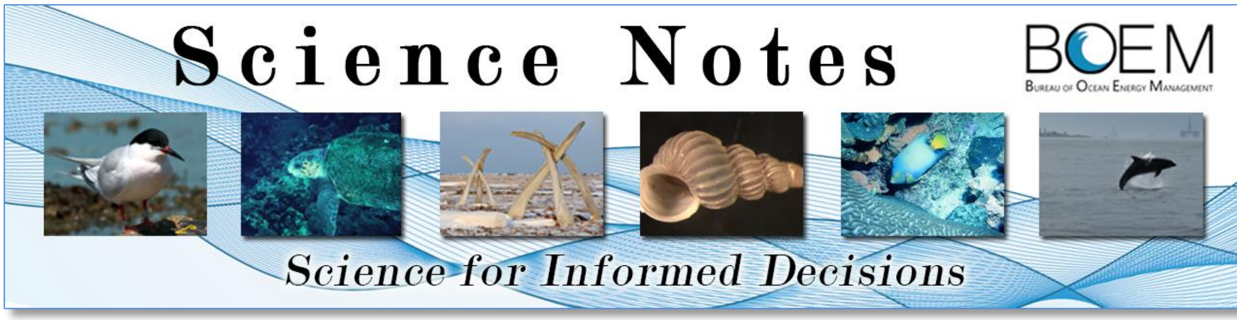


March 28, 2017

Dear Reader,

On a recent winter day, several staff members from BOEM's Environmental Studies Program and I had the opportunity to visit the Smithsonian Natural History Museum Support Center outside of Washington, D.C. The support center has been archiving BOEM's collection of marine specimens for nearly 40 years, and I love to visit. This trip focused on the cutting-edge use of genomics at the center and how DNA from our specimens is enabling researchers everywhere to advance knowledge about the organisms and the environments in which they live. This month's Science Note is devoted to the BOEM-Smithsonian partnership, acknowledging our joint contributions to science and looking at the genomics revolution. Please enjoy reading it, and as always, feel free to send your comments to us at boempublicaffairs@boem.gov.

Sincerely,

William Y. Brown
Chief Environmental Officer

BOEM-Smithsonian partnership advances cutting-edge science on ocean organisms, their DNA, and their environment

Nine miles southeast of the National Mall in Washington, D.C.—home to famous museums, monuments, and memorials—sits a plain building housing hundreds of thousands of creatures from the ocean and coastal areas. Two female giant squids painted on the floor in a stylized manner welcome you – the larger one is a life-size painting 25 feet long, and the adolescent about half that size. Replicas of dolphins and sharks are displayed from the ceiling. Rounding the corner, an upright, preserved polar bear greets you with open arms. Suddenly, the doors open and reveal rack after rack of specimens in jars. In other rooms are freezers and tanks holding larger specimens. You have arrived at the Smithsonian National Museum of Natural History Museum Support Center (NMNH/MSC), where members of the Smithsonian Invertebrate Zoology Department brain trust do hands-on science every day.

Life-size paintings of two female giant squids greet visitors to the Smithsonian Natural History Museum Support Center. *Photo by Marjorie Weisskohl, BOEM.*

They are busy identifying, cataloging and in many cases, giving specimens their official scientific names or facilitating other scientists around the world in doing so. The Smithsonian's Invertebrate Zoology Department, or IZ, is immense. It currently holds 50 million specimens.

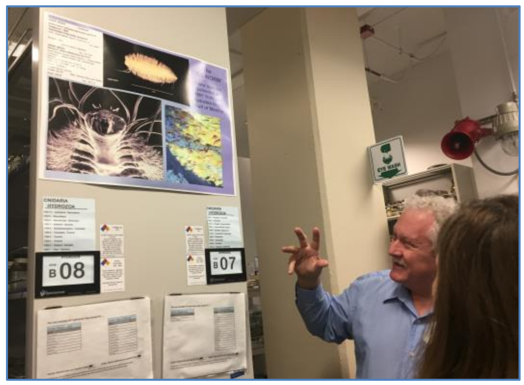
The section BOEM visited this winter, Pod 5, contains 18.1 linear miles of shelving and 95 steel tanks.

The BOEM collection alone, amassed over 38 years, contains more than 280,000 specimen lots collected from all four U.S outer continental shelf (OCS) regions as part of the bureau's Environmental Studies Program (ESP). To date, over 350 species from the BOEM collection have been officially named and introduced to science for the first time.

Bill Moser (center left, blue shirt), Acting Invertebrate Zoology Collection Manager, describes the giant squid in one of the tanks during the BOEM visit to the MSC. *Photo by Marjorie Weisskohl, BOEM.*

In recent years, Smithsonian researchers and external partners have begun to generate DNA barcodes from BOEM's historical collections, specimens stored in jars of ethanol for years.

Who could have imagined when BOEM sent its first specimens to the Smithsonian for cataloging in the 1970s that someday they would be part of the Global Genome Initiative? BOEM is one of 11 organizations partnering with the Smithsonian, universities, research centers, government agencies, industry, and museums from around the globe to preserve and understand the genomic diversity of life on Earth.



Greg Boland, BOEM oceanographer, describes an ice worm gathered from one of BOEM's CHEMO II research cruises in the Gulf of Mexico in 1997. *Photo by Marjorie Weisskohl, BOEM.*

BOEM's Smithsonian specimens from past studies loaned to outside researchers have yielded DNA barcodes (CO1, cytochrome oxidase 1 gene) from four BOEM expeditions dating back more than 30 years: Atlantic Slope and Rise Program (ASLAR, 1984-85); the Canyon and Slopes Processes Study (CASPS, 1979-82); and two Gulf of Mexico projects: Lophelia coral program (LOPH, 2005), and Chemosynthetic Ecosystem Study (CHEMO III, 2007). Barcoding collections from recent studies, such as the Pacific region's Multi-Agency Rocky Intertidal Network (MARINe) project, is now underway, but much remains to be done.

Protecting Ecosystems, Preserving Biodiversity

The ESP's mandate under the Outer Continental Shelf Lands Act Section 20 is to study the human, marine and coastal environments. This involves sampling existing biological diversity to help characterize cumulative impacts of oil and gas exploration and development along the continental shelf. Specimens are sent to the Smithsonian after they are analyzed by researchers following the original science cruises. By archiving new specimens and analyzing the genome, we are improving our ability to conduct long-term monitoring, understand the presence or absence of protected species, food habits or food web patterns, or geographic population shifts due to climate change or other factors.

This ice worm, discovered in 1997, was living on exposed frozen methane hydrate at a depth of 1,800 ft. The specimen is among those on display at the Natural History Museum, titled "Objects of Wonder," open to the public until 2019. *Photo by Greg Boland, BOEM.*

BOEM's 280,000 specimen lots represent more than 8,300 unique taxa or organisms. They include Annelida (segmented worms), Crustacea (shell fish such as crabs and shrimp), Cnidaria (including corals and jellyfish), Echinoderms (includes starfish and sea urchins), Mollusca (such as snails, clams, octopus), and Porifera (sponges).

The BOEM collection represents one of the most extensive collections of marine organisms from the U.S. continental shelves and slopes in terms of geographic coverage, the period of time covered, the number of taxa represented, and the data collected. These specimens are impossible to replace and are permanently available for researchers world-wide.

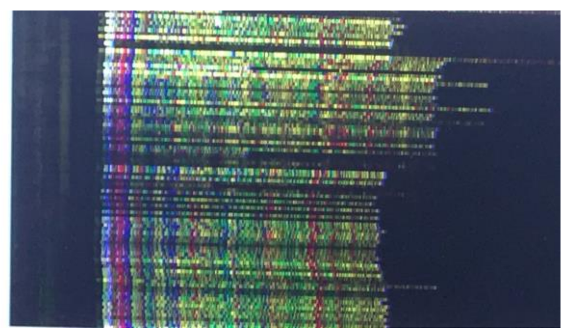
Leveraging New Technology, Sequencing the DNA, Building the Library

There has been exponential progress in genome sequencing. According to the National Institutes of Health, it took 13 years to complete the original human genome project. Today, gene sequencing technology can do the equivalent processing in about one hour.

Software produces the spectrograph and optical bar code. Below, each row of code is unique and represents a single sample. *Photo by Marjorie Weisskohl, BOEM.*

Different types of technology are used to extract and sequence the DNA. At the MSC, we saw how NMNH uses an automated robot to extract almost 400 samples in four hours. The process starts with small pieces of tissue enzymatically digested overnight, then placed in an automated extractor where a series of treatments separates and creates pellets of the DNA using a centrifuge.

A particular target region of the DNA is replicated millions of times via a polymerase chain reaction to obtain enough sample material for DNA nucleotide sequencing.

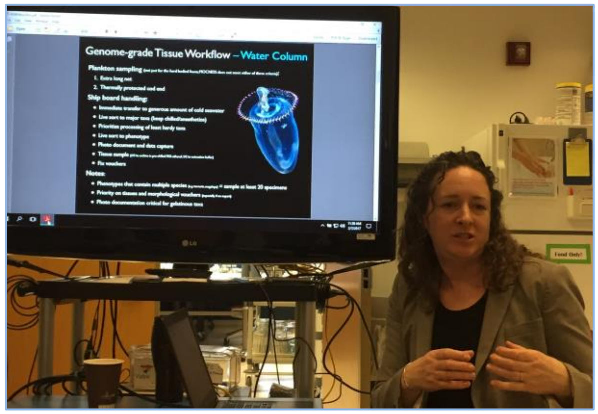


Illumination by a laser produces colors in the bar code as each of four possible nucleotides (G, A, T and C) constituting the genetic code passes by a sensor. The color bar coding is an easy way to visualize how the sequencing is going. The actual DNA barcode might look something like this, row after row:
tatatgatcaggtttggttgggacagcccttagtttattaattcgagcagaatta
Photo by Marjorie Weisskohl, BOEM.

The images to the right show the sequencing run in progress, with each row a visualization of each sample. The machine can run 96 samples at a time. The colors result from illumination by a laser as each of four possible nucleotides (G, A, T and C) constituting the genetic code passes by a sensor. Each species has a distinctive series of nucleotides that allow scientists to identify species, even from eggs or fillets.

BOEM collections are contributing species critical to building a global reference library. The extracted DNA and remaining tissues are housed in a state-of-the-art biorepository for future research and broader genomic work. One Smithsonian partner, the Food and Drug Administration, uses DNA analysis to test seafood imported from other countries in order to authenticate labeling. The Smithsonian also uses next generation sequencing technologies to sequence whole genomes or multiple subregions for better understanding genome evolution, population structure, conservation status, and overall relationships across the tree of life.

A new dimension of genetics research is called environmental DNA or e-DNA. It has the potential to detect DNA from sloughed off tissue in the water column and help researchers compare the DNA to previously analyzed physical specimens. It is like fingerprints being left behind. One needs a database of identified fingerprints to identify the owners, and that is why BOEM specimens are important. While BOEM samples are not being analyzed under this procedure yet, it has tremendous potential, including long-term monitoring and assessing ecosystem health. We are contributing toward unlocking this potential.



Smithsonian's Karen Osborn describes an e-DNA project off Florida's East Coast for identification and genetic characterization of Gulf Stream fauna.
Photo by Marjorie Weisskohl, BOEM.

The Smithsonian's Natural History Museum, often called the Fort Knox of biodiversity, serves the global scientific community. To learn more about BOEM's contribution to this amazing collection, visit the BOEM-Smithsonian page.

BOEM's Environmental Studies Program develops, funds, and manages scientific research to inform policy decisions regarding the development of energy and mineral resources on the Outer Continental Shelf.

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