THE SKIMMER ON MARINE ECOSYSTEMS AND MANAGEMENT

Published on ***Marine Ecosystems and Management (MEAM)*** **(https://meam.openchannels.org)**

New technologies for improving ocean management and ecosystem health

Stories about the use of new technologies for ocean planning and management often have the drama of a spy or science fiction thriller. Environmental non-profits are using satellite data and photos to find pirate fishing vessels offloading illegal catches in remote seas. Scientists are developing robots to kill invasive starfish. Fisheries inspectors may eventually be able to use facial recognition software to monitor whether fishing crews return endangered species to the water or keep them illegally. Citizen scientists can help track coastal flooding and storm damage using personal drones.

Unfortunately, the use of new technologies in the marine environment will have its problems and villains as well. Many of the technologies now available to managers and scientists are also available to others who may intentionally or unintentionally do harm to marine animals and ecosystems – such as harassing marine mammals or using tracking information to hunt threatened and endangered species ("cyber poaching").

Given the rapidity with which new technologies are advancing, we at MEAM wanted to catch up with leading technologists to learn which technologies they are using in their work, and which ones they feel will be most influential in improving ocean management and ecosystem health. We spoke with Matt Merrifield, chief technology officer at The Nature Conservancy; Dawn Wright, chief scientist at Esri; Renata Ferrari Legorreta, a spatial and quantitative ecologist at the University of Sydney; and Kerry Sink, marine program manager at the South African National Biodiversity Institute. We also feature several insightful and informative comments from EBM Tools Network members in the Comments section below.

MEAM will continue to cover new technologies and their potential applications in our EBM Toolbox columns. If you would like to see us focus on a particular technology or want to share your own use of technology for ocean planning and management, please send us a note at meam@openchannels.org or in the Comments section below.

Technology can facilitate stakeholder-driven planning in the ocean

Editor's note: Matt Merrifield is the chief technology officer at The Nature Conservancy. In this role, he is responsible for following technologies that can be utilized for the Conservancy's mission of protecting nature around the world. He works closely with the Conservancy's Oceans program which includes initiatives in fisheries, spatial planning, and coastal resilience.. He can be reached at mmerrifield@tnc.org.

MEAM: What technologies do you think have the most potential to improve ocean planning and management and ocean ecosystem health, and why?

Merrifield: When I think of ocean planning I immediately think about maps because I'm a geographer by training. The intersection of technology and maps has typically meant GIS, but in the mid 2000's, we saw massive uptake of online mapping platforms that were actually scalable (e.g., Google Maps) and that allowed you to write custom code to do things like markup and reporting. All of a sudden, a GIS workflow could be exposed to a lot of people with no geospatial skills. Seasketch.org has taken this concept to it maximal potential and has a great product for stakeholder-driven spatial planning in the oceans. That is hardly new tech, but it's proven to be durable. The SeaSketch developers cut their teeth in the California Marine Life Protection Act process. *[Editor's note: Learn more about SeaSketch on an upcoming webinar co-hosted by MEAM.]*

In terms of new tech, like everybody else, I see a lot of potential with artificial intelligence (AI), specifically for fisheries and electronic monitoring. There's been a lot of research into computer vision for enumerating catch, and I think we're reaching a point where we can start implementing this technology as the tech sector continues to release open source frameworks (e.g., TensorFlow) that can be applied to a wide variety of problems. This makes it possible to create and use classifiers (algorithms that automate categorization of input) that can drastically reduce the amount of time it takes to review video from electric monitoring systems. This ideally translates to three to ten times more observational coverage and data at similar cost, which fills critical gaps for science and compliance management in fisheries.

MEAM: Can you provide any examples of how this is working in practice, or could work?

Merrifield: SeaSketch has supported hundreds of marine spatial planning projects around the world, so they are a great example of what is currently working in practice. In terms of AI, TNC is bullish and investing in creating enthusiasm and awareness of its potential solutions for fisheries. We are currently partnering with Kaggle and hosting a competition to develop algorithms that can determine common species types in the longline tuna fishery. That is looking promising. It will take some effort to actually operationalize the output, though, so it is too early to tell the ultimate value.

In another case, we are using computer vision to automate length measurements for abalone. Again, it is in the early stages, but the results you can get with OpenCV, an Amazon Lambda server, and some JavaScript are pretty impressive.

MEAM: Are there any threats to ocean ecosystems posed by aspects of emerging technologies that marine managers and conservation practitioners should be aware of?

Merrifield: We live in a world with more and more sensors, and the sophistication of data science is growing rapidly as we figure out how to produce insights from those data. It will not be long before someone makes a better fish finder not just utilizing ocean surface data from satellites but incorporating in situ data from vessels as well. And in many cases, it is already being done with things like ROFFS (Roffers Ocean Forecasting Fishing Service) or DigitalGlobe's SeaStar service. These models can help fleets optimize their time on the water and lower their carbon footprint. That's great in a fishery with enforced stock limits, but it gets problematic in underregulated or underenforced fisheries.

Ironically, these tools also provide good insight into how to optimally task enforcement assets (e.g., where to send patrol vessels) when this optimization is critical to success.

Technologies that only require a web browser have tremendous potential to improve ocean planning

Editor's note: Dawn Wright is chief scientist of the Environmental Systems Research Institute (Esri). She is a leading authority on the application of GIS technology to the field of ocean and coastal science and co-edited one of the first books on marine GIS. She can be reached at dwright@esri.com.

MEAM: What technologies do you think have the most potential to improve ocean planning and management and ocean ecosystem health, and why?

Wright: Our team at Esri would like to highlight one category of emerging technology and three related issues for ocean planners and managers:

Geoplanner and other apps that allow geospatial analysis
Esri's Geoplanner (and other similar apps such as SeaSketch) have tremendous potential to improve ocean planning, management, and ultimately ecosystem health because they provide geospatial analysis directly within a web browser (i.e., not just *viewing* of data or maps but actual use of geoprocessing tools). GeoPlanner includes dozens of powerful geoprocessing tools that are much easier to access, run, and understand than those within the more complex world of the desktop tools. They also run much more quickly and are shareable with others almost instantaneously allowing for faster decision-making.

For example, a new kind of image service called a weighted raster overlay can be used in online analytic models that in turn feed into dashboards (displays that allow the user to track statistics about an analysis or to show analytic performance indicators). An example of how this can aid ocean management is finding the best places to site wind power turbines. A weighted raster overlay model using depth, bathymetric slope, distance from ports, and other relevant layers can weight layers (up to 100% total) and assign an importance according to the pixel value ranges within each raster, essentially normalizing disparate pixel values. A model could assign more importance to shallow water, lower slopes, areas that are closer to shore, closer to ports, and/or farther from shipping lanes. The results display areas with the highest potential for alternative energy sites using these criteria. The app could run this particular model *for the entire world* in less than a second, due to the raster function being intelligent enough to process the data and run the analysis only within the current view and at the appropriate map scale within that view. The user can also draw their own polygons of any shape directly on the screen to delineate areas of interest, which in turn would bring up dashboards for each of the polygons with histograms of the varying potentials for alternative energy development. Two polygons from different areas, along with their dashboards can be visually compared within the app. All analyses can be exported as data layers and maps for sharing on desktops or as image services for others to use in their browsers.

In a nutshell, these technologies that only require a web browser have tremendous potential to improve ocean planning because they instantly increase our versatility and ability to come up with creative solutions. It is the versatility of being able to access the data sitting on our machines, but much more importantly, the data services, web mapping services, and the like that are freely available out on the internet. The versatility allows us to mash up our own unique maps (our "intelligent web maps") that will automatically update as new data become available, all while adhering to standard specifications that make the output interoperable and useable anywhere.

Ecological Marine Units
Ecological Marine Units (EMUs) are an unprecedented point mesh framework of the oceans' physical and chemical properties that are most likely to drive ecosystem responses. The framework is based on 52 million global measurements made over a 50-year period. Rigorous statistical clustering applied to this mesh resulted in 37 physically and chemically distinct volumetric regions (EMUs), from the ocean surface all the way down to the ocean floor. This differs from existing maps of marine ecoregions or biogeographic realms in being globally comprehensive, *quantitatively* data-driven, and truly 3D. EMUs provide a standardized, rigorous, and ecologically meaningful set of ocean ecosystem units. The EMUs can be the basis for a variety of climate change impacts studies, biodiversity priority setting, economic and social valuation studies, research, and MSP. For example, EMUs will be used in the revision and evolution of the "Hope Spots" computer platform. The EMUs will be used to help users visualize the extent of existing large marine ecosystems and nominate their own hope spots in the context of where current MPAs and ocean uses are. NOAA is also adding data on carbonate chemistry and pteropod shell dissolution to the EMU 3D point mesh framework to provide additional information on the responses of ecosystems to influences such as ocean acidification. This will be used to develop visualization tools and explore how to include the impacts of ocean acidification in the Atlas of Ocean Wealth.

Ocean planners and managers can access the underlying data, EMU mesh, and EMU clusters; explore the EMUs on the web or mobile devices; and join a community of researchers improving the EMUs and using the EMUs in their own work. *[Editor's note: Learn more about EMUs on an upcoming webinar co-hosted by MEAM.]*

Electronic Navigation Charts
Electronic Navigational Charts (ENCs) will be the base of much future MSP and conservation analysis because their full-bottom coverage provides highly-detailed maps of ecosystem rugosity and other features that will enable better habitat management. Also, their vector features are readily consumed by GIS so that data need not be downloaded and therefore instantaneously out-of-date; managers can have access to the latest data all the time.

Typically, ENC vector data are maintained by national hydrographic offices (HO) or ports that are primarily concerned with mapping hazards to navigation and channels. They recognize conservation and management purposes as valuable additions to their value proposition to the government, but the International Hydrographic Organization (IHO) has not yet agreed upon a legal framework for sharing ENC for non-navigational purposes. The US National Oceanic and Atmospheric Administration Office of Coast Survey has led the way, however, by providing free access to their ENC.

Active treatment for invasive species
The International Maritime Organization Ballast Water Management (BWM) Convention will come into force in September 2017 and will require shipping companies to have an active treatment procedure to manage the risk of invasive species. This will impact coastal zones and ports as these procedures affect port management (port state control measures will likely require an environmental control officer at the main ports) as well as environmental studies to review changes to near-coastal ecosystems. GIS offers tools to conduct risk assessment of shipping and ports of call to highlight vessel voyage origins and ballast exchange locations that present the greatest risk of invasive species. Additionally, BWM systems onboard ships could have controls that are location-sensitive so that exchanges are prevented when in a high-risk or controlled area.

MEAM: Are most of these technologies accessible to and usable by practitioners in the developing world, who may have limited access to high-speed internet connections/computing resources/etc.?

Wright: Web browser-based spatial analysis can be a powerful tool for ocean planning even for areas with limited access to the highest internet speeds. In lieu of that, another resource to consider is a data appliance, an on-premises data and hardware solution that provides an organization with basemaps, reference data, and apps such as GeoPlanner. Oftentimes appliances are used for the purposes of creating, publishing, and sharing map services securely behind a firewall. But they can also provide a solution in developing countries where internet service is poor. There would likely need to be financial assistance offered to help cover the cost of the appliance. With regard to working with Esri, hopefully many are already aware of our special Nonprofit and Conservation programs that offer special licenses and other assistance to help meet the needs of those in small organizations or in developing countries.

MEAM: Are there any threats to ocean ecosystems posed by aspects of emerging technologies that marine managers and conservation practitioners should be aware of?

Wright: I think many of the potential problems are more related to hardware such as drones and ROVs rather than the technologies we focused on.

3D maps derived from imagery for marine ecosystem monitoring in Australia

By Renata Ferrari Legorreta

Editor's note: Renata Ferrari Legorreta is as a spatial and quantitative ecologist at the University of Sydney. She can be reached at renata.ferraril@gmail.com.

I have been developing, testing, and applying high-resolution 3D maps derived from imagery for marine ecosystem monitoring for the past five years. We are using off-the-shelf cameras (such as GoPro cameras) in underwater housings to image large areas of reef (100s of m^2) and then off-the-shelf software to create high-resolution 3D maps of these areas. From these maps, we measure habitat structure - community composition and habitat structural complexity. These data are extremely useful for assessing, monitoring, and predicting ecosystem health in temperate, subtropical, and tropical marine ecosystems.

How is this different from multibeam sonar digital elevation models (DEMs)? Multibeam is not a visual technique; therefore, community composition cannot be derived from it. In addition, even high-resolution multibeam can only achieve resolutions of approximately 50 cm. Close range photogrammetry, which underlies our 3D maps, generates 3D maps of the seafloor and benthic organisms with millimetric accuracy, making it more powerful and relevant to the ecology of both sessile and mobile fauna.

How do our 3D maps differ from in-water surveys? Images can be captured from a wide range of platforms – autonomous underwater vehicles (AUVs), diver rigs, ROVs, drones, etc. Metrics are orders of magnitude more accurate and precise than traditional in-water surveys, and the area of extent covered is orders of magnitude larger.

The main limitation of this technology right now is that it requires significant effort, so covering large areas (square kilometers) would be extremely costly. Right now, it is a complementary technology to lower-resolution technologies such as multibeam sonar or satellite/aerial remote sensing. It is non-intrusive, so there is no threat to surveyed ecosystems. And it is readily usable by practitioners with limited internet connectivity and computing resources. Training opportunities are more limited, however, and one to two weeks of training are probably necessary for any practitioner interested in applying the technology.

Remote camera systems for ocean planning in South Africa

By Kerry Sink

Editor's note: Kerry Sink is the marine program manager at the South African National Biodiversity Institute and a 2016 Pew Marine Fellow. She can be reached at K.Sink@sanbi.org.za.

In South Africa, we are using remotely operated vehicles (ROVs) and tow cameras to support ecosystem classification and mapping, identify and propose protection for sensitive habitats, monitor threatened species, and understand human impacts in the ocean. Ecosystem classification and mapping is foundational to the implementation of effective ecosystem-based MSP, including decision making in the ocean, environmental impact assessment, and the design of representative MPA networks.

The first use of an ROV for science in South Africa started when scientists became frustrated with the limitations of relying on international partners and borrowed submersibles to access an incredible research asset - the shallowest population of living coelacanths. The coelacanths were discovered by mixed gas divers in Sodwana Bay, South Africa. The use of a small boat and hired ROV opened new windows into deeper ocean habitats. Last year, a month-long expedition used a tow camera and a GoPro in a deep water housing to shed light on 16 ecosystem types and 7 newly proposed MPAs.

South African researchers are also making extensive use of Baited Remote Underwater Videos (BRUVs) to assess fish populations and are using this data to improve the national habitat map for the next national biodiversity assessment.
