marine pollutants (Klemas 2012a).

Studying large-scale ocean currents is also vital to studying large marine ecosystems. SRS, like infrared SST, is used to track currents such as the Gulf Stream Kuroshio currents which moves warm water and creates warm water eddies along the current boundaries (Klemas 2012b). Another SRS approach to studying large marine ecosystems is to use "feature mapping," which uses SRS imagery to track the movement of ocean abnormalities such as chlorophyll plumes (ocean color) or temperature anomalies (SST). By tracking the displacement of these features relative to fixed and coastal landmarks, current speeds can be estimated from SRS images.

3.2 Identifying Species-Specific Habitat Features

One of the fundamental goals of fishery management is to support fisheries catches or yield. Beyond measuring general ocean features, directly mapping the distribution and ocean habitat for target species is often a central objective of fisheries management applications. The use of fishery logs, fishery-independent surveys, and fish tagging combined with SRS data is common to study and predict fish distributions, where concurrent SRS ocean data are analyzed to understand current and projected future habitat associations for target species. Analyses of in situ biological data paired with SRS data has been identified as one of most powerful means to determine habitat preferences on large spatial scales (Cushing 1982; Bakun 1996; Chassot et al. 2011).

One oceanographic feature often associated with fish distribution is SST (Ramos et al. 1996; Klemas 2013). An early application of SRS on sardine (Sardina pilchardus), an economically important fisheries target species in the Atlantic, used SST to map sardine distribution (Santos and Fiuza 1992). These authors found that sardines were clustered around upwelling areas, ocean regions where cold, nutrient rich water from depth displaces warmer, surface waters. Similar patterns have been found with numerous other fish species, e.g., some species of tuna tend to be found in upwelling regions, particularly near thermal fronts (Santos 2000), areas where cold and warm water masses meet. In some cases, thermal limits for target species can be determined by comparing fish distribution to SST data (Klemas 2013), even relatively small changes in temperature as some fish are sensitive to water changes on the magnitude of 0.1 °C. Fish species distribution can also be influenced by regional productivity as measured by chlorophyll concentration (ocean color). A general trend indicates that viable fishery populations require a chlorophyll concentration; at least 0.2 mg/m^3 (FAO 2003). Particularly in pelagic habitats, which are typically characterized by low biological productivity, fish tend to be found along ocean fronts with high chlorophyll levels (e.g., Royer et al. 2004; Santos 2000).

Species-specific habitat models have become a key element of many fisheries stock assessments, which are population models or evaluations that are used to set harvest levels. Zwolinski et al. (2011) used a combination of predictive habitat modeling and previous catch data to demonstrate how SRS data can be used to improve fishery survey design for Pacific sardine (*Sardinops sagax*), the target species for an economically important fishery in the Northwest United States. In the 1930s, excessive fishing pressure along with environmental fluctuations led to a stock collapse in the species (Radovich 1982) but the stock recovered sufficiently for the fishery to resume in the 1990s (Smith and Moser 2003). Despite the large spatial range of sardine, several recent studies have suggested that sardine distribution is limited temporally by SST (~12–16 °C; e.g., Checkley et al. 2000; Lynn 2003; Weber and McClatchie 2010). To build a Pacific sardine habitat suitability model, Zwolinski et al. (2011) used 12 years of sardine presence data and SRS data, including SST, chlorophyll *a* (ocean color), and SSH. In order to avoid future stock collapse, the Pacific Fishery Management Council has set harvest rates based on annual stock assessment for the species, which requires SRS data.

3.3 Identifying Movement or Migration Pathways

Long distance movements of both fisheries target and nontarget populations challenge fisheries management (Rose et al. 2000) and understanding the ecological drivers of movement patterns on both spatial and temporal scales is essential for management of highly migratory target and nontarget species. The field of biotelemetry has expanded rapidly over the past two decades with developments in satellite tracking technology (Bograd et al. 2010; Hammerschlag et al. 2011). These technological developments have led to an increased understanding in the spatial and temporal scale of animal movements, and combining SRS data with these new types of movement data have broadened the understanding of the drivers and mechanisms behind these movements (Chassot et al. 2011).

Over the past decade, pop-up satellite archival tags (PSATs) have been developed that allow scientists to track species at depth with high frequency temperature-depth-light sensors. PSATs provide previously unavailable observations of fish species that rarely use the surface water over relatively large ocean areas. Pairing data from PSATs and SRS has also led to new insights into migration and movement patterns of difficult-to-monitor highly migratory fish species. Studying an economically important species, the porbeagle sharks (Lamna nasus), in the southwest Pacific Ocean, Francis et al. (2015) used SRS and PSAT data to quantify the horizontal and vertical migration of porbeagles, revealing that, seasonally, porbeagles make horizontal movements of hundreds to thousands of kilometers but also capturing the large daily vertical migrations that this species makes. By integrating a merged SRS product and data from PSAT deployments, Luo et al. (2015) identify new insights into migration pathways for yellowfin tuna (*Thunnus albacares*), blue marlin (*Makaira nigricans*), white marlin (*Tetrapturus albidus*), and sailfish (*Istiophorus platypterus*) in the Caribbean Sea and Gulf of Mexico, where these species were found to track highly specific ocean front and eddy features.

3.4 Forecasting Fishing Hotspots

Marine fisheries are an important global food source, accounting for at least 15 % of the world's animal protein consumption (FAO 2009). The costs associated with commercial fishing, including fuel and search costs, can be substantial (Santos 2000). As such, commercial fishers rely on SRS data to help find productive fishing grounds in an efficient manner. The application of SRS to identifying productive fishing grounds started as early as the 1960s with the availability of SST and ocean color data (Chassot et al. 2011). Since then, many countries have allocated public funds to provide SRS data to fishermen, a step aimed at reducing fishing costs and increasing productivity (Santos 2000). SRS data has been shown to reduce the search time by 50 % for US commercial fishing fleets (Santos 2000) resulting in statistically higher catch rates (Wright et al. 1976).

In the US, NOAA has provided SRS data on ocean fronts and SST on a regular basis since 1980 (reviewed in Santos 2000). Even in these early years, economic analyses demonstrated that SRS support saved the Northwest salmon and albacore fisheries upwards; $500,000 per year (Breaker 1981). Similar analysis showed that individual New England fishers saved thousands of dollars in fuel costs per year (Cornillon et al. 1986). The Japan Fisheries Information Service Centre, often described as the most well organized commercial fishery support service (Santos 2000), also synthesizes SRS data to share with commercial fishers to increase in fishery efficiency and reduce seafood prices for consumers (Yamanaka 1988). Similar SRS data is collected by governments around the globe which is shared with their respective fishing industries (reviewed in Santos 2000).

3.5 Identifying Bycatch Hotspots

Fisheries bycatch, the incidental catch of unused or unmanaged species (Davies et al. 2009) poses a substantial impediment to fisheries sustainability (Hall et al. 2000; Kelleher 2005). Bycatch of juvenile target species, foundational species, like sponges or corals, as well as long-lived marine megafauna has both direct and indirect ecological effects that are challenging to mitigate and manage (Lewison et al. 2004). SRS data are a critical element to many applications that have been developed to avoid or minimize bycatch. Characterization of bycatch spatial patterns (Gardner et al. 2008) and hotspots (Lewison et al. 2009) in conjunction with research on animal movement patterns has identified relationships between a wide range of SRS products like SST, chlorophyll, and SSH and other ocean, fishery, or gear characteristics and bycatch (James et al. 2005; Polovina et al. 2006; Sims et al. 2008; Zydelis et al. 2011; Briscoe et al. 2014). For example, using SRS data to characterize oceanographic conditions and habitat features associated with loggerhead and leatherback turtles off Hawaii, the NOAA-led program Turtlewatch creates weekly maps for fishermen depicting ocean areas where bycatch of both species is more likely (Howell et al. 2008, 2015). SRS data paired with sophisticated predictive ocean models integrating oceanographic and telemetry data have also been developed to forecast the presence of high-risk bycatch species like bluefin tuna in eastern Australia, guiding dynamic spatiotemporal fisheries restriction decisions (Hobday et al. 2010).

3.6 Marine Reserve Identification and Monitoring

The development of marine protected areas (MPAs) has been recognized as one important tool in maintaining marine biodiversity and supporting fisheries yields (Brown et al. 2015). The Convention on Biological Diversity set a target of conserving 10 % of available habitats by the year 2020 (https://www.cbd.int/sp/targets/).

As MPA designation continues to reach the 2020 target, the challenge of protected area selection is central to planning activities. SRS data provides planners and managers with quantifiable information on biotic and abiotic conditions which is a key element for marine reserve design (Kachelriess et al. 2014). In the context of MPAs implementation, SRS data are also vital to monitor the environmental correlates of biodiversity (Soykan and Lewison 2015), monitor MPA-protected systems, and assess the impacts of human threats to biodiversity (Kechelriess et al. 2014).

Two of the major impediments to MPA implementation are characterizing how to designate protected areas that promote biodiversity and how to monitor human impacts on MPA efficacy. SRS data is vital for optimally designating and managing protected areas (Pettorelli et al. 2014). Kechelriess et al. (2014) defined three discrete ways that SRS data can improve MPA design and management: (1) monitoring environmental correlates to biodiversity, (2) monitoring habitats within MPAs, and (3) assessing anthropogenic impacts and threats. SRS-based habit designation is routinely incorporated into terrestrial reserve design (Lengyel et al. 2008) and a similar approach has been proposed for pelagic systems (e.g., Hobday et al. 2011). Currently, SST, ocean color, and current patterns have all been used to characterize pelagic habitats, and incorporating a range in each of those environmental variables can help build MPAs that are more representative of the ocean at large. In coastal, marine systems, SRS can be used to identify structural biota and substrate such as mangroves, seagrass beds, kelp forests, and coral reefs (reviewed in Kachelriess et al. 2014). The ability to pinpoint these biomes at large scale can help managers incorporate each into networks of MPAs.

One of the primary criticisms of MPAs is the resources required to enforce them. SRS data can aid in MPA monitoring at large spatial and temporal scales without the need for expensive ship time. Ocean color sensors can detect suspended particles in the water column indicative of terrestrial runoff (Kachelreiss et al. 2014). Monitoring the presence of these suspended particles helps assess the interaction of land use and marine ecosystem health. Ocean color sensors can also detect the presence of and spreading of oil spills in protected areas. Both large and small oil spills can have devastating impacts on marine habitats. SRS allows them to be detected early to allow for rapid response. Finally, SRS allows for the detection of illegal fishing vessels within MPA boundaries. Large, heavily fished species are often the conservation targets of MPAs and illegal or underreported fishing can have detrimental population and community level results. The ability of remote optical sensors to pick out boats in remote reserves can minimize the impact of illegal fishing. As satellite technology and data precision and accuracy increases and MPAs get implemented, SRS data are likely to continue to serve as an instrumental tool in MPA design and monitoring.

3.7 Dynamic Ocean Management

Given the variable nature of marine systems, recent papers have posited that the inherent multi-objective nature of fisheries (i.e., economic profitability and viability coupled with ecological sustainability) requires a management framework that can integrate biotic and abiotic complexity and ocean dynamics (Hobday et al. 2014; Maxwell et al. 2015; Lewison et al. 2015; Dunn et al. 2016). The term dynamic ocean management refers to methods that explicitly account for dynamic oceanographic and fishing conditions and dynamic management approaches are increasingly gaining traction worldwide, typically building on the foundation of existing SRS applications. Dynamic ocean management combines technological advances to utilize and share near-real-time environmental and biological data to promptly communicate fisheries conditions to a broad stakeholder community (managers, industry, fishermen, and conservation organizations). These types of approaches can allow managers and fishermen to rapidly adjust fishing practices, efforts, and locations in response to changing conditions. Importantly, the development and effective application of these dynamic tools is reliant on robust high-resolution ocean data, making continued collection of SRS critical to the innovation of fisheries and other sectors of ocean management.

3.8 SRS in Fisheries Management: The Road Ahead

There have been numerous papers, workshops and evaluations of the integration of SRS into fisheries management and the conclusion reached in these documents continues to hold true today: while there is a substantial amount of SRS-generated oceanographic information, there remains a limited ability to apply these data. This conclusion is predicated on a critical assumption: SRS ocean data will continue to be collected and that new SRS technologies will be developed that improve accuracy and precision of the ocean data collected. This assumption is paramount as the continued collection of high-resolution SRS ocean data is central to sustainable fisheries management now and in the future. Without continued collection of high-resolution SRS data, sustainable fisheries management, within the larger ecosystem management context, will not be possible.

Even with decades of exciting innovations of SRS applications in fisheries and ocean management, there are several gaps that must be addressed to support the continued use and development of SRS data in fisheries management. These gaps include the ongoing disconnect between data acquisition and fisheries applications, and the need for wider SRS data integration and application. However, the most critical gap to address may be the limited support for actionable, need-driven science that uses SRS (and other) data to support fisheries management.

Both NASA and NOAA have developed many accessible online platforms to promote the use and distribution of SRS data. For example, NASA's Physical

Oceanography Distributed Active Archive Center (PO.DAAC), an element of the Earth Observing System Data and Information System (EOSDIS) provides SRS data to a wide community of users (https://podaac.jpl.nasa.gov/). Similarly, NOAA's ERDDAP web-based data server (http://coastwatch.pfeg.noaa.gov/erddap/information.html) provides a simple, consistent way to combine and download multiple sets of SRS data in common file formats. These and many similar efforts have made tremendous advances in delivering SRS data to the community of potential users. However, these efforts have not permeated the fisheries management community and there remains untapped potential in the development of SRS applications in direct service of fisheries management.

Robust fisheries management, of course, relies, on robust oceanographic data. However, in many cases, SRS and other oceanographic data are necessary but not sufficient, for robust fisheries management. Fisheries management also requires the integration of data on policy, social structure, culture, economics, and other related fields (Hall et al. 2007). Integrated frameworks that merge natural and social science data have been developed and applied to identify the factors affecting ecosystem management (Chan et al. 2012; Schultz et al. 2015), however, these types of integrated frameworks that merge SRS data with socioeconomic, policy and other data are still rare in a fisheries management context.

The final issue to be addressed is the critical need for actionable, management-driven science that uses SRS and other data to support fisheries management. Despite the growing, and in many areas of the world desperate, need for practical and implementable solutions to fisheries management problems, there are still comparatively fewer resources focused on actionable, applied science that can support innovative management solutions. This, in part, stems from a disconnect between the scientific and management communities. Analyzing SRS data is fundamentally complex and often requires highly specialized analytic tools and skills. For some fisheries managers and decision makers, this can be prohibitive. To interpret and apply SRS data or merge it with other in situ biological or other data also requires tools to apply the data into decision-making. There are very few applications available that enable managers to use SRS data in a scientifically robust but straightforward manner. This integration requires collaboration between researchers, scientists, data analysts and conservation practitioners to develop accessible tools, all the while ensuring such approaches are scientifically robust and defensible and are directly meeting the needs of the management community. Even with the remarkable advances in SRS sensors and platforms, the applications of SRS data in support of fisheries management have not yet fully capitalized on the rich SRS data sets. Given the substantial global investment in SRS technology and the ever-increasing pressure for sustainable fisheries worldwide, continued support and resources for SRS data distribution, integration, and management-relevant science are needed to maximize the return on this investment in support of sustainable fisheries.

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