Developing a Coherent National Backbone for Living Coastal Resources
IOOS is a distributed system that brings together federal, academic, and commercial partners to provide an integrated national ocean observing capability for the US coastal zone. While this core partnership is the unique strength of IOOS it has yet to achieve its full potential as a truly integrated observing system. This could be accomplished by first collecting, in a uniform comparable manner, a common set of environmental observations, and second by developing a national backbone for core biological measurements. Recommendations for enhancing and building new capabilities focused on marine living resources include:

Develop a national inventory of biological measurements that are routinely made across IOOS regions.

This inventory should include basic information such as the specific measurement, latency of the measurement, precision, and sensitivity of the measurements taken, methods, and post-processing techniques.

Focus on standardization of core biological measurements across the IOOS enterprise.
Biological patterns are mobile (advective transport, fish migration, etc.) and require integrated measurements over regional scales. Therefore providing standardized measurements across the regions is critical to providing data streams to meet the needs of potential stakeholders (management, conservation, research, commercial). This will be critical to collect relevant information spanning from climate impacts to effective management and conservation.

Develop the capacity to ensure the development of a specific biological capability across the IOOS enterprise. Given potential investment develop a critical new national capacity across the RAs. While biological monitoring is inherently complex, the GOOS-Panel-BioEcosystems with significant community engagement are developing Essential Ocean Variables (EOV) for biology and ecosystems. Each EOV has a specification sheet that was developed by a GOOS Expert Panel that documents the background and justification for the measurements, along with a description of the derived products, supporting variables, and in some cases the societal drivers and pressure that the EOV addresses. Example EOVs include but are not limited to Ocean Color, Phytoplankton Biomass and Diversity, Marine Turtles, Birds and Mammals Abundance and Distribution, Fish Abundance and Distribution, Macroalgal Canopy and Cover and Harmful Algal Blooms. While many EOVs are still under development they can serve as a starting point for defining the IOOS backbone for biological monitoring. Adopting a common set of standards and protocols will be critical for the validation and calibration of remotely sensed ocean color and for consistent documentation of HABS. This will enable the connection of local or regional measurements to the GLOBAL observing systems. Climate signals requires that we measure physics and chemistry in a standard manner with strong quality control and assurance to extract the potential changes. For example, most of the current ocean acidification technologies vary in the precision of their measurements by orders of magnitude. What is most concerning about this is that although there are a few instruments employed within coastal zones to monitor the pH of coastal waters, many of the instruments deployed have error ranges that exceed the change in pH predicted over the next 100 years.

While there are many potential biological observations that can be made, not all of them are operational. GOOS differentiates between EOVs that are in the concept phase, the pilot phase, and those that are mature. Mature EOVs are those that can deliver routine measurements in an operational context. BioEco EOVs that are considered mature include animal tracking of upper trophic levels and passive and active acoustics. The Animal Tracking ATN is an excellent example of an IOOS operational system that collects data across all RAs in a consistent manner, which can be accessed by researchers from any RA. Passive acoustics is another system that currently operates nationally within NOAA as the Soundscapes program and within the National Marine Sanctuary program. Clearly, these existing efforts within NOAA and NERRS should be integrated into or at least be accessible through IOOS. Finally, some of the EOVs are relevant across disciplines. For example, the ocean acoustics EOV and the Animal Borne Ocean Sensors Network are relevant to GOOS Physics, Chemistry, and BioEco panels.

As there are many promising emerging technologies on the horizon, now is the time to establish standard practices and procedures. The RAs can serve as a test bed to develop and test these new observation tools but with an emphasis on implementing these new techniques as part of an integrated national system. These pilot observational tools include measurements of eDNA which show much promise but remain in the early phases of development and interpretation.

Environmental DNA (eDNA) Metabarcoding

As various organisms living within an ecosystem interact with their environment they tend (both opportunistically and forcibly) to leave traces of themselves behind (e.g., skin/hair, secretions, feces, etc.) which contain their genetic material (e.g., nuclear or mitochondrial DNA). This resulting “environmental DNA (eDNA)” is constantly being released by nearly every multicellular organism within an ecosystem and thus, environmental samples collected from the universal substrates (e.g., abiotic habitat features, including soil, water, air, etc.) theoretically contain traces of DNA from all of the organisms within that ecosystem. In this regard, metabarcoding and other forms of eDNA analyses have great potential for rapid assessment and monitoring of biodiversity within ecosystems, but similar to many emerging technological advances, its abilities to achieve our shared goal of “real-time monitoring of biodiversity for conservation and policy” are grossly overestimated. Indeed, several recent publications have demonstrated eDNA’s ability to overcome the more famous challenges of conventional long-term biodiversity monitoring techniques (i.e., traditional taxonomic surveys), which often are heavily dependent upon the taxonomic expertise of the individuals who conduct them, cause some measure of disturbance within the ecosystem, and are time-limited causing some species to be routinely missed. Yet, they are remiss in terms of matching the strengths of conventional approaches, including the in situ determinations of the health of organisms/ecosystems, assessing spatiotemporal changes in population demographics and distributions within the ecosystem (a key component of understanding 'causes and effects' to a population), as well as being entirely unable to determine the size of any population of species detected beyond perhaps rank order of abundance measurements - although this is also a stretch. What the emerging field of eDNA neglects to share as fervently as it does its accomplishments is that the very presence of an organism's DNA in any given place in an environment is ruled by chance because the rates of eDNA degradation and dissolution vary greatly in both space and time - think of it as an eDNA sample being taken from a place with a lot of current ten minutes before a mass spawn vs ten minutes after. This resulting heterogeneity of genetic material within marine ecosystems makes it essential that each procedure is proven prior to its inclusion within a national system. However, the sensitivity of newly emerging eDNA metabarcoding techniques (e.g., targeted amplification) does show promise in early detections of nonnative species introductions, if performed routinely. Therefore, although eDNA has obvious potential for applications in conservation, monitoring, and biodiversity assessment in the marine realm, these applications should not be considered as "replacements," but rather "additional enhancements" to current biological monitoring paradigms.