New technologies for high resolution coastal data collection

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The problem
We collect time series data on many coastal systems at great expense, with the expectation that it will improve our capacity for science-based decision-making. Unfortunately, these long-term data are sparse, and most monitoring efforts that do exist in coastal systems are small-scale, rendering them inadequate to address regional and global shifts in coastal communities, geomorphology, biodiversity and ecosystem services that result from climate change, pollution, fishing, and other regional- to global-scale impacts. Needed are cheaper, faster, higher-quality ways to collect time series data with a finer degree of spatial resolution.

Recommendation
New and existing but under-utilized technologies have the potential to dramatically expand our ability to assess coastal change at all scales. Coordination of available tools, development of new techniques and infrastructure, and integration of these components into a cohesive program will significantly advance our knowledge and understanding of the patterns and drivers of change in coastal systems. We recommend:

- Increasing our capabilities to collect high-resolution (spatial and temporal) data
- Expanding use of cost-effective, off-the-shelf sensors and platforms
- Making existing and new data openly available and easily discoverable

Impact

- Time series and spatially dense data necessary for building and validating models.
- High-resolution data can better support local decision making.
- Pair with remote sensing data for stronger large-scale inferences and ground truthing.
- The availability of new low-cost, robust, and user friendly technologies may encourage their adaptation by citizen scientists and facilitate wide-spread participation in data collection.

Examples
Aerial & underwater drones & sensor suites
Unit costs are dropping, and capabilities and user-friendliness are rising for many drone technologies including both aerial and underwater versions. These can serve the urgent need for cheaply-obtained, fine-grained data

collection on both the land and water sides of the coastline. NSF can help drive fundamental innovation in the underlying technologies (hardware and software) and can also support projects that deploy these tools at a high-enough level of density to construct rich and fine-grained time-series data sets for coastal processes.

In situ imaging (flow cytometry for plankton, time lapse video for fish, human activity)

Sampling plankton has traditionally involved laborious microscope counts that are impractical to do on large scales and high frequency. In situ imagers combined with machine learning image analysis are now available and can revolutionize our knowledge of plankton dynamics including HABS. At least three versions of in situ systems are available. For example, the imaging flow cytobot (iFCB) was developed by Heidi Sosik and Rob Olson at WHOI and can be used with discrete samples or in a flow thru arrangement including moorings. Images are sorted by their scatter and fluorescence and then sized and classified to taxa when possible.

Machine learning for image analysis

Optical imagery has long been used to record data in marine habitats; for example, underwater video allows us to maximize information gathered during limited diving time. Nevertheless the potential of imagery is seriously underdeveloped due to a bottleneck at the analysis stage. Although automated image analysis is now routinely used in biomedical and engineering applications, the majority of video and still image analysis by ecologists is still done manually. Machine-learning image analysis techniques have great potential to to automate analysis of marine and coastal imagery, including classifying substrate, identification of species in video and still imagery, and quantifying human activities such as coastal trap fishing. Such tools will empower citizen scientists who may lack expertise but could collect imagery on much larger scales than scientists alone.

Low-cost Lidar, sonar (coastal erosion, bathymetry, biological habitats)

Better spatial resolution for coastal data is an urgent need for applications ranging from siting buildings to rebuilding oyster beds. Dramatic cost reductions in technologies such as Lidar provide researchers with opportunities to map broad areas repeatedly and at high resolution. A similar dynamic is playing out with sonar and associated underwater spatial data collection technologies. NSF can support continued technology development as well as support field researchers today in deploying large networks of inexpensive, high-quality spatial measurement devices.

Metagenomic data (microbes, plankton)

Taxonomic identification of microorganisms has traditionally been challenging because, in addition to limited morphological characteristics, less than 1% of the microbial diversity has been cultured successfully. The introduction of genomic approaches over the past two decades has allowed microbiologists to overcome these limitations and assess microbial diversity in terrestrial and aquatic ecosystems. These methods use nucleotide sequences of small sections of an organism’s genome to differentiate one taxonomic group from another. In microbial ecology it is now common for researchers to collect seawater, concentrate that sample onto a filter, extract DNA, PCR amplify a region of the 16S rDNA and sequence that amplicon for identification. Similar techniques targeting different regions can be used for eukaryotes. The use of such genetic markers with high-throughput Next Generation (Next Gen) sequencing provides high-resolution taxonomy for phylogenetic analyses as well as data for biogeographical distributions of microbes, including pathogens that can impact shellfish, marine mammals, and humans. These relatively fast and inexpensive methods provide the data needed to link microbial diversity and community structure information with physical processes and human impacts.