U.S. WEST COAST

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ATN • MBON • OTN

BIOLOGICAL OBSERVATIONS WORKSHOP SUMMARY REPORT

NOVEMBER 7–9, 2018
HOTEL PARADOX
SANTA CRUZ, CALIFORNIA

Identifying Regional Needs and Priorities for Animal Telemetry and Biodiversity Observations of Aquatic Species

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Thanks to our planning committee and all who helped to make this workshop a success. Special thanks goes to our note-takers Callan Yanoff, Theresa Keates, Roxanne Beltran and Megan Hepner, and also to Callan Yanoff and Helen Worthington for their valuable assistance in preparing this report.

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Cover and Inside Cover Photo: A Humpback Whale Breaching in Monterey Bay National Marine Sanctuary

Photo Credit: Chad King, NOAA

WORKSHOP PARTICIPANTS

A complete list of workshop participants can be found on pages 49–51.

WORKSHOP SPONSORS

MBON Marine Biodiversity Observation Network

IOOS Integrated Ocean Observing System

OCEAN TRACKING NETWORK

SOUTHERN CALIFORNIA COASTAL OCEAN OBSERVING SYSTEM

ATN ANIMAL TELEMETRY NETWORK

CENTRAL & NORTHERN CALIFORNIA OCEAN OBSERVING SYSTEM

NASA

NANOOS

WORKSHOP OUTLINE

This is one in a series of U.S. regional workshops being convened to identify priority stakeholder needs for regional telemetry, biodiversity, and other types of observations of aquatic species that could be served by an Animal Telemetry Network (ATN)/ Marine Biodiversity Observation Network (MBON)/Ocean Tracking Network (OTN) baseline network and to examine whether the type and extent of existing telemetry and biodiversity observing assets could adequately satisfy these requirements.

The three U.S. IOOS West Coast Regional Associations, NANOOS (Northwest Association of Networked Ocean Observing Systems), CeNCOOS (Central and Northern California Ocean Observing System), and SCCOOS (Southern California Coastal Ocean Observing System), partnered with the U.S. ATN, the U.S. MBON, and the Canadian OTN to convene a regional stakeholder workshop in Santa Cruz, California on November 7–9, 2018. More than 100 participants from multiple agencies and organizations, including NOAA (National Oceanic and Atmospheric Administration), NASA (National Aeronautics and Space Administration) , the U.S. Navy, BOEM (Bureau of Ocean Energy Management), Monterey Bay Aquarium, Point Blue Conservation Science, Consortium for Ocean Leadership, Monterey Bay Whale Watch, Ocean Science Analytics, multiple state agencies and universities, and more worked together over three days to address these four objectives:

Objective I. Identify and prioritize stakeholder marine animal telemetry and biodiversity monitoring and observational needs in the West Coast Region.

Objective II. Identify the existing telemetry and biodiversity observing assets and scientific capabilities in the region.

Objective III. Document regional stakeholder specific uses of marine animal telemetry and biodiversity data.

Objective IV. Identify infrastructure and data management challenges and opportunities that exist in the region.

Forty-three speakers covered topics that provided perspectives from the resource management, commercial and research communities.

BREAKOUT SESSIONS

Two breakout sessions were created and structured along stakeholder lines (Day 1) and by relevant animal telemetry and biological observation application priorities (Day 2). Participants were asked to consider the following questions:

- What types and extent of existing assets could compose an integrated biological observations network?
- Who are the important organizations/institutes to engage?
- What is lacking or missing completely? What mechanisms can identify to fulfill these gaps?
- How can biological observations be improved or better served to address private sector and resource management needs?
- How can telemetry and biological observations be used to better address the key sector needs identified on Day 1–2?
- What is the value of a regional baseline network approach versus individual research efforts?
- What are the potential challenges to building a regional biological observations network?
- What actions can be taken to address those challenges?

A summary of the breakout session discussions, as well as those in the Day 3 Plenary Session, is provided on page 46.

https://ioos.noaa.gov/project/atn/

https://ioos.noaa.gov/project/bio-data/

OPENING REMARKS

The ATN: Providing Unity, Stability, and Continuity to the U.S. Animal Telemetry Network

Bill Woodward, Network Coordinator, U.S. Animal Telemetry Network, U.S. IOOS Program Office, NOAA/NOS, Silver Spring Maryland

A considerable amount of marine animal telemetry infrastructure and expertise exists in the U.S., but it is currently limited in its coordination and connectivity. The U.S. Animal Telemetry Network (ATN) vision is to create an alliance of collaborating partners, which enables science by assembling these national capabilities into a cohesive network, complete the network incrementally where needed and provide a stable, unifying, long-term underlying infrastructure including a data aggregation and management capability for it.

The multi-agency ATN was established in 2016 and is implemented on three foundational pillars: 1) building alliances and collaborations, 2) providing telemetry data aggregation, management, display and delivery, and 3) funding high priority regional baseline animal telemetry observations. Governance is provided by a steering group of representatives from nine federal agencies and four non-federal institutions.

At the heart of the ATN data management vision is a centralized data assembly center (DAC), which is a community resource where regional telemetry data are aggregated in a single place, and one-stop-shopping is provided for access to all U.S. national animal telemetry data. The DAC both serves national stakeholder needs effectively and enables cost/time savings to principal investigators. Examples of current ATN community support include two regional acoustic node data managers, a National Marine Fisheries Service-funded DAC data coordinator, a Georgia Department of Natural Resources acoustic receiver array, and financial support of the Argos fees for ATN satellite tag researchers.

The U.S. Marine Biodiversity Observation Network (U.S. MBON)

Gabrielle Canonico, U.S. MBON Manager, U.S. IOOS Program Office, NOAA/NOS, Silver Spring Maryland

MBON was borne out of the Census of Marine Life and the recognition through that process that, while huge investments are made in ocean observing systems and biodiversity monitoring, there is no systematic and integrated global effort to observe life in the sea that can tell us about status, trends, and shifts over time, and further—how that impacts people. In the U.S., MBON is emerging as a long-term, multi-sector, multi-disciplinary network to observe marine life and ecosystem interactions.

The network started in 2014 with three demonstration projects, expanding in 2019 to six projects covering the Arctic, California Current, Pacific Northwest, Gulf of Maine, and South Florida. MBON priorities include making data available from existing biodiversity monitoring efforts and filling gaps where they exist, integrating remote sensing with in situ observations, and advancing new technologies and approaches (remote-sensing based Seascapes and other approaches, acoustics, environmental DNA, still and video imagery, and machine learning)—all in the service of users and stakeholders such as National Marine Sanctuaries, Integrated Ecosystem Assessment, state management agencies, federal managers, and others.

Like ATN, MBON seeks to build communities through alliances and collaborations in the U.S. and globally, support baseline observations, and advance data management and delivery.

The Ocean Tracking Network: Global Infrastructure and Research Network for Aquatic Animal Research

Fred Whoriskey, Executive Director, Ocean Tracking Network , Dalhousie University, Halifax, Nova Scotia, Canada

The Ocean Tracking Network (OTN) is a collaborative, globally-linked infrastructure platform and research network originally formed as an International Joint Venture from the Census of Marine Life. OTN uses electronic telemetry to research animal movements and survival and their link to environmental conditions to achieve its overall goal of advancing conservation and management of aquatic biological resources. Headquartered in Canada the OTN includes more than 400 investigators from 20 countries detecting over 140 individual marine animal species.

The OTN infrastructure includes global acoustic telemetry networks and world class glider and data teams. They are an Associate Data Unit of the IOC's IODE, and a Tier 2 OBIS node. Their research projects are focused on:

- Managing fisheries (assigning spatially-linked quotas and monitoring endangered and highly valued species)
- Assessing Marine Protected Areas
- Understanding changing animal distributions due to climate change
- Performing environmental impact assessments
- Conducting ecosystem and fundamental science research

OTN recently renewed funding support for infrastructure for 5 years beginning in 2018 with no obligatory sunset provision. They are adding additional new gliders and receivers, seeking new research funding to pair with their infrastructure (e.g., Strategic Project Grants; SeaMonitor; Industry/OFI, working to enable new Canada International funding), and implementing a new data node for MigraMar (Central, North, and South America).

Coho on the Salmon River. Photo Credit: Northwest Indian Fisheries Commission

WORKSHOP HIGHLIGHTS

I. STAKEHOLDER MONITORING/ OBSERVATIONAL NEEDS

- A time series is the cornerstone of what we do: "Today's time series is tomorrow's baseline."
- Reductions in the presence of chemicals don't define success – the responses of the fish to the reductions need to be observed in order to determine success.
- The Marine Mammal Protection Act (MMPA) and the Endangered Species Act (ESA) require information about distinct population segments, population size, stock structure, human-caused mortality, threats, and trends in abundance.
- Observations of biomass and species distribution, abundance, and diversity are needed to furnish answers to the 17 questions in the Sanctuaries Condition Reports on water quality, habitat, and living resources; for example, "What is the status of biodiversity and how is it changing?"
- The Port of Long Beach needs higher quality telemetry/biodiversity data: they welcome assistance with telemetry solutions that reduce whale strikes from incoming vessels and improve marine mammal monitoring, especially during pile driving/blasting, as well as community partnerships to implement cost-effective, less invasive eDNA sampling methods.
- There is a need to quantify temporal trends in the biology of ecosystems for a wide array of organism types and whether any changes can be attributed to water quality.
- The Bureau of Ocean Energy Management (BOEM) requires observations that enable them to determine the effects of activities that have impact on the environment and on affected resources from U.S. Outer Continental Shelf energy and mineral resources development.
- Observing ocean microbes is critical because they produce at least fifty percent of the oxygen in our atmosphere while removing large amounts of carbon dioxide. They also form the foundation of marine food webs, including those that support global ocean fisheries.
- Long-term data sets are needed of marine mammal distributions in the Monterey region describing the presence/absence of various species over time.

II. EXISTING OBSERVING ASSETS

University of California Santa Barbara

- Ocean data and species archetype modeling to uncover the complex and multiscale drivers of kelp forest communities
- Remote sensing to assess kelp forest condition, age and extent plus phytoplankton functional diversity
- Acoustic detection of marine mammals and their foraging patterns
- Genomics looking at microbial diversity and community structure
- eDNA and acoustic telemetry for detection of great white sharks
- Bottom mounted, shallow water, acoustic broadband receivers for soundscape monitoring
- Gliders for deeper waters or targeted monitoring of cross-boundary species
- Co-deployment/maintenance of acoustic telemetry receivers for shark detections

Stanford University, Hopkins Marine Station

Goldbogen Lab

Using commercially available CATS (Customized Animal Tracking Solutions), Goldbogen Lab employs these self-contained, suction-cup attached tags to collect 3D movement data and dual video at high resolution to measure the fine-scale kinematics of engulfment (extreme lunge-feeding strategy exhibited exclusively by rorquals) relative to the speed of the body.

Block Lab

- 811 archival tag releases, 403 recaptures 2002–2018, more than 84,000 days of data to determine when Eastern Pacific Ocean bluefin tuna go to the spawning grounds in Japan and the Philippines
- White Shark Café: 34 satellite tags timed to pop up during a cruise to the Café
- Sentinel tagging at Café confirming that the Café location remains unchanged for ~ 20 years
- The combined efforts of TOPP and the Tag a Giant (TAG) Foundation today: representing more than 6,500 tag deployments
- Acoustic tagging of bluefin tuna to estimate survivorship for International Commission for the Conservation of Atlantic Tuna or ICCAT spatial models: ~100 tags during 2010- 2017, Gulf of St. Lawrence, Newfoundland, Nova Scotia
- Acoustic tagging of Pacific bluefin, salmon sharks, and white sharks for long-term monitoring: hundreds of tags; receivers at Tomales Pt., Pt. Reyes., Farallon Islands, Ano Nuevo Islands, Monterey Bay/Hopkins and deployed on wave gliders
- SharkNet app: monitors detection of white sharks from real-time receivers/buoys.

NOAA/National Marine Fisheries Service

Southwest Fisheries Science Center - Marine Mammal and Turtle Research Division

Marine Biodiversity

- Cetacean Abundance and Ecosystem Assessment Surveys
  - ◊ California Current - 1996, 2001, 2005, 2008, 2014, 2018, future goal ~4–5 year periodicity
  - ◊ Eastern Tropical Pacific - 1986–90, 1998–2000, 2003, 2006, no future surveys planned
  - ◊ Hawaiian Archipelago (partnership with Pacific Islands Fisheries Science Center) 2002, 2010, 2017, Future goal ~6-year periodicity

Animal Telemetry

- Leatherbacks: ~140 tags deployed, Monterey Bay, Indonesia, Solomon Islands
- Loggerheads: ~25 tags deployed, Mexico, Peru, Southern California
- Hawksbills: ~40 tags deployed, El Salvador, Nicaragua, Ecuador
- Greens: ~50 tags deployed, Galapagos, Mexico, California
- Killer whales, minke, humpback, gray whales, sperm, short-finned pilot, melon-headed whales, Blainvilles, Cuviers beaked whales, and rough-toothed dolphins: >200 spot and splash limpet tags deployed, 10 species, three ocean basins, 2009–2015

Monterey Bay Aquarium Institute

Time series was started at three stations (C1, M1, M2) in the Monterey Bay region in 1988, where a broad suite of biogeochemical measurements are collected (temperature, salinity, sigma-t, chlorophyll, chlorophyll A, oxygen). The stations are visited by ship at approximately three-week intervals, and moorings are maintained at two of the stations. These are part of a demonstration Marine Biodiversity Observation Network (MBON) project in the region.

U.S. Navy

The U.S. Navy has funded satellite tagging studies along the U.S. West Coast and Baja Mexico (2008–2019).

Catalina Sea Ranch

Automated offshore aquaculture monitoring system, dubbed the "Ocean Internet of things," relays observations of temperature, salinity, pH, dissolved oxygen, and phytoplankton density in real-time via cellular technology to a cloud server for analyses by marine scientists via the Internet.

University of California Santa Cruz

Costa Lab

Antarctica

- Leopard seals - 22 in 2018–2019—GPS Argos location and dive behavior tags, Antarctic Peninsula
- Weddell seals (Ross Sea)- 65 in 2010–2013—SMRU CTD, Argos location and diving behavior tags
- Crabeater seals - 34 in 2001–2002 and 8 in 2007—Argos location tags
- Southern elephant seals - 56 in 2005–2009—SMRU CTD and Argos location and diving behavior tags

Everywhere else

- Northern elephant seals - 800+ tags deployed 2004–2018. A wide array of CTD, GPS, Argos location and diving behavior tags, as well as archival tags.
- California sea lions - 32 females in 2003–2005, 35 females in 2005–2008. Southern California GPS, Argos location, and dive behavior tags. 22 males in 2005–2008. GPS and CTD tags.
- Galapagos sea lions - 30+ females. GPS, dive behavior tags.
- Southern sea lions - 30+ tags. Argos location and diving behavior.

Friedlaender Lab

- Multi-sensor suction cup tags attached to baleen whales: Monterey Bay, Cape Cod, Alaska, Antarctica
- Fisheries echosounders
- Satellite tags: Antarctica
- Current and future (~3 years) status of tagging/biodiversity observation program
  - ◊ 15+ years in Antarctica: National Science Foundation, IWC, Southern Ocean Research Partnerships, World Wildlife Fund
  - ◊ 10+ years in Stellwagen Bank National Marine Sanctuary
  - ◊ 5+ years in Monterey Bay: National Science Foundation
  - ◊ 8+ years Southern California Behavioral Response Studies: Office of Naval Research, LMR

Attaching a motion sensing suction cup tag on a blue whale off the coast of California. Photo Credit: Jeremy Goldbogen

III. STAKEHOLDER USE OF TELEMETRY/ BIODIVERSITY DATA

- Ultimately, we aim to move toward Ecosystem Based Management (EBM), for which fisheries is one of a number of issues that need to be managed in an integrated, holistic way, with trade-offs amongst multiple interests.
- Long-term sustained telemetry/biodiversity observations are required to address and understand the functional and context-dependent responses of marine mammals to change and disturbances (including Navy sonar) and to understand the structure and function of marine ecosystems.
- California Current Integrated Ecosystem Assessment Status reports evolve yearly to include currently relevant indices: e.g., biodiversity indicators from MBON and ecosystem impacts of the "blob."
- Current operating models for bluefin tuna want spatial data combined with genetic and microchemistry data utilized in assessing the overall catch and biomass of tunas.
- The data collected by the Oregon State University Whale Telemetry Group in the last 30 years offers a unique global view of whale movements, with great potential to improve our understanding of movement ecology in space and time and to provide management bodies (e.g., NMFS, International Whaling Commission, etc.) and industry with data and information to improve conservation and management policies.
- Ocean assessments are organized around three questions: Is it safe to swim? Is it safe to eat fish? Is the ecosystem protected? The biological data are used to quantify temporal trends, to assess whether any changes can be attributed to water quality, and to answer the three questions above.

IV. DATA MANAGEMENT OPPORTUNITIES AND CHALLENGES

Opportunities

- Biodiversity monitoring is a critical tool in understanding baseline and abnormal conditions in pelagic environments.
- Opportunities must continue for supporting large scale tagging projects like TOPP and associated data sharing (ATN) because they are necessary to make tag data useful for monitoring biodiversity and informing management.
- To bridge the gaps between information known and unknown, the California Fisheries sees the ATN as an opportunity to connect them with accessible researcher data.
- IOOS has a great opportunity to provide community leadership in biological assessments by ensuring sustained support of MBON.
- There is an opportunity for biologging to play a significant role in studying marine biodiversity observations by providing observations on distributions and collecting quantitative data that can be used in modeling of biomass and critical life history parameters.

Challenges

- "Two things to never do with a time series: 1) Start one; 2) End one."
- Federal permitting authorities and funding agencies need to highlight and enforce data sharing requirements before permits/grants for tagging are renewed.
- While individual animal tag tracks are very useful, bigger datasets are needed that allow for derivation of species-specific home ranges if we are to understand habitats and their variability.
- Because ocean biological processes are continually changing, long term sustained observations are essential in order to keep models and modelers in check.
- The NOAA Fisheries Marine Aquaculture Strategic Plan FY 2016–2020 calls for "At least a 50% increase in responsible U.S. marine aquaculture production by the year 2020." This will necessitate substantial increases in associated biological observations to support the permitting requirements.

WORKSHOP CONCLUSIONS

OBJECTIVE I: Identify and Prioritize Stakeholder Marine Animal Telemetry and Biodiversity Monitoring and Observational Needs in the West Coast Region.

THEME A: Reductions in the presence of chemicals don't define success —the responses of the fish to the reductions need to be observed in order to determine success.

THEME B: Processes change, and thus require long-term sustained observations to keep models and modelers in check.

THEME C: Observations are needed from animal borne sensor tags (biologging), which simultaneously sample the ocean environment while providing detailed information on marine species.

THEME D: "Today's time series is tomorrow's baseline."

THEME E: Biology and biological condition assessments are central to water quality manager interests. There is a need to quantify temporal trends in the biology of ecosystems for a wide array of organism types and whether any changes can be attributed to water quality.

THEME F: Long-term data sets are needed of marine mammal distributions in the Monterey region describing the presence/absence of various species over time.

THEME G: Data types needed include telemetry, phytoplankton, zooplankton, vertebrates, chemical and physical oceanography, (marine geology).

FEDERAL AGENCIES

Bureau of Ocean Energy Management (BOEM)

BOEM requires observations that enable them to determine the effects of activities that impact the environment and on affected resources from U.S. Outer Continental Shelf energy and mineral resources development.

NOAA/National Marine Sanctuaries

The National Marine Sanctuaries need observations of biomass and species distribution, abundance, and diversity to furnish answers to the 17 questions in the Sanctuaries Condition Reports on water quality, habitat, and living resources, e.g., "What is the status of biodiversity and how is it changing?"

NOAA/National Marine Fisheries Service/Southwest Fisheries Science Center

- Key observing technologies that provide the data needed to implement ecosystem-based fisheries management (EBFM) are:
  - ◊ Observations from animal borne sensor tags (biologging), which simultaneously sample the ocean environment while providing detailed information on marine species, and
  - ◊ Observations from autonomous ocean samplers (e.g.gliders), which can collect high-resolution, continuous water column data that can be assimilated into regional models.
- For climate vulnerability assessments, the focus is on 62 species (e.g., groundfish, CPS, HMS, salmon), and a large number of sensitivity attributes and climate exposure factors for them.

TRIBAL

Northwest Indian Fisheries Commission

The Northwest Indian Fisheries Commission (NWIFC) is a natural resources management support service organization for 20 treaty Indian tribes in western Washington. They provide policy coordination and technical support services for their members which includes observations of the following species to provide data for tribal ecosystem-based fisheries management:

- Coho salmon
- Lake Ozette sockeye salmon
- Chinook salmon/southern resident killer whales (many Puget Sound and British Columbia stocks are threatened/endangered)
- Pinnipeds/other marine mammals
- Whale entanglement occurrences
- Sea lion
- Sea otters

Sockeye salmon. Photo Credit: Northwest Indian Fisheries Commission

NGO

The Marine Mammal Center (TMMC)

TMMC is a partner with and a contributor to the Marine Mammal Health M.A.P. (Monitoring and Analysis Platform), a web-based tool for evaluating changes in marine mammal health by geographic location and time. Observations are needed of marine mammal health in the wild that can be correlated with related physical, chemical, and biological environmental parameters.

Blue Point Conservation Society

The Blue Point Conservation Society's keystone datasets seek/collect information on seabird reproduction/survival and life history parameters. The society needs tracking observations/studies that address knowledge gaps in summer breeding season movements, winter movements/post breeding season, whether winter conditions may be most limiting, and specific conservation needs.

O'Neil Sea Odyssey (ONSO)

The ONSO is a non-profit organization that provides a living classroom on board a 65-foot catamaran sailing the Monterey Bay where 4th–6th grade students from schools throughout Central California receive hands-on lessons about the marine habitat and the importance of the relationship between the living sea and the environment. ONSO would like to have access to biodiversity and telemetry from the boat and in the plankton samples they collect.

Southern California Coastal Water Research Project Authority (public agency)

Biology and biological condition assessment are central to water quality manager interests. Chemical stressors are what is managed, but the goal is to improve "beneficial uses," and biological endpoints are at the core of beneficial uses. There is a need to quantify temporal trends in the biology of ecosystems for a wide array of organism types and whether any changes can be attributed to water quality. Reductions in the presence of chemicals don't equal successthe responses of the fish to the reductions determine the success.

COMMERCIAL/PRIVATE SECTOR

Port of Long Beach

- Physical characteristics (water quality and sediment grain size)
- Benthic infauna
- Ichthyoplankton
- Demersal fish and macroinvertebrates
- Pelagic and shallow-water fishes
- Riprap epifauna
- Kelp and macroalgae
- Eelgrass
- Birds
- Marine mammals
- Presence of non-native species
- The Port of Long Beach collects and uses their own telemetry/biodiversity data but are open to new ideas for improving:
  - ◊ Methods for reducing whale strikes from incoming vessels
  - ◊ Marine mammal monitoring during pile driving and blasting
  - ◊ Community partnerships to help implement eDNA sampling methods

H.T. Harvey & Associates

- Observations that are needed are telemetry, phytoplankton, zooplankton, vertebrates, chemical and physical oceanography, (marine geology).
- Considerations that are essential for renewable energy siting are environmental attributes, human uses, ecological attributes, and marine spatial planning.

Monterey Bay Whale Watch

The Monterey Bay Whale Watch needs long-term data sets of marine mammal distributions in the Monterey region describing the presence/absence of various species over time.

Pacific Coast Federation of Fishermen's Association

The association generally has good information on catch, stock abundance, maritime weather, and spatial use patterns of big boats. Areas where information is lacking though include: spatial use patterns of small boats, socioeconomics/ethnographics, the sea food supply chain/imports, integrity of food supply/toxicity/trophic dynamics, gear/marine mammal interaction, climate change impacts (i.e., anticipating winners and losers) and facilitating transitions (e.g., from one stock to another based on how predicted to fare in future) and managing for resilience.

Catalina Sea Ranch

The Catalina Sea Ranch requires the following: real-time temperature, salinity, pH, dissolved oxygen and phytoplankton density observations to analyze and evaluate the aquaculture farm conditions.

OBJECTIVE II: Identify the Existing Telemetry and Biodiversity Observing Assets and Scientific Capabilities in the Region.

FEDERAL

U.S. Navy

The U.S. Navy funded satellite tagging studies along the U.S. West Coast and Baja Mexico (2008–2019).

Name	Location	Date	Agency/Organization	Status
Steelhead trout Chinook salmon Bull trout	Pacific Northwest	2019	Northwest Fisheries Science Center	20 proposed
Humpback whales	Washington, Oregon, California	2017–2018	Oregon State University	44
Gray whale	Oregon	2012	Oregon State University	11
Blue and fin whales	Southern California	2014–2017	Oregon State University	92 blue whales 32 fin whales 1 blue fin hybrid 1 Bryde's whale
Green sea turtles	San Diego Bay	2015–2016	Southwest Fisheries Science Center	8
Beaked whales	Southern California	2008–onging	Marine Ecology and Telemetry Research (MarEcoTel)	30 Cuvier's beaked whales 14 Risso's dolphins 8 Killer whales 2 Baird's beaked 1 bottlenose dolphin
Sperm whales	Southern California	2010–ongoing	MarEcoTel	3
Fin whales	Southern California	2008–ongoing	MarEcoTel	62
Cuvier's beaked	Southern California	2018–2019	MarEcoTel	4 in 2018
Guadalupe fur seals	Guadalupe Island, Mexico	2019	The Marine Mammal Center	35 proposed

A pair of fin whales off Palos Verdes in Southern California.
Photo Credit: John Calambokidis, Cascadia Research (NMFS Scientific Research Permit #21678)

NOAA/National Marine Fisheries Service

Southwest Fisheries Science Center/Marine Mammal and Turtle Research Division

Marine Biodiversity

- Cetacean Abundance and Ecosystem Assessment Surveys
  - ◊ California Current - 1996, 2001, 2005, 2008, 2014, 2018, future goal ~4–5 year periodicity
  - ◊ Eastern Tropical Pacific - 1986–90, 1998–2000, 2003, 2006, no future surveys planned
  - ◊ Hawaiian Archipelago* - 2002, 2010, 2017, Future goal ~6-year periodicity (*partnership with Pacific Islands Fisheries Science Center)
- Aerial Surveys
  - ◊ Leatherback and loggerhead turtle distribution and abundance, ~2–4 year periodicity
  - ◊ Pinniped abundance, ~3-year periodicity
  - ◊ Coastal cetaceans, irregular
- Small Boat and Shore-Based Research
  - ◊ Cetacean health assessment
  - ◊ Green and leatherback turtle ecology
  - ◊ Gray whale abundance and reproductive output
  - ◊ Cetacean and marine turtle stranding response

Animal Telemetry

- Leatherbacks: ~140 tags deployed, Monterey Bay, Indonesia, Solomon Islands
- Loggerheads: ~25 tags deployed, Mexico, Peru Southern California
- Hawksbills: ~40 tags deployed, El Salvador, Nicaragua, Ecuador
- Greens: ~50 tags deployed, Galapagos, Mexico, California
- Killer whales, minke, humpback, gray whales, sperm, short-finned pilot, melon-headed whales Blainvilles, Cuviers beaked whales and rough-toothed dolphins: >200 spot and splash limpet tags deployed, 10 species, three ocean basins, 2009–2015

Northwest Fisheries Science Center/Manchester Research Station/Puget Sound acoustic telemetry research (2004–Present)

- Hundreds of tags
  - ◊ Lingcod and Pacific cod
  - ◊ Coho salmon
  - ◊ Harbor seals
  - ◊ Steelhead trout
  - ◊ Cutthroat trout
- Research applications
  - ◊ Develop rearing and release strategies for stock enhancement
  - ◊ Identify limiting factors for ESA-listed species
  - ◊ Quantify predation impacts
  - ◊ Test effectiveness of management actions

U.S. Geological Survey

Marine Biodiversity

- Aerial marine bird and mammal abundance and distribution surveys
  - ◊ Southern California Current (1999–2002, 2017–21); Northern California Current (2011–12); future goal ~10–20 year-periodicity
- Small Boat Surveys
  - ◊ Central California Marbled Murrelet abundance surveys: 1996–annually, ongoing

Animal Telemetry

>1,338 tags deployed, 15 seabird species

- Cassin's Auklet: VHF tags (N=99; 1999–2001, California Channel Islands)
- Xantus's (Scripps's) Murrelet: VHF tags (N=112, 2002–2003, California Channel Islands [with Humboldt State University])
- Ashy Storm-Petrel: VHF tags (N=57; 2004–2005, California Channel Islands)
- Sooty Shearwater: satellite PTTs (N=109; 2004–2009, California Current [with Moss Landing Marine Labs])
- Pink-footed Shearwater: satellite PTTs (N=42; 2006–2015), GPS tags (N=49; 2015–2017) [with Oikonos Ecosystem Knowledge]; California Current and Chile)
- Black-footed Albatross: satellite PTTs (California Current N = 8 and NW Hawaiian Islands N=7 [with Oikonos Ecosystem Knowledge])
- Common Murre: satellite PTTs (N=58; 2011–2012, 2015–2016, California Current [with NOAA NWFSC and Oregon State University])
- Hawaiian Petrel: satellite PTTs (N=30; 2006–2008, 2013–2014, Main Hawaiian Islands)
- Newell's Shearwater: satellite PTT (N=50; 2014–2018, Kauai [with Kauai Endangered Species Recovery Project]
- Grey-faced Petrel: satellite PTTs (N=32; 2006–2007, New Zealand [with Landcare New Zealand])
- Laysan Albatross: GPS-accelerometry tags (N=35; 2014, 2016, Main Hawaiian Islands)
- Wedge-tailed Shearwater: GPS tags, TDRs (N=368; 2013–2015, Main Hawaiian Islands)
- Red-footed Booby: GPS tags, TDRs, accelerometry (N=172; 2013–2016, Main Hawaiian Islands)
- Brown Booby: GPS tags, TDRs (N=43; 2014–2015, Main Hawaiian Islands)
- Red-tailed Tropicbird: GPS, TDRs (N=67; 2014–2016, Main Hawaiian Islands)

ACADEMIA

University of California Santa Barbara

- Ocean data and species archetype modeling to uncover the complex and multiscale drivers of kelp forest communities
- Remote sensing to assess kelp forest condition, age and extent plus phytoplankton functional diversity
- Acoustic detection of marine mammals and their foraging patterns
- Genomics looking at microbial diversity and community structure
- eDNA and acoustic telemetry for detection of great white Sharks
- Bottom mounted, shallow water, acoustic broadband receivers for soundscape monitoring
- Gliders for deeper waters or targeted monitoring of cross-boundary species
- Co-deployment/maintenance of acoustic telemetry receivers for shark detections

University of California Santa Cruz

Costa Lab

Antarctica

- Leopard seals - 22 in 2018–2019—GPS Argos location and dive behavior tags, Antarctic Peninsula
- Weddell seals (Ross Sea)- 65 in 2010–2013—SMRU CTD, Argos location and diving behavior tags
- Crabeater seals - 34 in 2001–2002 and 8 in 2007—Argos location tags
- Southern elephant seals - 56 in 2005–2009—SMRU CTD and Argos location and diving behavior tags

Everywhere else

- Northern elephant seals - 800+ tags deployed 2004–2018. A wide array of CTD, GPS, Argos location and diving behavior tags, as well as archival tags.
- California sea lions - 32 females in 2003–2005, 35 females in 2005–2008. Southern California GPS, Argos location, and dive behavior tags. 22 males in 2005–2008. GPS and CTD tags.
- Galapagos sea lions - 30+ females. GPS, dive behavior tags.
- Southern sea lions - 30+ tags. Argos location and diving behavior.

Friedlaender Lab

- Multi-sensor suction cup tags attached to baleen whales: Monterey Bay, Cape Cod, Alaska, Antarctica
- Fisheries echosounders
- Satellite tags: Antarctica
- Current and future (~3 years) status of tagging/biodiversity observation program
  - ◊ 15+ years in Antarctica: National Science Foundation, IWC, SORP, World Wildlife Fund
  - ◊ 10+ years in Stellwagen Bank National Marine Sanctuary
  - ◊ 5+ years in Monterey Bay: National Science Foundation
- 8+ years Southern California Behavioral Response Studies: Office of Naval Research, LMR

California State University Long Beach (Shark Lab)

Historically

- 20 VR2W acoustic receivers in Southern California area in gridded arrays up to 20 km^2 in size with more than 2,300 acoustic tags deployed over the last 20 years

Current

- 110+ juvenile white sharks tagged since 2006 (60 with currently active coded acoustic transmitters), 18 SPOTs (up to 8 months) and 35 PATs (programmed deployments 40–270 days), 29 internal acoustic tags (8–10 year life), 46 external acoustic tags (1–2 year life), 3 Smart tag tracks (up to 24 hours)
- More than 70 VR2W acoustic receivers and HOBO temp loggers spread along Southern California beaches and offshore islands with 2 VEMCO real-time acoustic receiver buoys

Oregon State University

Tagging of Pacific Predators (TOPP) – 121 tracks

- blue (104), fin (2), humpback (15)
- Block et al. (2011) Tracking apex marine predator movements in a dynamic ocean. Nature. 475:86-90. doi:10.1038/nature10082

WhaleWatch – 133 tracks

- blue (104), gray (19)

Animal Telemetry Network (ATN) – 25 tracks

- blue (21), fin (1), sperm (3)

MoveBank – 21 tracks

- blue (2), fin (8), sperm (11)

Marine Megafauna Movement Analytical Program (MMMAP) and Migratory Connectivity in the Oceans (MiCO) – 348 tracks

- blue (139), bowhead (12), fin (8), gray (19), humpback (94), NARW (15), Southern right (18), sperm (43)

Tagging Best Practices Workshops

- Multiple tagging groups, work to develop "Best Practice" protocols for tagging and tag design to minimize impacts to whales

San Jose State University

A large number of western gulls tracked from the Farallon Islands between 2013 and 2018.

Stanford University, Hopkins Marine Station

Goldbogen Lab

The lab used commercially available CATS (Customized Animal Tracking Solutions) self-contained, suction-cup attached tags to collect 3D movement data and dual video at high resolution to measure the fine-scale kinematics of engulfment (extreme lunge-feeding strategy exhibited exclusively by rorquals) relative to the speed of the body.

Block Lab

- 811 Archival tag releases, 403 recaptures 2002-2018, > 84,000 days of data to determine when Eastern Pacific Ocean bluefin tuna go to the spawning grounds in Japan and the Philippines
- White Shark Café: 34 satellite tags timed to pop-up during a cruise to the Café
- Sentinel tagging at Café confirming that the Café location remains unchanged for ~ 20 years
- The combined efforts of TOPP and the Tag a Giant (TAG) Foundation today: representing more than 6,500 tag deployments
- Acoustic tagging of bluefin tuna to estimate survivorship for ICCAT spatial models: ~100 tags during 2010–2017, Gulf of St. Lawrence, Newfoundland, Nova Scotia
- Acoustic tagging of Pacific bluefin, salmon sharks, white sharks for long-term monitoring: hundreds of tags; receivers at Tomales Pt., Pt. Reyes., Farallon Islands, Ano Nuevo Islands, Monterey Bay/Hopkins and deployed on wave gliders
- SharkNet app: monitors detection of white sharks from real-time receivers/buoys

NGO

Marine Ecology and Telemetry Research (MarEcoTel)

MarEcoTel is a non-profit organization of a small group of biologists whose mission is to support the conservation of marine species and populations.

MarEcoTel - Tag Deployments 2008–2018

Species	Number Tagged	Mean Duration (Days)
Blue Whale	3	103.8
Fin Whale	76	35.4
Minke Whale	1	25.6
Sperm Whale	3	36.6
Baird's Beaked Whale	2	18.9
Cuvier's Beaked Whale	24	33.9
Killer Whale	35	43.9
Risso'sDolphin	14	11
Bottlenose Dolphin	1	59
Total	**169**	

Current and Future Telemetry Projects

Project	Region	Tentative End	Priority Species
Behavioral response to sonar	SoCal	2020	Beaked and fin whales
Distribution and demographics	SoCal	Ongoing	Cuvier's beaked and fin whales
Cuvier's in a sonar-free area	Guadalupe Island, Mexico	2020	Cuvier's beaked whales
Killer whale surveys	Washington outer waters	2019	Offshore Biggs and killer whales
SMRT tag development	Hawaii/SoCal	2019	

Cascadia Research Collective

Cascadia Research is a non-profit Washington State that conducts scientific research and education primarily in the fields of marine mammal and bird biology, animal behavior, ecology, and pollution ecology.

Dart-attached tags off California Coast

Species	Number Deployed	TDR	Acoustic
Blue	29	21	8
Fin	8	1	7
Humpback	23	23	0

Blue Point Conservation Science

Winter movements of some of the alcid family of diving seabirds have been tagged:

- Planktivores - Pelagic - 123 tagged (2015–18)
- Piscivores - Benthic - 60 tagged (2017–18)

O'Neil Sea Odyssey

An example of the data collected on their educational boat trips:

Navigation Station Data Entry	Biology Station Data Entry	Ecology Station Data Entry
Measurement Time: 2:54 PM	Measurement Time: 2:55 PM	Measurement Time: 2:52 PM
Measurement Date: 10/24/2018	Measurement Date: 10/24/2018	Measurement Date: 10/24/2018
Bearing #1: 240 Location Mile Buoy	Surface Temperature: 54° Fahrenheit	Otter Count: 6
Bearing #2: 270 Location Steamers Lighthouse	Seawater Depth: 45 feet	Seawater pH: 7.9
Bearing #3: Location Dream Inn	Seawater Visibility: 3 feet	
GPS latitude: 36° 56' 393"	Plankton Sample: mostly zooplankton	
GPS longitude: 122° 00' 360"	Plankton Notes: diatoms, copepods, tintinid, barnacle, crab velliger, bristle worm	
Weather Observation: sunny	Seawater Color: green knots	
Wind Speed: 2 knots		
Depth: 66 feet		

COMMERCIAL/PRIVATE SECTOR

Catalina Sea Ranch

Automated offshore aquaculture monitoring system, dubbed the "Ocean Internet of things," relays observations of temperature, salinity, pH, dissolved oxygen, phytoplankton density in real-time via cellular technology to a cloud server for analyses by marine scientists via the Internet.

OBJECTIVE III: Document Regional Stakeholder Specific Uses of Marine Animal Telemetry and Biodiversity Data.

THEME A: Marine animal telemetry/biodiversity observations provide the U.S. Navy with basic biology that supports their National Environmental Policy Act (NEPA) preparation, Marine Mammal Protection Act (MMPA) and Endangered Species Act (ESA) consultations, responses to critical habitat proposals, and anthropogenic effects analysis.

THEME B: Based on our observations of how animals are using the environment, we can begin to build simple habitat models and even make projections about changes in critical habitat based on climate projects.

THEME C: Current operating models for bluefin tuna require spatial data in combination with genetic and microchemistry data utilized in assessing the overall catch and biomass of tunas.

THEME D: The California Current Integrated Environmental Assessment Ecosystem status reports evolve yearly to include currently relevant indices: e.g., environmental drivers of sablefish recruitment, ecosystem impacts of the "blob," biodiversity indicators from MBON, and spatially explicit risk analyses through dynamic ocean management studies.

THEME E: Determine the effect of habitat or landscape alteration from BOEM-regulated activities on ecological and cultural resources.

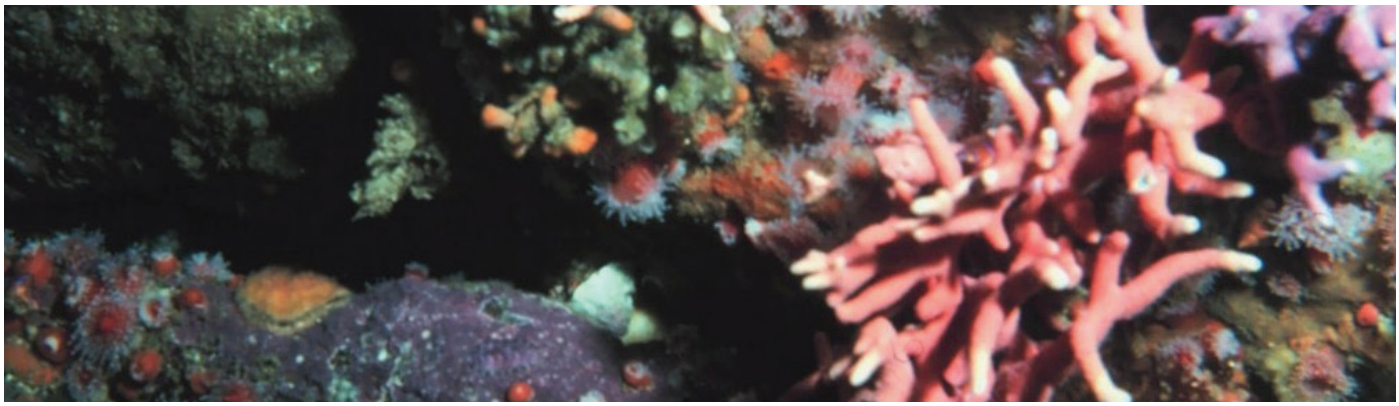
THEME F: Long-term sustained telemetry/biodiversity observations are required to address and understand the functional and context-dependent responses of marine mammals to change and disturbances (including U.S. Navy sonar) and to understand the structure and function of marine ecosystems.

THEME G: Understanding the operational impact risks of the renewable energy technology: bird collisions, mammal disruption, entanglement, effects of structure on behavior and ecology, and effects on physical environment.

FEDERAL AGENCIES

BOEM

- Determine the effect of habitat or landscape alteration from BOEM-regulated activities on ecological and cultural resources.
- Evaluate the acute and chronic effects of sound from BOEM-regulated activities on marine species and their environment.
- Determine the extent to which future ocean conditions and dynamics will amplify or mask effects of BOEM-regulated OCS activities.
- Assess cumulative effects within the framework of environmental assessments.



Life on rocky offshore ledges at Monterey Bay National Marine Sancturary. Photo Credit: Kip Evans

NOAA/National Marine Sanctuaries

The Sanctuary Condition Reports are used to inform and to dynamically update in real-time the assessment of the status and trends of the marine sanctuary resources for the benefit of resource managers, researchers, policy makers, and educators.

U.S. Navy

The U.S. Navy marine animal telemetry/biodiversity observations assist basic biology supporting NEPA preparation, the Marine Mammal Protection Act (MMPA) and Endangered Species Act (ESA) consultations, U.S. Navy responses to critical habitat proposals, and anthropogenic effects analysis.

MMPA and ESA Consultations, Critical Habitat, Basic Biology

- What is occurrence and importantly residency times within and outside of sea ranges?
- Are designated or proposed biologically important areas really important?
- Range specific monitoring supporting permit requirements and commitments
- What are overlaps between critical habitat and species movements within U.S. Navy range areas?

Anthropogenic Effects Analysis

- Does a given species respond to U.S. Navy stressors (e.g., sonar)?
- What is level of response, if any?
- What variables are most impactful in a response (e.g., behavioral state, proximity to source, etc.)?

Potential growth area for U.S. Navy

- To combine marine telemetry tracks with other environmental and impact assessment analysis.

NOAA NMFS/Southwest Fisheries Science Center (SWFSC)

The California Current Integrated Ecosystem Assessment (CCIEA), coordinated at the SWFSC, is an interdisciplinary research effort by U.S. West Coast NOAA scientists with its own website that displays status and trends indicators (e.g., ecological integrity (diversity, forage ability, biomass ratio, etc.) and large-scale oceanographic indices. CCIEA ecosystem status reports evolve yearly to include currently relevant indices (e.g., environmental drivers of sablefish recruitment, ecosystem impacts of the "blob," biodiversity indicators from MBON) and spatially explicit risk analyses through dynamic ocean management studies. Future of the CCIEA includes integration with fisheries ecosystem plans, plus automation and regular updating of time series/reports and telemetry data, including time series of animal movement data.

Ultimately, the goal is to move toward EBM, in which fisheries is one of a number of issues that need to be managed in an integrated, holistic way, with trade-offs amongst multiple interests. As with any in situ ocean data, biologging observations can be used both for model validation and assimilation. Because biologging/animal borne sensor tags are on actively diving animals, we can obtain information on 3D ocean structure, often with enough vertical resolution to identify things like mixed layer depth, and with enough temporal resolution to observe event-scale variability (e.g., the ocean and elephant-seal response to storm passage). We can also see track fidelity among individuals and within populations—which gives a kind of "repeat hydrography" from which we can begin to look at interannual variability.

We've also seen the preferred utilization of eddies and frontal features by many species. From these data, we can learn a great deal about eddy/frontal structure and evolution, and based on the observed behaviors, we can also speculate on prey aggregation mechanisms. Also, based on our observations of how animals use the environment, we can begin to build simple habitat models and even make projections about changes in critical habitat based on climate projects. From biologging we are learning about the distribution, migration, and foraging behavior of bluefin tuna, a key top predator, in relation to environmental conditions and the forage base; we are also learning about ecosystem structure and function in relation to the environment.

US Geological Survey

Western Ecological Research Center-Santa Cruz Field Station, Seabird Studies Program

Current studies are focused in the California Current System (CCS) and Hawaii, but telemetry data and collaborations span the Pacific Ocean. Telemetry activities complement an ongoing series of California Current-based regional aerial seabird surveys conducted every 15–20 years since the 1970s. This and other data have enabled studies of seabird vulnerability to ocean wind energy infrastructure in the CCS. Also, with (CCS) data from U.S. Geological Survey, NOAA, and others, the NOAA/ National Ocean Service/ National Centers for Coastal Ocean Science Biogeography Group is planning to produce a species-based predictive modeling framework for seabird marine spatial planning in the region.

ACADEMIA

University of California Santa Barbara

MBON data can predict how fish biomass and abundance will change under different decommissioning scenarios of several offshore platforms.

University of California Santa Cruz

Costa Lab

Telemetry data are used to: i) understand the behavior of marine animals and their adaptations to life in the marine environment, especially the movement, foraging ecology, and energetics of pinnipeds, cetaceans, and seabirds, ii) understand the population-level consequences of anthropogenic disturbance and environmental change in marine mammals and, iii) develop science-based tools that can be used by resource managers to support the development of realistic population risk assessments as well as effective wildlife management and conservation strategies.

Friedlaender Lab

The focus is to understand the functional and context-dependent responses of marine mammals to change and disturbances, including U.S. Navy sonar and understand the structure and function of marine ecosystems.

Lunge feeding. Photo Credit: John Calambokidis, Cascadia Research (NMFS Scientific Research Permit #21678)

California State University Long Beach

Shark Lab

The research goals of the Shark Lab's juvenile white shark monitoring and beach safety program include:

- Providing water safety officials with shark abundance and movement data
- Developing prediction models
- Providing public outreach – outlet data in public friendly forms
- Archiving, serving and sharing data

Oregon State University

Large endangered whale species research objectives aim to:

- Characterize:
  - ◊ Spatial and temporal distribution of whales throughout their range
  - ◊ Foraging behavior
  - ◊ Ecological relationships to help explain whale movement patterns
- Identify migration routes, home ranges and core areas of use.

The data collected by the Whale Telemetry Group in the last 30 years offers a unique global view of whale movements, with great potential to improve our understanding of movement ecology in space and time and to provide management bodies (e.g., NMFS, International Whaling Commission, etc.) and industry with data and information to improve conservation and management policies.

San Jose State University

Use tracking and other data from western gulls to:

- Examine interannual variability in habitat use
- Efficacy of sanctuaries for spatial coverage
- Model the threats from:
  - ◊ Continued use of urban sources
  - ◊ Interactions with fisheries
  - ◊ Impacts of coastal development for offshore wind farms (in partnership with USGS)

Stanford University, Hopkins Marine Station

Goldbogen Lab

The focus is on studying the physiological ecology of marine organisms, functional morphology and biomechanics, biologging kinematic and physiological parameters, and effects of anthropogenic activities on marine life.

Block Lab

Management models are trying to capture the biological complexity and status of Atlantic bluefin tuna populations from electronic tags combined with genetic and microchemistry data utilized in assessing the overall catch, and biomass of tunas.

The lab's biologging activities focus on studying behavior of fish in the wild including habitat utilization, foraging and spawning behaviors, population biology, mortality, maturity, management and assessment, climate change, and physiology.

They are applying a game-changing technology to monitor global fishing fleets in real-time using Automatic Identification System (AIS) data. Through a collaboration with the Global Fishing Watch, Skytruth, Google, and other academic partners, they are analyzing these data—matching these signals with vessel census lists from fisheries management organizations around the world to detect overfishing.

TRIBAL

Northwest Indian Fisheries Commission (NWIFC)

A primary goal of the NWIFC is to provide data and information necessary for tribal ecological-based fishery management. This will include habitat data categorized using the Coastal and Marine Ecological Classification Standard (CMECS) to provide a common language for decision makers and technical experts and will ultimately be a tool to help decision makers understand the interconnectedness of marine ecosystems and how management decisions will impact marine resources. Specific data uses include:

- Understanding whale entanglements to learn more about this so they can be proactive to avoid similar issues encountered by New England lobster fishermen
- Understanding the life cycle of specific salmon species (coho, Lake Ozette sockeye, chinook) because of their importance to tribal fisheries
- Studying the movement and survival of the marine mammals (sea lions, sea otters) to better understand the effects of their predation on the tribal fisheries

NGO

Monterey Bay Aquarium Research Institute

The data collected are used to identify the biological response to climate and global change by:

- Determining the mean and fluctuating components of phytoplankton primary production, biomass, and species composition on timescales ranging from days to decades
- Determining the physical, chemical, and biological processes responsible for the mean and fluctuating components
- Determining the time-varying biogeochemical and ecological (zooplankton, fish) fate of primary production

The Marine Mammal Center (TMMC)

Easy accessibility of this data gives the public, scientists, and resources managers the ability to detect and communicate potential public and animal health risks and to prioritize management and conservation efforts.

Blue Point Conservation Society

The Blue Point Conservation Society bird tracking data can help inform policy and management decisions related to impacts of large vessel traffic, oil spill risks and offshore wind energy farms.

O'Neil Sea Odyssey

The O'Neil Sea Odyssey provides hands-on lessons to 4th–6th grade students from schools throughout Central California about the marine habitat and the importance of the relationship between the living sea and the environment.

Southern California Coastal Water Research Project Authority (public agency)

Ocean assessments are organized around three questions: Is it safe to swim? Is it safe to eat fish? Is the ecosystem protected? The biological data are used to quantify temporal trends, to assess whether any changes can be attributed to water quality, and to answer the three questions above.

COMMERCIAL/PRIVATE SECTOR

Port of Long Beach

- Implement their Green Port Policy dedicated to reducing the harmful environmental effects of port-related operations.
- Provide compliance with CEQA/NEPA required environmental control measures on site during pile-driving and blasting operations.
- Mitigate whale strikes from ships entering the port.

H.T. Harvey & Associates

- Data are applied to help understand the operational impact risks of renewable energy technology. The risks include: bird collisions, mammal disruption, entanglement, effects of structure on behavior and ecology, effects on physical environments (e.g., wave shadow), operational models (e.g., shut-down procedures), and ecological effects of climate change.
- The data types that are applied include: spatial and temporal distribution of listed species, animal behavior, physical environment, and temporal patterns of fishing activity.
- Additional applications include: monitoring animal movement (e.g., seabird flight height), species diversity (foraging hotspots), detecting ecosystem effects (climate change), and defining essential or critical habitats and species.

Monterey Bay Whale Watch

The Monterey Bay Whale Watch applies data describing the long-term variability of presence/absence of marine mammals to implementing dynamic species protection methods.

Pacific Coast Federation of Fishermen's Association

The association creates information from all the data we have and applies it to support:

- Prevention of large marine mammal-fishing gear interaction
- Efforts on how to manage for resilience
- Application of local ecological knowledge as a data product

Catalina Sea Ranch

The biology observations collected through the Catalina Sea Ranch real-time "Ocean Internet of Things" are used:

- To understand trends, anticipate problems, and devise mitigation measures for immediate corrective actions
- To support aquaculture operations including permitting requirements, data for applications and expansion, predicting attacks from crop predators, predicting plankton availability for filter feeders and where to situate the farm, plus prediction of harmful algal blooms
- Along with oceanographic data to help with growth projections (ocean acidification, climate change) and layout/ design of the farm

OBJECTIVE IV. Identify Infrastructure and Data Management Challenges and Opportunities that Exist in the Region.

Opportunities

Observations

- There is an opportunity for biologging to play a significant role in studying marine biodiversity observations by providing observations on animal distributions, and collecting quantitative data that can be used in modeling of biomass and critical life history parameters.
- eDNA data collection represents a cheaper, less invasive, and larger scale approach to monitoring species diversity, especially since preserved DNA samples allow the eDNA analysis of long time series—where other methods of analysis may be unavailable.
- Fishermen are data users and data generators in both the scientific and management contexts. "Think about all 2,000 fishing boats as observation platforms of opportunity."
- Biodiversity monitoring is a critical tool in understanding baseline and abnormal conditions in pelagic environments.
- Opportunities must continue for supporting large scale tagging projects like TOPP and associated data sharing (ATN) because they are necessary to make tag data useful for informing management.
- Because genomic methods for biological assessment can be automated and field deployed, they provide an opportunity for continuous real-time measurements of conditions.

Applications/Products

- The future of the integrated ecosystem analysis (IEA) efforts will benefit from opportunities to integrate fisheries ecosystem plans with automated and regular updating of time series and reports, as well as with telemetry data, especially time series of animal movement data.
- Adding observatory data on critical parameters from all four environments of Monterey Bay National Marine Sanctuary (estuarine, nearshore, offshore, seamount) will significantly improve their IEA supported condition reports.
- Implement interactive and iterative data collection and product development within the marine sanctuaries, and be sure to include joint discussion of needs and potential products with the resource managers and the scientists.
- Future opportunities will address investigating interannual variability in habitat use and the efficacy of sanctuaries for spatial coverage, and modeling threats, including urban source use, interactions with fisheries and impacts of coastal development for offshore wind farms.

Data Accessibility/Management

- Based on CALCOFI experience, the recommended guidelines for maintaining a time series are: share your data, involve scientists, ensure your data is compatible, document your data diligently, make your data publicly available, make fewer measurements but do these well, and don't collect data that will address specific questions, but rather data that provide a framework for diverse questions.
- As with any in situ ocean data, opportunities also exist to access biologging observations for both model assimilation and validation.
- To bridge the gaps between information known and unknown, the California Fisheries sees the ATN as an opportunity to connect them with accessible researcher data.
- The ATN can provide opportunities by helping to develop data management standards for acoustic telemetry data and providing data archiving capability for small-scale acoustic telemetry users.
- The TOPP (Tagging of Pacific Predators) program has demonstrated that animals can be a very effective and opportunistic method for monitoring the ocean, and the data collected can easily be archived in databases along with measurements from traditional platforms.

Community Building/Collaboration

- Developing partnerships with NOAA/Office of Ocean and Atmospheric Research can create opportunities for synthesizing the climate projections needed for Climate Vulnerability Analyses.
- Opportunities can arise for enhanced collaboration and integration among studies if 1) universities getting serious about supporting data management, 2) funders encouraging researchers to budget for data management (supplies and staff support) and increasing funding availability to analyze and publish current data sets (to balance out continued collection of new data), 3) improving organization and standardization of data (formats, analysis, etc), and 5) federal permitting authorities and funding agencies enforcing data sharing.
- IOOS has a great opportunity to provide community leadership in biological assessments by ensuring sustained support of MBON, avoiding avoid scientific overlap, identifying best practices to make technologies useful without obtaining further funding, and standardizing methods used.
- Partnerships and trust, in particular with fishermen, are both increasingly critical to fulfill our science mission.
- Leveraging consumer electronics and economies can create opportunities to develop cheaper tags with longer lifetimes and attachment times, more data, and improvements in accuracy.
- Connect the educational programs with researchers and managers to respond to emerging needs. The O'Neill Sea Odyssey and others would benefit from collaboratively brainstorming with the marine biology community on how to get scientists to participate and how to improve their collection of data and possible use of archival data.

Sea lions on navigation buoy. Photo Credit: Photo courtesy of the Port of Long Beach

Challenges

Observations

- Two things to never do with a time series: 1) Start one; 2) End one."
- Regarding the siting of wind energy plants—is anyone looking at how those wind patterns might change with climate change?
- NOAA Fisheries Marine Aquaculture Strategic Plan FY 2016-2020 calls for "At least a 50% increase in responsible U.S. marine aquaculture production by the year 2020." This will necessitate substantial increases in associated biological observations to support the permitting requirements.
- Future observing systems should focus on processes rather than on fixed stations or grids.
- An optimal observing system must provide a larger throughput of data (Argos messages are limited to 256 bits), higher spatial and temporal resolution of oceanographic data, and information on the spatial and temporal evolution of whale prey to better explain whale movement patterns in their feeding areas.
- Key investments are needed in methods standardization, library development (for benthic invertebrates), understanding eDNA dynamics (do all animals shed DNA equally?, How quickly does eDNA dissipate/degrade?), PCR automation/miniaturization (MBARI is the world leader in this).
- Because ocean biological processes are continually changing, long-term, sustained observations are essential in order to keep models and modelers in check.

Applications/Products

- How can the stakeholders cull the relevant information from the telemetry/biodiversity studies underway in the science community that could enable offshore energy permitting procedures? This must be done correctly for renewable energy development projects to be conducted in a way that is responsible and environmentally safe.
- To map hot spots, MPAS, and distributions, biologgers must help solve the geolocation state space modeling challenges.
- Whale entanglements—more knowledge about their occurrence is needed so we can be proactive on this issue rather than face what New England lobster fishermen have.
- Ways to use oceanographic modeling and telemetry to reinforce food web and ecosystem health must be found.
- Access to tracking/telemetry data more rapidly than via typical written reports is needed to provide quicker graphics to respond to emergent consultation questions.

Data Analysis/Accessibility/Management

- How can understanding of the ecological/physiological effects be scaled up, while also building in the effects of changing climate?
- Funders need to encourage researchers to budget for data management costs.
- How can the biodiversity/telemetry data be analyzed to assess the level of any risk, and how can it be determined if the risk is even occurring?
- Federal permitting authorities and funding agencies need to highlight and enforce data sharing requirements before permits/grants for tagging are renewed.
- There should be more funding to analyze and publish current data sets to balance out the continued collection of new data.
- How can all this information be integrated and managed? The federal government must play a role in order to ensure continuity.
- Adequate data are not always available/accessible to answer the questions in the Sanctuaries Condition Reports.
- While individual animal tag tracks are very useful, bigger datasets are needed that allow for derivation of species-specific home ranges if we are to understand habitats and their variability.
- Education needs would be better served by making current and historical oceanographic and marine biology data publically available.

Two northern elephant seal pups vocalize in a rehabilitation pool during treatment at The Marine Mammal Center's hospital in Sausalito, California.
Photo Credit: The Marine Mammal Center

SPEAKERS

RESEARCHER, RESOURCE/CONSERVATION MANAGEMENT, AND COMMERCIAL/ PRIVATE PERSPECTIVES, OBSERVING SYSTEM AND DATA VISUALIZATION

Topics covering resource management, commercial, researcher, and observing system/data visualization perspectives were presented by invited speakers in three sessions with 30 minutes of panel discussions following each set of speakers.

COMMERCIAL/PRIVATE PERSPECTIVES

Wildlife Monitoring and Management at the Port of Long Beach

Justin Luedy, Environmental Specialist, Port of Long Beach

The San Pedro Bay Port/Harbor complex houses the Ports of Long Beach and Los Angeles, both of which take pride in their role as environmental stewards and implementing a Green Port Policy dedicated to reducing the harmful environmental effects of port-related operations. The Green Port Policy serves as an umbrella for air, water, and sediment quality and remediation (landslide soil) and community engagement. Although they have conducted biosurveys, acoustic fish tracking studies (white croaker and halibut), and some bird and marine mammal monitoring, they would like to do more. The Port of Long Beach needs higher quality telemetry/biodiversity data. In particular, the ports welcome assistance with telemetry solutions that will reduce whale strikes from incoming vessels and improve marine mammal monitoring, especially during pile driving/blasting. Additionally, they would welcome community partnerships as they begin to implement cost-effective, less invasive eDNA sampling methods.

Offshore Industries - Understanding Baseline Environmental Conditions and Evaluating Project Effects: Environmental data requirements for project siting, permitting, and operations

Pete Nelson, Marine Ecologist
H.T. Harvey & Associates, California

H.T. Harvey and Associates provide consulting to a variety of offshore industries, including marine renewable energy, fisheries, aquaculture, oil and gas, and subsea data, power, and communications. The largest hurdle when starting a contract with a new organization is the permitting process and understanding the relevant offshore technologies, e.g., offshore wind turbines, wave energy conversion, tidal energy conversion, etc. Permitting requires compliance with ESA, MMPA, Magnuson-Stevens Act, Migratory Bird Treaty Act, NEPA/CEQA, etc. Next, there are the scientific requirements: siting considerations (environmental attributes, human uses, marine spatial planning) and operational impacts (bird collision, mammal disruption, effects of structure on behavior and ecology, operational models, climate change). They would benefit from knowing how the ecological community can utilize relevant information from on going telemetry/biodiversity studies to assist in completing permitting procedures. Main conclusions: i) Telemetry is applicable but has limitations (can address site-specific needs), ii) biodiversity data are needed for permitting, monitoring and assessment, iii) physical environment and ecological effects monitoring are critical, iv) collaboration is essential for safe and effective operations, v) the challenge is how to scale up to commercial levels.

Monterey Bay Whale Watch

Nancy Black, Marine Biologist and Owner of Monterey Bay Whale Watch

For over 26 years Nancy Black has worked with cetaceans in Monterey Bay, including as the primary investigator for the Oceanic Society's whale and dolphin research program. She founded the Monterey Bay Whale Watch to serve the tourism industry and has conducted multiple ambitious research, education, and conservation programs. In collaboration with organizations such as MBARI, the NOAA Marine Sanctuaries, NMFS, and Cascadia Research, she has created long-term data sets of marine mammal distributions in the Monterey region describing the presence/absence of various species over time, in particular during the blob. Understanding marine protection recognizes that it must be dynamic and not static, because, for example, as climate changes the habitat utilization of animals will also change.

Information Gaps and Paths Toward Resilience in California Commercial Fisheries

Noah Oppenheim, Executive Director, Pacific Coast Federation of Fishermen's Association

The Pacific Coast Federation of Fishermen's Association attempts to strike a balance between data and information: high quality data without good integration into management plans is bad management. The association generally has good information on catch, stock abundance, maritime weather, and spatial use patterns of big boats. Areas where information is lacking include: spatial use patterns of small boats, socioeconomics/ethnographics, the seafood supply chain/imports, integrity of food supply/toxicity/trophic dynamics, gear/marine mammal interaction, climate change impacts (i.e., anticipating winners and losers) and facilitating transitions (e.g., from one stock to another based on how predicted to fare in future), managing for resilience, etc. To bridge these gaps, they hope ATN can connect fisheries with researchers with accessible data. A main example of the importance of applying adequate data/information to fishery management was the failure to predict the severity of the domoic acid event in 2015 and its significant impact on the Dungeness crab fishery, one of the most important small scale fishery efforts in California.

Offshore Aquaculture at the Catalina Sea Ranch

Lindsay Cruver, CEO, Catalina Sea Ranch, Los Angeles, Calif.

The Catalina Sea Ranch (CSR) is the first offshore aquaculture operation in U.S. federal waters. It currently occupies 100 acres 6 miles off the California coast with plans to expand to 3,000 acres located six miles off the coast of Southern California. CSR has developed an automated offshore aquaculture monitoring system for remotely collecting real-time environmental data for collaborative and transparent web-based scientific analyses.

CSR uses a well-equipped moored NOMAD buoy to "take the pulse" of the ocean area in real-time at the farm location. Sensors on the buoy collect environmental and aquaculture husbandry data including: temperature, salinity, pH, dissolved oxygen, and phytoplankton density. The data collected through this "Ocean Internet of Things" is used to understand trends, anticipate problems, and devise mitigation measures for immediate corrective actions. Biology observations are critical for aquaculture operations, specifically: permitting requirements, supporting data for applications and expansion, predicting attacks from crop predators, predicting plankton availability for filter feeders and where to situate the farm, plus prediction of harmful algal blooms. Integrating with oceanographic data helps with growth projections (ocean acidification, climate change) and layout and design of the farm. CSR's current monitoring plan as required by the permitting regulations includes: chemical analysis of seafloor sediment, benthic surveys, plankton tows, evaluation of fouling organisms, water quality analysis current measurements, and fish/seabird/marine mammal observations.

RESOURCE/CONSERVATION MANAGEMENT PERSPECTIVES

Environmental Science to Inform Offshore Energy Decisions

Donna Schroeder, Pacific Region Lead, Bureau of Ocean Energy Management (BOEM)

The BOEM mission is to manage development of U.S. Outer Continental Shelf energy and mineral resources in an environmentally and economically responsible way by using sound environmental science. Donna Schroeder is the Pacific Region Lead (Washington, Oregon, California and Hawaii) for renewable energy, conventional energy and marine minerals. To provide such guidance on energy in the Outer Continental Shelf off the West Coast, e.g. ,Humboldt, Morro Bay, and Diablo Canyon offshore wind energy call areas, BOEM must be fully informed on existing baseline surveys, cumulative impacts, affected resources, and compliance laws.

MBON really ties the region together for BOEM by providing information regarding: effects of impacting activities, affected resources, monitoring, cumulative impacts, and compliance. Similarly, BOEM depends on the ATN to provide a scientific basis for marine fisheries and protected/endangered species management, determine and delineate critical habitats, provide real-time (or near real-time) monitoring of marine fish, turtles, birds, and mammals and evaluate the potential effects of anthropogenic disturbances. Being part of the federal government, BOEM plays a critical role in maintaining long-term datasets, and values guidance from partners on how best to integrate and manage all their research findings.

Using Ocean Observing Data to Understand and Protect Areas of National Significance

Andrew DeVogelaere, Research Coordinator/SIMoN Director, Monterey Bay National Marine Sanctuary, NOAA

The Monterey Bay National Marine Sanctuary is one of the largest users of ocean observing data. The mission of all the National Marine Sanctuaries is to understand and protect the coastal ecosystem and cultural resources of their sanctuary. Their responsibilities include promoting multiple use; advancing research, education, and resource protection programs; addressing public concerns through a management plan development process; generating regular reports on the condition of the sanctuary; and providing regional expertise for other government programs.

Ocean observing data are an essential ingredient in both their regular Sanctuaries Condition Reports, which focus on water quality, habitat, and living resources and in their management plans, which include 31 activities that are ocean observing system/observatory data related. Both MBON and ATN are helpful resources in identifying critical parameters associated with key climate and oceanographic drivers and human activity in Monterey Bay, including biomass and species distribution, abundance and diversity. The condition reports are used to inform and to dynamically update in real-time the assessments of the status and trends of the marine sanctuary resources for the benefit of resource managers, researchers, policy makers, and educators.

Biological Observation Needs of the Water Quality Management Community

Stephen Weisberg, Executive Director, Southern California Coastal Water Research Project Authority

SCCWRP is an independent public agency with a mission to provide an unbiased scientific foundation for water quality management in California. The agency is a powerful interface between science and management. It conducts chemical and biological research assessments and communicates findings to its 14 partner organizations, which include city, county, state and federal wastewater treatment, stormwater management, and water-quality regulatory agencies. Benthic invertebrates are the primary indicator species in addressing the priorities of ocean assessments (e.g., is it safe to swim, is it safe to consume seafood, is the ecosystem protected?). Agency research methods are moving toward genomics for biological assessments, e.g., PCR automation/miniaturization in gliders by Monterey Bay Aquarium Research Institute. The agency looks forward to collaborating with U.S. IOOS to avoid scientific overlap, identify best practices make technologies useful without obtaining further funding, and to standardize the methods used.

Marine Mammal Health, Stranding and Telemetry Data

Tenaya Norris, Marine Scientist
The Marine Mammal Center, Sausalito, Calif.

The non-profit Marine Mammal Center (TMMC) was established in 1975 to advance global ocean conservation through marine mammal rescue and rehabilitation, scientific research, and education.

Their work is focused in three areas: animal care, scientific research and education. They work closely with volunteer stranding and entanglement networks, as well as local, tribal, state, and federal government agencies, particularly the NOAA Fisheries Marine Mammal Health and Stranding Response Program, to coordinate and conduct emergency responses to stranded or entangled marine mammals.

TMMC is a partner in and a contributor to the Marine Mammal Health M.A.P. (Monitoring and Analysis Platform), an interactive web-based tool for rapid communication, visualization, and analysis of marine mammal health data integrated with physical, chemical, and biological environmental data.

TMMC has done some tagging and seeks to become more involved with telemetry/biodiversity projects.

Northwest Indian Fisheries Commission Marine Biological Observation Priorities

Tommy Moore, Oceanographer, Northwest Indian Fisheries Commission-Coastal Office (remote attendance)

The Northwest Indian Fisheries Commission (NWIFC) was founded in 1974 as a tribal natural resource management effort and provides policy coordination with technical support services for members. A primary goal of the NWIFC is to provide data and information necessary for tribal ecosystem-based fisheries management (EBFM). Their specific priorities include understanding the life cycle of specific salmon species (coho, Lake Ozette sockeye, chinook) because of their importance to tribal fisheries and studying the movement and survival of the marine mammals (sea lions, sea otters) to better understand the effects of their predation on the tribal fisheries. The NWIFC has been dealing with declining numbers of chinook salmon because they are the preferred food of the Southern Resident killer whales.

U.S. Navy Conservation Needs From Marine Animal Telemetry Data

Chip Johnson, Natural and Marine Resource Program Manager
Environmental Readiness Division
U.S. Navy Pacific Fleet, San Diego, California

The Environmental Readiness Division of the U.S. Navy Pacific Fleet manages natural resource conservation projects at U.S. Navy ranges in the Pacific and conducts environmental analysis on effects of U.S. Navy activities (NEPA). Their marine animal telemetry/biodiversity observations assist basic biology supporting NEPA preparation, MMPA and ESA consultations, U.S. Navy responses to critical habitat proposals, and anthropogenic effects analysis. The U.S. Navy Pacific Fleet funded nine U.S. West Coast telemetry projects from 2008–2019 and anticipates similar U.S. West Coast work continuing into the future, although annual needs or species may vary by range complex and consultation status. Continuing technical and data needs include longer tag durations, bigger datasets and derivation of species-specific home ranges or core areas for groups, and quicker access to track data. A potential growth area for the U.S. Navy is to combine marine telemetry tracks with other environmental and impact assessment analyses.

Ecosystem-Based Fisheries Management at NOAA

Steven Bograd, Acting Division Director
Environmental Research Division/
Southwest Fisheries Science Center (SWFSC)/NMFS

The mission of the SWFSC is to generate the science necessary to conserve and manage living marine resources. The approaches for supporting this mission have evolved from historical efforts on single-species stock assessments, the classical workhorse of fisheries management (FM), to developing ecosystem approaches to FM that bring climate and environmental considerations into fisheries ecosystems plans (e.g., goal of the FATE—Fisheries And The Environment program). The SWFSC is now moving toward ecosystem-based fisheries management (EBFM), where the climate and the environment are built into their ecosystem models, and where regional management strategy evaluations are developed to assess the effectiveness of various management scenarios in improving ecosystem functions and services. Also, a major NOAA objective related to advancing EBFM capacity in the Northern California Current System is climate vulnerability assessments. These are aimed at producing a practical and efficient tool for assessing the vulnerability of a wide range of fish stocks to a changing climate.

The main research themes of the SWFSC/ERD are North Pacific climate variability and change and ecosystem response; seasonality of physical-biological coupling; characterizing critical habitat of marine populations; and EBFM / dynamic ocean management. Combining marine animal tag data from the TOPP (Tagging of Pacific Predators) Program with climate models to develop species distribution models is a nice example of how to look for possible changes in, for example, top predator biodiversity in the North Pacific.

Just like other in situ ocean data, biologging observations can be used both for model validation and assimilation. Specific biologging contributions to observing the ocean include: i) 3D ocean structure, ii) track fidelity among individuals and within populations, iii) mesoscale dynamics: eddy/frontal structure and evolution plus prey aggregation mechanisms, iv) monitoring of critical habitats and developing climatologies and v) model data assimilation/validation, habitat model building and projections of change.

NOAA's California Current Integrated Ecosystem Assessment Program

Elliott Hazen, Research Ecologist
Environmental Research Division /
Southwest Fisheries Science Center (SWFSC)/NMFS

At the center of the various components of EBFM are the fisheries ecosystem plans that are driven by the fisheries councils and the NOAA Fisheries Climate Science Strategy. These are informed by several regionally implemented programs, e.g., stock assessment improvement plans, habitat assessment improvement plans, regional action plans, and climate vulnerability assessments. The tool that enables these individual programs to succeed and interact effectively is the Integrated Ecosystem Assessment (IEA). The California Current Integrated Ecosystem Assessment (CCIEA) Program was developed under the NMFS Western Region Action Plan and provides the analytical framework for organizing the science needed to inform ecosystem-based management of the California Current—a complex ecosystem in which natural and human systems are inextricably linked.

The CCIEA, coordinated at the SWFSC by Elliott Hazen, is an interdisciplinary research effort by U.S. West Coast NOAA scientists. The CCIEA website displays status and trends indicators on things such as ecological integrity (diversity, forage ability, biomass ratio, etc.), and large scale oceanographic indices. Annual written ecosystem status reports are produced and include information on a range of drivers from climate/physical to socioeconomics. The status reports provide an

ecosystem status backdrop for council decision-making and sanctuary condition reports. These reports evolve yearly to include relevant indices: e.g., environmental drivers of sablefish recruitment, ecosystem impacts of the "blob," biodiversity indicators from MBON, spatially-explicit risk analyses through dynamic ocean management studies. The future of the IEA includes integration with fisheries ecosystem plans (plus automation and regular updating of time series and reports) and telemetry data, including in particular, time series of animal movement data.

Informing Ocean Zoning and Seabird Management Using Tracking Data

Michael Johns, Pete Warzybok, and Jaime Jahncke,
Point Blue Conservation Science
Greg Breed, University of Alaska Fairbanks

Point Blue Conservation Science is a non-profit organization whose mission is to conserve birds, other wildlife, and ecosystems through science, partnerships, and outreach. Founded in 1965 as the Point Reyes Bird Observatory, they now have more than 180 scientists and staff who partner with government agencies, private landowners, and other wildlife and habitat managers to study birds and other environmental indicators to protect nature's benefits and manage over one billion ecological observations. Using long-term data from their Palomarin Field Station and from their 50-year partnership with the U.S. Fish and Wildlife Service studying the changing seabird patterns of the Farallon Islands and other places, they have been evaluating natural and human-driven environmental change over decades. Their tracking data can help inform policy and management decisions related to impacts of large vessel traffic, oil spill risks and offshore wind energy farms. Future activities will address new datasets (ROMS current modeling), new geolocator tags (miniature GPS and TDR combinations) and new species and colonies.

O'Neill Sea Odyssey

Cyndy Dawson, Executive Director, O'Neill Sea Odyssey

The O'Neill Sea Odyssey (OSO) organization educates fourth- through sixth-grade students through hands-on lessons on the relationship between the ocean and the environment. Focusing on underserved schools, OSO covers marine biology, ecology, and navigation. Even though students primarily ask only about marine mammals, OSO would like to use biodiversity and telemetry data to illustrate how food availability and oceanographic conditions are driving what the students are observing from the boat and in the plankton sample. The students collect basic data such as pH, temperature, visibility, depth, and plankton samples from the boat. The OSO would benefit from collaboratively brainstorming with the marine biology community on how to get scientists on board, and how to improve their collection of data and possibly use archival data. Student class size averages per class, totaling 5,276 and more than100,000 since inception.

Risso's dolphins outfitted with tags to track their movement and depth. Photo Credit: Brandon Southall (NMFS permit #19116)

RESEARCH PERSPECTIVES

Marine Biodiversity Observations: A Major Role for Biologging in our Oceans

Barbara Block, Charles and Elizabeth Prothro Professor in Marine Sciences, Hopkins Marine Station, Stanford University

Barbara Block outlined several challenges and the associated observational complexities the ocean science community faces: 1) How will we know when our seascapes are changing?, 2) Can we monitor ecosystems?, 3) Can we monitor fisheries?, 4) Can we monitor human predators?, 5) How can we estimate biomass of fish? The observing capabilities and networks addressing these challenges are broad and evolving and include multiple technologies, many of which the Block Lab are implementing. The lab finds that biologging can play an important role in studying marine biodiversity observations by providing quantitative observations on species distributions that can be used in modeling of biomass and critical life history parameters. The Block Lab has been at the forefront of the ecology of tracking fish, the science of which has more recently become critical for stock assessment models. Current operating models for bluefin tuna require spatial data in combination with genetic and microchemistry data utilized in assessing the overall catch and biomass of tunas.

The full suite of animal telemetry and biodiversity observing systems includes: biologging/tags, receivers, buoys, gliders/drones, eDNA & Ecogenomics. eDNA has the promise of providing a cheaper, less invasive and larger scale approach to monitoring species diversity and the study of ecogenomics is critical because ocean viruses profoundly impact microbial community composition and metabolic activity in the oceans, thereby affecting global-scale biogeochemical cycling.

In the Pacific, the team began with the Tagging of Pacific Pelagics (TOPP) program, a 10-year effort to tag large pelagics from 2000–2010 that was a project of the global Census of Marine Life Program. Over 1,500 tunas were tagged in this period by Block's team, the Inter-American-Tropical-Tuna-Commission, and NOAA—all funded by TOPP. The combined efforts of TOPP and the Tag a Giant (TAG) Foundation today represent more than 6,500 tag deployments. Along with the Tuna Research and Conservation Center, a collaboration between the Hopkins Marine Station and The Monterey Bay Aquarium, their biologging activities focus on studying behavior of fish in the wild, including habitat utilization, migrations, foraging and spawning behaviors, population biology, mortality, maturity, management and assessment, climate change and physiology. For example, tracks collected over a decade provide strong evidence that juvenile bluefin that have come from Japan are using the west coast for foraging and are migrating on an annual cycle between Baja and the waters off northern California. Plus, satellite tagging "Has shown the way to the White Shark Café!"

Marine Biodiversity Observation Network, Santa Barbara Channel

Bob Miller, Research Biologist
Marine Science Institute, UC Santa Barbara

The Santa Barbara Channel Marine Biodiversity Observation Network (SBC MBON) is a prototype project to track biodiversity of organisms from microbes to whales at large spatial scales and is led by the main Principal Investigator, Bob Miller at the Marine Science Institute of University of California Santa Barbara. SBC MBON is one of three such projects in the U.S., supported by NASA, BOEM, and NOAA with goals to provide data to managers and society about patterns of biodiversity across taxa, space, and time by integrating existing data, developing new methods and products, and building a widely applicable model for expanding the MBON concept nationally and internationally. Local partners include the Southern California Water Research Project, the Channel Islands National Park, the Santa Barbara Coastal Long Term Ecological Research Project, and the Channel Islands National Marine Sanctuary.

This SBC project is specifically focused on using: i) ocean data and species archetype modeling to uncover the complex and multiscale drivers of kelp forest communities, ii) remote sensing to assess kelp forest condition, age, and extent plus phytoplankton functional diversity, iii) acoustic detection of marine mammals and their foraging patterns, iv) genomics looking at microbial diversity and community structure, v) eDNA and acoustic telemetry for detection of great white sharks, vi) bottom mounted, shallow water, acoustic broadband receivers for soundscape monitoring, vii) gliders for deeper waters or targeted monitoring of cross-boundary species, and viii) co-deployment/maintenance of acoustic telemetry receivers for shark detections. They are also applying deep learning techniques for improving image analyses. An important issue on the West Coast is the impending decommissioning of several offshore oil platforms. MBON data have been used to predict how fish biomass and abundance will change under different decommissioning scenarios.

Advancing Conservation and the Understanding of Whale Ecology, Movements and Migration, Incorporating Habitat and Environmental Aspects

Barbara Lagerquist, Senior Faculty Research Assistant
Marine Mammal Institute (MMI), Whale Telemetry Group (WTG) , Oregon State University

With the goal of advancing conservation and understanding whale ecology, the MMI tracks whale movements and migration and links them with habitat and environmental factors. Since 1986, MMI has tagged 832 large whales in North America with a wide range of state-of-the-art tags and sensors: long-duration, implantable, location-only, Argos (Telonics and Wildlife Computers); intermediate-duration, recoverable, Fastloc GPS/TDR (advanced dive behavior) tags (Wildlife Computers); and long-duration, implantable, dive-monitoring Argos tags (Telonics).

The current MMI program, supported by the U.S. Navy Pacific Fleet, is focused on using Argos long-duration dive monitoring tags on humpback, blue, and fin whales. These tags will help us understand foraging behavior in relation to habitat variables and ultimately how behavior may change in the presence of anthropogenic activities and to possibly develop acoustic sensor capabilities to monitor ambient and anthropogenic sounds. The data collected by the WTG in the last 30 years offer a unique global view of whale movements, potentially to improve our understanding of movement ecology in space and time and provide management bodies (e.g., NMFS, International Whaling Commission) and industry with data and information to improve conservation and management policies.

Monitoring Essential Marine Biodiversity Variables

Elliott Hazen, Research Ecologist
Environmental Research Division,
Southwest Fisheries Science Center/NMFS

The goal of the Environmental Research Division (ERD) is to assess, understand, and predict the effects of climate and environmental variability—from global to local scales—that are important to fish populations, protected species, and marine ecosystems, as well as to deliver integrated scientific information for sound decision-making and ecosystem management. This includes, for example, using marine top predators as climate and ecosystem sentinels. As the climate changes, new ocean conditions result with new associated risks. An example is the dramatic increase in fishing gear-related whale entanglements along the California coast due to the 2015–2016 persistent marine heat wave, which modified the type and location of prey and drove the humpback whales onto the shelf in search of their prey. This created an unusual and dangerous time-space overlap of large numbers of foraging humpback whales and crab pots/lines. Conditions like this have led to a shift toward implementing dynamic ocean management (DOM): management that rapidly changes in space and time in response to the shifting nature of the ocean and its users through the integration of near real-time biological, oceanographic, social and/or economic data—thereby better balancing ecological and economic objectives.

Biodiversity monitoring is a critical tool in understanding baseline and abnormal conditions in pelagic environments and hence is critical for DOM. Also, large scale tagging projects (TOPP) and data sharing (ATN) are necessary to make tag data useful for monitoring biodiversity and informing management, and ERD could use greater collaboration with those large-scale efforts when monitoring biodiversity. Synthetic datasets can also inform DOM—a better match with ecological processes **and** human activities in space and time. Examples of existing DOM implementations include Turtle Watch, Whale Watch and EcoCAST.

Demographics and Behavior of Fin Whales and Cuvier's Beaked Whales on a Navy Range

Greg Schorr, Research Biologist,
Marine Ecology and Telemetry Research, Seabeck, Washington

Marine Ecology and Telemetry Research (MarEcoTel) is a non-profit organization of a small group of biologists whose mission is to support the conservation of marine species and populations by conducting scientific research into their biology, behavior, and physiology for use by managers and stakeholders and to improve public knowledge and awareness of these species and the ways that human activities affect them. Their research questions include population levels, diving behavior and behavioral responses to sonar, shipping and explosions; their research tools include photo-ID, biopsy/eDNA, acoustic recordings, photogrammetry, and tagging. Their work extends from South America to Alaska and from Hawaii to the Atlantic, although most of their projects are focused on the U.S. West Coast. MarEcoTel uses a wide range of different satellite tag types because it is essential to use the right tag for the right task/species, and tag development is an important part of their research efforts. Also, because some species, e.g., Cuvier's beaked whales, are notoriously poor performers with connecting to Argos (long dives

and short surface times), they have been experimenting with deploying mote stations (land-based line-of-sight receivers) and have increased the number of receptions from the tags by 140%! A coastal network of mote receivers could be a valuable asset for West Coast telemetry activities.

An Overview of SWFSC's Marine Mammal and Turtle Research Division in the Context of Animal Telemetry, Marine Biodiversity, and Ocean Tracking

Lisa T. Ballance, Director and Karin Forney, Research Biologist Marine Mammal and Turtle Research Division/Southwest Fisheries Science Center/NMFS

The Southwest Fisheries Science Center (SWFSC) is one of six regional NMFS Science Centers in the U.S. The research priorities of the centers are guided by the policy foci of their regions and include sustaining fisheries, protecting marine species, and conserving marine habitat. The primary information needs of the Marine Mammal and Turtle Research Division are prescribed by the Marine Mammal Protection Act and the Endangered Species Act statutes, which collectively require information about distinct population segments, population size, stock structure, human-caused mortality, threats, and trends in abundance. A primary emphasis of their science mission is to perform species assessments that support management objectives. These assessments include: i) estimating abundance, status, and trends, ii) clarifying population structure, iii) assessing condition and health and placing all of these into an ecosystem context. Since marine mammals and turtles do not recognize political boundaries, their statutes require research outside U.S. waters. Marine biodiversity observations embrace cetacean abundance and ecosystem assessment surveys using aerial, small boat, and shore-based research, as well as animal telemetry-ocean tracking of marine turtles (4 species) and cetaceans (10 species). The time series being created today will be tomorrow's baseline, so they hope to build structure in assessing environments and their current state. Partnerships across sectors are increasingly critical in fulfilling their science mission, although the future of their tagging programs is unclear.

Devil's in the Details: Adaptability in Habitat Use of Western Gulls

Scott Shaffer, Professor, Biological Sciences, San Jose State University

There is a strong relationship between seabirds and at-sea ocean observations. Seabirds are i) major apex predators that integrate resources over ocean scape, ii) respond rapidly to ocean conditions because of their mode of transportation (flight), iii) have excellent breeding success, making them good indicators of ocean health (resource availability), and iv) use resources at land/sea interface for food and for breeding.

Scott Shaffer's research objectives focus on understanding how seabirds use marine resources, identifying environmental features that influence habitat use, examining how adaptable the animals are to environmental change and characterizing changes in behavior and distribution associated with human activities or threats. Western gulls can provide diverse results because of their flexibility in habitat use (marine and terrestrial) and in their diet, which seems to vary with marine conditions. This is supported by tracking studies showing a remarkable combination of both ocean and land foraging trips from the Farallons and Año Nuevo Islands. Since finding large amounts of garbage in the diets of the gulls from Año Nuevo, Shaffer is moving toward interdisciplinary research that examines topics like microbe exposure, heavy metals as pollutants, and quantifying the amount of garbage in their diets.

Using Suction-Cup Tags to Study Cetacean Physiology and Biomechanics

Jeremy Goldbogen, Assistant Professor of Biology Hopkins Marine Station, Stanford University

The focus of the Goldbogen Lab at the Stanford University Hopkins Marine Station is on studying the physiological ecology of marine organisms, functional morphology and biomechanics, biologging kinematic and physiological parameters, and effects of anthropogenic activities on marine life. By using commercially available Customized Animal Tracking Solutions or CATS, which are self-contained, suction-cup attached tags that measure 3D movement and capture dual video at high resolution, they measure the fine-scale kinematics of engulfment relative to the speed of the body. This engulfment or extreme lunge-feeding strategy is exhibited exclusively by rorquals, a family of baleen whales that includes species such as humpback, fin, and blue whales. The data from these tags are critical to understanding the energetic consequences of this unique feeding mechanism, and they suggest that rorqual species can

fine-tune and modulate the kinematics of feeding in order to optimize foraging efficiency across a wide range of scales and ecological seascapes. This new technology has changed the way we think about how whales feed and how they interact with their environment.

To enhance collaboration and integration among studies, Goldbogen encourages: i) universities to support data management, ii) funders to encourage researchers to budget for data management, iii) funders to make more support available to analyze and publish current data sets—to balance the continued collection of new data, iv) researchers to better organize and standardize data (formats, analysis methods), and v) federal permitting authorities and funding agencies to enforce data sharing.

Using Electronic Tags to Follow the Behavior of Animals In the Context of Their Environment

Dan Costa, Director Institute of Marine Science, University of California Santa Cruz

The main focus of the Costa Lab at the University of California at Santa Cruz is on understanding the behavior of marine animals and their adaptations to life in the marine environment, especially the movement, foraging ecology, and energetics of pinnipeds, cetaceans, and seabirds. Using animal tags with integrated ocean sensors for temperature, salinity, and chlorophyll, the Costa Lab has identified a wide range of behavioral responses to physical oceanography anomalies including e-seals spending more time foraging but gaining less mass, and the substantial increase in offshore foraging by California sea lions during the 2005 warm water anomaly. Their telemetry data also indicate that individuals with strong site fidelity used areas with greater habitat stability. In particular, tracks of the same female elephant seal collected 11 years apart showed amazing site fidelity traveling thousands of miles to the same site from the same location in California. The lab is also focused on understanding the population-level consequences of anthropogenic disturbance and environmental change in marine mammals and developing science-based tools that can be used by resource managers to support the development of realistic population risk assessments, as well as effective wildlife management and conservation strategies. They also participate in the community based Retrospective Analysis of Antarctic Tracking Data (RAATD), also called the "Southern Ocean TOPP," aimed at conservation and management of Antarctic seabirds, seals and cetaceans.

The Need for Sustained Observations of Marine Ecosystems

Francisco Chavez, Senior Scientist/Biological Oceanographer, Monterey Bay Aquarium Research Institute (MBARI)

MBARI is a private, non-profit oceanographic research center where scientists and engineers work together to develop new tools and methods for studying the ocean. They have a strong emphasis on the importance of global observations with a strong focus on the Central California Current. They started a time series at three stations in the Monterey Bay region in 1988 where a broad suite of biogeochemical measurements are collected. The stations are visited by ship at approximately three-week intervals, and moorings are maintained at two of the stations. These are part of a demonstration Marine Biodiversity Observation Network (MBON) project in the region.

Understanding the biological response to climate and global change requires: i) determining the mean and fluctuating components of phytoplankton primary production, biomass, and species composition on timescales ranging from days to decades, ii) determining the physical, chemical, and biological processes responsible for the mean and fluctuating components and, iii) determining the time-varying biogeochemical and ecological (zooplankton, fish) fate of primary production. In order to accurately interpret local to regional observations, a basin-scale context is needed. MBARI time-series measurements have shown, among other things, that over the past few decades, a decrease in oxygen (less ventilation) and pH has been observed, while there has been an increase in partial pressure of carbon dioxide and ocean acidification.

As ecosystem processes change, there is a critical need for long-term sustained observations (to keep models and modelers in check). Future observing systems should focus on understanding processes rather than on fixed stations or grids and should apply cheaper, less invasive and larger scale approaches to monitor species diversity such as eDNA. Fleets of long range AUVs with environmental sample processors and other samplers/instruments should also be employed because they can provide a new window for observing life in the sea. Almost a decade ago, there was an effort to build an integrated sustainable biological observing system for the West Coast called PaCOOS—it failed but maybe the time is right today.

Development of Medium Duration Archival Tags on Blue, Fin, and Humpback Whales and their Utility in Assessing Human Impacts

John Calambokidis, Research Biologist, Cascadia Research Collective

The ambitious program at Cascadia Research Collective aims to develop and use a wide variety of tag types and attachments to collect data that will answer questions about the whales' detailed movements around shipping lanes and opportunistic interactions with ships, exposure and response to mid frequency active sonar, calling behavior of whales, detailed kinematics and energetics over extended periods with good position data, night-time behavior and movements and avoiding bias related to their behavior state at the time of tagging. The tags include, for example, short-term suction-cup archival tags, medium duration dart-attached archival tags, medium duration LIMPET (Low Impact Minimally Percutaneous Electronic Transmitter) tags, and deep implant position-only implant tags. The medium duration dart-attached tags can carry an assortment of different sensors such as satellite transmitters, an Acousonde archival tag paired with a VHF transmitter for easier recovery, acoustic and GPS receivers, and high resolution accelerometers.

A total of 60 dart-attached tags have been deployed on blue, fin, and humpback whales with the maximum duration of about 3 weeks on the blue whales.

A humpback whale (CRC-15406), about to fluke off of Half Moon Bay, California. Photo Credit: Kiirsten Flynn, Cascadia Research (NMFS Scientific Research Permit #21678 to John Calambokidis).

A challenge of using these types of tags is that, even though longer deployment times are desired, they actually result in more potential for animal-animal contact, which can damage the tags. Greater data storage capacity to handle high resolution longer-term data would be ideal, as would the ability to download the data from floating tags (for example, after tags have fallen off from blue whales) would be an advantage.

Scaling Down to Scale Up: Studying the Ecological Interactions between Marine Predators and Prey at Fine/Functional Scales

Ari Friedlaender, Associate Researcher, Institute of Marine Sciences, UC Santa Cruz

The three main research questions that Ari Friedlaender is focused on are: i) How to quantify the ecological interactions between marine mammals and prey across spatio-temporal scales, ii) How the foraging behavior of marine mammals is affected by changes in prey availability, and iii) what the functional and context-dependent responses of marine mammals to disturbances (e.g., Navy sonar) are. High-tech motion-sensor and video recording tags are attached with non-invasive suction cups for up to 48 hours. The tags include sensors for time, depth and temperature, 3-axis accelerometers, magnetometers and gyros with very high sampling rates (400 Hz) and audio up to 242k Hz and 2K of video plus a VHF transmitter for recovery and a GPS receiver. By using echosounders to determine distribution, abundance, and density of krill, researchers can link fine-scale foraging behavior measured by the tags with prey. Also, by coupling the prey and tag observations with controlled exposure experiments (CEE), they are able to determine context-dependent behavioral response of blue whales to Navy sonar. This includes the fact, for example, that deep-feeding whales respond more clearly and strongly to CEEs than those in other behavioral states. This is only evident due to the increased explanatory power that comes with incorporating prey contextual covariates.

Among his conclusions are that fine-scale tag data are critical to understand basic behavior and ecological interactions that include energetics, competition between species, and prey availability. Without these data, broad-scale movement/behaviors and relationships to remotely sensed and modeled data cannot be understood. Overall, the context is critical to evaluate the decisions animals make and how they respond to disturbance/environmental change.

Monitoring White Sharks along Southern California Beaches

Chris Lowe, Marine Biology Professor and Shark Lab Director, California State University Long Beach (CSULB)

The Shark Lab at CSULB has an impressive background of historical research that involves quantifying movement patterns and site fidelity of nearshore fishes, assessing Marine Protected Area (MPA) design and efficacy based on fish movement and habitat use, investigating fish contaminant exposure based on their movement, identifying the ecological importance of artificial reefs (e.g., offshore platforms, mitigation reefs) and promoting acoustic telemetry data sharing in Southern California (SoCal) through development of Southern California Acoustic Telemetry Tracking Network (SCATTN). This has been supported by installation of 120 VR2W acoustic receivers in SoCal area in gridded arrays up to 20 km^2 in size with more than 2,300 acoustic tags deployed over the last 20 years. With this as a backdrop, Chris Lowe outlined their current research activities, which are driven by public safety concerns and are focused on identifying the spatial and temporal distribution of people and white sharks in the SoCal beach areas.

Current activities have already involved 12 years of tagging in collaboration with the Monterey Bay Aquarium, CICESE, and CINMS using a combination of tools including active and passive acoustic tracking, biologgers, SPOT and PAT satellite tags, HOBO temperature loggers, and new VEMCO real-time acoustic receiver buoys. They have also combined tagging with aerial surveys to create a database of video transects collected by police, fire staff, coast guard, news helicopters, and lifeguards. Newer techniques including "Smart-tags," AUV beach surveys, and white shark eDNA are being explored. Lowe indicated that he is looking for a good place to put his data where it could be accessed by others and sees the ATN DAC as a possible candidate.

Factors Affecting the Early Marine Survival of Puget Sound Steelhead

Barry Berejikian, Fisheries Enhancement and Conservation Program Manager and Manchester Station Chief

Megan Moore, Research Fisheries Biologist
Manchester Research Station, Northwest Fisheries Science Center/NMFS

Steve Jeffries, Washington Department of Fish and Wildlife

The NWFSC Environmental and Fisheries Sciences Division uses acoustic telemetry to track the factors affecting the decline (2006–2014) and recovery (2015–present) of early marine survival of steelhead trout in Puget Sound. Early acoustic telemetry research (mid-2000s) indicated low and declining steelhead smolt survival in Puget Sound (migrating from river mouths to the Pacific Ocean) triggering a number of researchers in Puget Sound to independently track the fate of steelhead smolts in the marine environment. Acoustic telemetry is an excellent data collection approach because steelhead are large enough to carry a surgically implanted transmitter, and the transmitter can be detected by moored hydrophone receivers up to several hundred meters away. A meta-analysis of the data from six different river systems by Megan Moore illustrated a few clear patterns: i) migration was rapid, ii) survival was low, and iii) mortality patterns were different in Hood Canal and Puget Sound. South/Central Puget Sound was a significant source of mortality, so there was clearly something happening in the estuaries that they were not capturing. In response, they tagged more smolts, added more receivers with broader spatial coverage across Tacoma Narrows, Central Puget Sound, river mouths, and redeployed lines across Admiralty Inlet. They also added some tagged seals and receivers in 2015 in South Puget Sound to enable mobile tracking of acoustic detections. The results showed that whatever was causing the shift in survival was not related to changes in smolt (prey) behavior but rather pointed to changes in predator behavior.

In 2014 when steelhead survival was at its lowest point, there was substantial evidence of predation by harbor seals, because many smolt tags were repeatedly being detected at Central and Northern Puget Sound haulouts. In 2016 when steelhead survival was six times higher than in 2014, they found only a single tag at one of the monitored haulouts. This suggests an inverse relationship between inferred predation by harbor seals and survival of steelhead and the likely possibility of a harbor seal diet shift toward anchovy (which had a corresponding increase in abundance) that made their numbers repopulate. Barry Berejikian believes that there continues to be value in using acoustic telemetry for both long-term monitoring and mechanistic studies since the two are complementary.

USGS Pacific Seabird Studies

Josh Adams, Research Biologist, U.S. Geological Survey, Western Ecological Research Center (WERC) Santa Cruz Field Station

The WERC seabird program focuses on determining distribution and abundance patterns of seabirds at sea, nesting biology, foraging ecology, and conservation science. Current studies are focused in the California Current System and Hawaii, but telemetry data and collaborations span the Pacific Ocean. These telemetry activities complement an ongoing series of California Current based regional aerial surveys

conducted every 15–20 years since the 1970s. This and other data have enabled studies of seabird vulnerability to ocean wind energy infrastructure in the California Current System (CCS). Also, with (CCS) data from U.S. Geological Survey (USGS), NOAA, and others, the NOAA/National Ocean Service/ NCCOS Biogeography Group plans to produce a species-based predictive modeling framework for seabird marine spatial planning in the region.

WERC seabird telemetry is focused on three main topic areas: i) distribution, behavior, environmental interactions and habitat-use at sea, ii) vulnerability of seabirds to threats at sea and on land and, iii) tag innovations and attachment methods. Their tag innovation work with NASA has included the idea of developing a small sensor to deploy on far-ranging pelagic seabirds like albatrosses to measure dimethyl sulfide (DMS), a trace gas produced by microscopic marine organisms, which is important for the global sulfur cycle and global climatic homeostasis. Integrating the DMS sensor with a miniature GPS logger could create a tag to measure DMS throughout the world's oceans. WERC has also created the California Current Ecosystem Seabird Telemetry Atlas to aggregate USGS seabird tracking data and data from cooperating researchers to provide streamlined, standardized methods to process and visualize extensive, spatially explicit tracking data.

With no plans in place at the moment to tag more birds for the next few years, Josh Adams will concentrate on large amounts of new and legacy data (two large projects through 2021), addressing data security, archival and distribution issues, tag and sensor innovation, as well as seeking additional collaborations.

Biological Effects of Ocean Acidification In Situ: Moving Towards Integrated Bioassessment

Nina Bednaršek, Senior Scientist, Biogeochemistry Department, Southern California Coastal Water Research Project

The Southern California Coastal Water Research Project transforms chemical observations for biological interpretation. Though there has been experimental evidence relevant to the causes of ocean acidification (OA), there is a lack of biological observations. SCCWRP aims to link sublethal to lethal population effects, increase data on the most vulnerable calcifying groups, and extract data to identify thresholds. The taxa are mostly sensitive to OA and are therefore representative of their habitat, mode of impact, data availability, and management endpoint. Identifying thresholds has become a key responsibility, from mild dissolution to mortality. SCCWRP's habitat suitability index models give a conceptual representation of potential habitat compression from just a few stressors. This modeling has allowed identification of OA hotspots with the greatest physiological impacts that might lead to population effects.

OBSERVING SYSTEM AND DATA VISUALIZATION

ATN Data Assembly Center/Data Portal and MBON Data Portal

Rob Bochenek, Information Architect and CEO, Axiom Data Science

The ATN data management vision includes a regionally distributed data collection, management and sharing capacity that builds on and integrates as many existing telemetry data links as possible to enable local and regional needs to be addressed. At the heart of this system is a centralized data assembly center (DAC) and ATN data portal located at Axiom Data Science. This DAC is a community resource where regional telemetry data is aggregated in a single place, and one-stop-shopping is provided by the portal for access to U.S. animal telemetry data. The DAC both serves national stakeholder needs effectively and enables cost/time savings to principal investigators.

Axiom can handle the large volumes of data associated with the DAC by adopting a shared infrastructure approach to leverage multiple applications, systems and hardware across several partners (including U.S. IOOS, ATN, MBON, and numerous other national and regional partners). Under this model, functional improvements can be funded by one partner and shared with the collective to accelerate progress. By using community developed software, standards and protocols, Axiom ensures interoperability through standardized systems and interfaces across partners. Axiom has a scalable computing and storage infrastructure to keep pace with data growth and availability which includes: ~5,000 processor cores, ~1.5 petabytes of functional storage/5 petabytes of actual storage (~1,500 hard drives) and a Level 2 Fat Tree Infiniband Network (40 gigabytes per second node to node and 240 gigabytes per second cluster to cluster.)

The MBON Data Portal is a data exploration tool with a customized public web interface that allows scientists, managers, and the general public to discover and access public marine biodiversity data. The portal integrates datasets from many different sources. You can search or browse real-time conditions, operational and research forecasts, satellite observations, and other spatially referenced datasets that describe regional

biological, chemical, and physical characteristics. Datasets in the portal can be interactively mapped or charted using advanced features, such as the ability to create comparisons between data sources, bin data by time, and plot climatologies and anomalies.

For both the ATN and MBON portals, Axiom utilizes an approach that applies custom services to manage the flow of data throughout the entire data lifecycle—from data creation through to use, reuse, and transformation. Short-term storage and documentation exist for access and sharing by colleagues. Long-term secure archiving exists for preservation and future access and discovery by a larger audience.

A California sea lion rests on Rodeo Beach in the Marin Headlands with The Marine Mammal Center's hospital visible in the background. Photo Credit: The Marine Mammal Center

Software Tools and Data Interoperability Considerations in Support of Animal Telemetry Observatories: Results from the NASA/OIIP Project

Vardis Tsontos, OOIP Principal Investigator
NASA/JPL

The Oceanographic In-situ data Interoperability Project (OIIP) is a two-year NASA/ACCESS funded technology development project (Oct. 2016–Sept. 2018) aimed at developing improved capacity to support NASA field campaign data via the enhancement and integration of higher technology readiness level (TRL) informatics technologies. OIIP is also an R&D project addressing some fundamental earth science data informatics challenges that include: i) the need for improved integration of multivariate datasets from diverse observational platforms in support of NASA science, satellite mission Cal/Val and decision support applications and, ii) the challenge of in-situ data: it is inherently diverse, complex and heterogeneous, and it has acute Interoperability issues, e.g., multiple ad hoc data file formats and insufficient metadata and/or non-standards compliant metadata. The project is also focused on both conventional field campaigns, plus marine animal electronic tagging data as a representative (but also more challenging) use case.

With a strong emphasis on community/stakeholder engagement, OIIP places a high priority on addressing the significant data interoperability issues in the community with the goal to have coupled systems communicate and exchange data via common formats and protocols and to meaningfully interpret and reproducibly act on exchanged data. The desired outcome is to enable efficient integration among all data types and systems through automated data processing workflows and assimilation, which will in turn significantly lower costs of data usage and preservation across the dataset lifecycle. Examples of their products are: ROSETTA—a generalized web-based conversion tool and associated web-service/API for the production of standards-compliant netCDF data files with CF/ACDD metadata from generic, columnar ASCII data file inputs, THREDDS enhancements, and their web-based OIIP Data Viewer that provides integrated visualization of raster and vector-based in-situ and satellite datasets, synchronized horizontal and vertical views of data and their evolution over time, integrated data search and filtering capability, and intuitive browser-based user interface—all open-source technology. Overall the OIIP Project has produced a range of useful outputs for the Earth Science Data Community, including standards enhancements and open-source tools addressing

in-situ data interoperability issues and demonstrating the value of multivariate data integration via their enhanced visualization tool, as well as providing a general approach to community metadata and vocabulary development.

Satellite-derived Dynamic Seascapes: A Biogeographic Framework for the U.S. and Global Marine Biodiversity Observing Network

Maria Kavanaugh, Assistant Professor
College of Earth, Ocean, and Atmospheric Science,
Oregon State University

Traditional landscape ecology provides a useful framework and context for both terrestrial and marine benthic ecologists to address complex issues of scale and patchiness, as well as ecosystem-based management in a changing climate. However, while marine pelagic ecosystems are similarly affected by the changing climate, they do not migrate slowly with time but are rather much more ephemeral, have boundaries that are diffuse; because their primary producers are microscopic and planktonic, they need instrumentation to visualize patterns. The move from landscape ecology to marine pelagic ecosystem management must consider not only the nature and scale of biophysical interactions associated with organisms ranging from microbes to whales but also our limited capacity to observe and monitor these phenomena across global oceans. To be effective, this effort must integrate in-situ and above water assets across multiple platforms and multiple scales and classify regions in the ocean using primarily satellite-based physics and ocean color data, providing a biogeographic framework similar to biomes or landscapes. However, these resulting seascapes in the ocean are very dynamic, and their boundaries can move both seasonally and interannually.

Dynamic seascapes form the biogeographic framework for the MBON and enable comparisons among ecosystems where patches and boundaries may be relatively less apparent. They allow studies like rarefaction, which determine if sampling has been sufficient to characterize biodiversity and compare across different methods that characterize biodiversity—methods like eDNA and microscopy. They are being used as indicators of pelagic habitat, and can provide a means to track features and plan research cruises. Because applying seascapes is an iterative process, Maria Kavanaugh works with stakeholders to compare in-situ data; then, these same in-situ data are used to inform future iterations of the seascape classification, to address global to regional trends, examine local variability, and generate products, including describing unique microplankton assemblages in the Florida Keys. For example, seascapes can describe dynamic habitat for the Monterey Bay National Marine Sanctuary (NMS) by evaluating patterns of rockfish and forage fish between seascapes in central California. Another example is combining ATN movement data and seascapes to illustrate the interannual variability of albacore, bluefin, and yellow fin tuna in the California Current transition zone.

U.S. IOOS Vision and Strategy for an Integrated and Sustained Biological Observing System

Carl Gouldman, Director, U.S. Integrated Ocean Observing System (U.S. IOOS)

Established in 2006, U.S. IOOS has a mission to produce, integrate, and communicate high quality ocean, coastal and Great Lakes information that meets the safety, economic, and stewardship needs of the nations and will improve the lives and livelihoods of those living in those regions. The Integrated Coastal Ocean Observing System (ICOOS) Act of March 2009 outlined specific mission areas for U.S. IOOS that included: Weather and Climate Variability, Preparedness and Risk Reduction for Coastal Communities, and Healthy Ecosystems and Water Quality. Among the associated societal goals were to more effectively protect and restore healthy coastal ecosystems, and enable the sustained use of ocean and coastal resources and to do so through programs implemented at the regional, national and global level.

A niche that U.S. IOOS has created is in the area of developing/furthering "communities of practice" where we are actively engaged in projects to improve ability of the individual communities to deliver valuable information for societal benefit. These include, among others, MBON and ATN, plus regional applications of West Coast harmful algal bloom (HAB) monitoring, Lake Erie HAB/hypoxia measurements, ocean observations supporting lobster fisheries in the Northeast, and water quality monitoring in the Southeast.

For biology activities, a significant current focus for U.S. IOOS is on implementing a community approach and customer emphasis to: i) understand and capture the demand pull for biology observations, ii) use the demand pull to activate and energize our stakeholder community, and iii) enable the advancement of a robust, customer-driven biological component of U.S. IOOS.

U.S. West Coast Integrated Observing System: Examples, Opportunities and Visions

The State of the West Coast Nearshore Ecosystem: The Importance of MARINe - Multi-Agency Rocky Intertidal Network

Pete Raimondi, MARINe, Professor, Department of Ecology and Evolutionary Biology, University of California Santa Cruz

MARINe was created in the aftermath of the 1989 Exxon Valdez oil spill when it was recognized that no baseline data existed to enable assessment of the structure and function of ecological communities and in particular, the impact of natural and anthropogenic disturbances on them. This total lack of understanding of coastal ecosystems, particularly the long-term dynamics, geographic patterns, and current and potential threats is what leads to reactionary rather than informed management and conservation policy decisions. MARINe informs policy and enables assessment of natural and anthropogenic disturbances by supporting a network of monitoring sites that provides both the critical baseline from which to judge changes in ecological community or dynamics, and the specific approaches needed for evaluation of questions of special interest (e.g., endangered species, disease, climate change, impacts of pollution, fisheries management, and coastal resilience). They have developed a common, query-enabled database, a set of web-based visualization tools for the public, managers, policy makers, and other scientists, as well as a diverse and sustainable funding model. Their data collection efforts at 207 West Coast sites apply a three-part approach: i) coastal biodiversity surveys: large geo-spatial grid-style surveys (3–5 year cycle) allowing 3D mapping of species at all sites, ii) long-term "core" methods: fixed observations that target "key" species that are sampled annually and iii) environmental monitoring of temperature and the wave climate.

An essential ingredient is that sampling/observation methods must never change, which ensures consistency and a usable comprehensive database. All long-term data have associated photos (more than 100,000). A current project is to build an assembly and query-based photo database that is linked with biological and environmental data. An example of climate application is their study of the sea star wasting disease, which has captured striking spatial/temporal patterns of progression of the disease. The co-occurrence between the decline of sea stars and high temperature anomalies illustrates the value that MARINe brings by linking time series of environmental datasets with their biodiversity assessments.

CalCOFI and CCE-LTER: An Integrated Ecosystem Observing System

Ralf Goericke, CalCOFI-SIO Supervisor, IOD/Scripps Institution of Oceanography

CalCOFI (California Cooperative Oceanic Fisheries Investigations) began in 1947 as an ecosystem monitoring program following the collapse of the sardine fishery with the mission "…in order… to derive workable methods of predicting where sardines will be found, and in what quantities, it is imperative to know certain underlying principles which govern the sardine's behavior, availability and total abundance." Originally a partnership among the California Department of Fish and Wildlife, NOAA Fisheries, and Scripps Institution of Oceanography, CalCOFI today receives 90% of its funding from NOAA. Sampling began in 1949 with monthly surveys, employing multiple ships, covering the coast of California (U.S.) and Baja California (Mexico) measuring: temperature, salinity, oxygen, mesozooplankton, and fish larvae. Today CalCOFI operates cruises four times a year covering their 75 station pattern during summer and fall and their 113 station pattern during winter and spring measuring physical and chemical parameters, plankton and small pelagics creating 16 separate time series, some of which are 70 years long. An example of CalCOFI results is rockfish management and stock assessments, where they've observed the relationship between mesopelagic fish abundance and oxygen at depth (about 200 meters). These observations show tight correlation, since a habitat constrained with low O^2 prevents mesopelagic species from escaping visual predators at depth.

The CCE-LTER (California Current Ecosystem - Long-Term Ecological Research) is part of a network of 28 NSF-supported terrestrial and marine LTER sites studying ecological processes over extended temporal and spatial scales. The overall LTER network has been in existence for more than three decades, and the CCE site since 2004. This CCE site has generated 16 individual time series of the states of its biogeochemical system and biological communities to address the overarching questions: What are the mechanisms leading to different ecosystem states in a coastal pelagic ecosystem? What is the interplay between changing ocean climate, community structure, and ecosystem function?

Ralf Goericke shared the following experience-based guidelines for maintaining a time series and integrating an observational network: i) Yes, you should start a time series, and it will be painful. ii) Don't overextend yourself; make fewer measurements but do these well and document your data diligently. iii) Be relevant to environmental management and to the research community. iv) Engage the public—they are paying the bill. v) Yes, you are serving three different constituencies.

vi) Generate synthetic products of use to all three constituents and serve these products in forms accessible to all constituents. vii) Don't collect data that will only address specific questions; collect data that provide a framework for addressing diverse questions. viii) Involve the research community in your work—without it the time series may become irrelevant. ix) Engage the modeling community and make your data publicly available without restrictions.

Sea Grant and Biological Observing Networks

Joshua Brown - Western & Pacific Regional Program Coordinator NOAA Sea Grant

Sea Grant was created by the U.S. Congress in 1966 to be a highly leveraged federal and state partnership to harness the intellectual capacity of the nation's universities and research institutions to solve problems and generate opportunities in coastal communities. Sea Grant engages citizens, communities, scientists, organizations, industries, and governments to sustain and enhance the vitality, value, and practical use of the nation's coastal resources. Administered and supported by NOAA and matched by the state institutions, Sea Grant provides unique access to scientific expertise and to new discoveries through the 33 university-based Sea Grant programs located throughout the nation.

Sea Grant is responsible for funding applied science to address coastal issues and conduct outreach—not just science for science. Sea Grant has strong ties to the U.S. IOOS Regional Associations and has helped to support West Coast biology programs addressing ocean acidification/hypoxia, harmful algal blooms, wildlife ecology, species range changes and human interactions and impact.

Josh Brown's vision for an integrated biological observing system includes a cohesive community that brings a rich history of generational knowledge and synthesis from many sources to collaboratively address the challenges our changing world poses to ecosystems and the organisms who live in and depend upon them.

Senorita Fish in a giant kelp forest, Monterey Bay National Marine Sanctuary. Photo Credit: Kip Evans

BREAKOUT SESSIONS

Two breakout sessions were created and structured along stakeholder lines (Day 1) and by relevant animal telemetry and biological observation application priorities (Day 2). Summaries of these two sessions and of the Plenary Session (Day 3) are provided below.

DAY 1: STAKEHOLDER FOCUS

Focus 1: Summarize by economic sector (energy, fisheries, navigation, recreation, etc.) the need for biological observations.

Focus 2: How can existing telemetry and biological observations better address information needs within your sector? What is needed?

Focus 3: Revisit requirements from question. Synthesize and prioritize unresolved sector observation needs. Which observing gaps in assets, operations, data handling and governance are most critical and address more than one stakeholder requirement?

Group 1: Commercial/Private Sector

Public-private partnerships can play a key role in spurring collaboration between industry, research, and government. Providing streamlined access to observational information produces cost-savings and ensures that research is being used. The largest need identified is a network of coordinating bodies to provide "matchmaking services" pairing commercial/private sector needs with current and available data. These public-private partnerships can help identify repositories of information that can properly address data gaps.

Private industry identified two high-priority information gaps and expressed an interest in establishing central repositories for: i) baseline ambient acoustic noise data and ii) soft bottom community composition. What does the ocean sound like in areas of industry interest today? To what degree does industry need to worry about affecting this sound-scape? What are the potential effects for soft bottom communities? How can control sites be used to understand project impacts?

The energy sector requires easier access to basic space-based biological information in order to make informed decisions, particularly related to the permitting process. Information needs include understanding which important biological processes and species occur in areas of energy interest, how those biological components might be impacted by energy activities, how to describe different benthic habitats, and how to monitor changes in biology that are potentially attributable to energy sector activities. NMFS should be included when defining these habitats and choosing the most appropriate variables to assess and monitor to understand potential impacts of private sector activities.

Group 2: Natural Resources/ Conservation Management

Managers continue to require more timely and easily digestible access to biological data. Making data more readily available requires renewed efforts of coordinating bodies such as U.S. IOOS and ATN, who can play a key role in facilitating needed progress in strengthening metadata standards and other data entry challenges. Data products at different scales will help to make information understandable for managers.

New observations might also be required to address management needs, but additional observations must be prioritized based on existing observations and a more complete understanding of what already exists. For instance, fisheries managers are preparing to take 'Omics to the next level and seek consortiums of experts in the region to help lead these efforts.

Organizations like IOOS, ATN, and MBON can help to identify and relay data needs from stakeholders (including industry and managers) to data providers in order to better pair research that is being planned and executed.

Group 3: Research

The research community recognizes that biological observations and the products made using biological data are desperately needed by the private sector. Now we must look to better entrain with existing observational efforts to deliver the abundance and distribution data that are essential but hard to collect. Tagging is a valuable form of data, but it is expensive. Engagement with potential funding entities for an integrated biological observing system may result in larger scale baseline data (border to border) supported by networks of acoustic and Argos receivers. Line transects should be layered with biological observations (e.g., eDNA, telemetry, and biogeochemical data **like** stable isotopes).

Improved standardization and uniformity of data collection and management practices, metadata formatting, etc., remains a challenge for the community, which is quickly moving from "data limited" to "analysis limited." A unified data management strategy will help build consensus and standardized methods for data curation, organization, and storage (DOIs) and to ensure OBIS compliance. Many groups are working to understand existing data quality and quantity and to relate that to stakeholder needs. In order for biologging data to parametrize complex ocean circulation models, data need to meet some established, core threshold.

Connecting databases might circumvent the need to create additional databases. Today, data repositories are littering landscape, and each one tends to have a very specific view of things. Making them as interoperable as possible will make them accessible by and sharable by all.

The U.S. IOOS Regional Associations can help close the loop on how the data being collected is making difference institutionally by connecting end-users to researchers to demonstrate how tracking and biologging data are used to make real world policy decisions. U.S. IOOS can convene workshops to integrate acoustics, genomics, and tagging to measure distribution/abundance. High resolution monitoring (including benthic infauna, chemistry, etc. data) along the West Coast enables us to view things at higher resolution by leveraging existing data to better expand information about human impacts.

Tagging and placing tracking device on large billfish.
Photo Credit: Derke Snodgrass

DAY 2: ANIMAL TELEMETRY & BIOLOGICAL OBSERVATION PRIORITIES

Group 1: Monitoring Animal Movement and Species Diversity, Distribution and Abundance

There are fundamental questions that require telemetry data to address, but access to that data remains a challenge. We don't have common resources and tools to access and use this data. Although a lot of data are being monitored, a cohesive network is needed in order to assess the gaps. This is huge resource question but also part of the solution.

Designing an ecosystem observing system requires a minimum baseline of long-term observing information on which to build. Users, data providers, and data managers need to better coordinate to assess who's doing what and where. Where are the time series? How long will current funding last? What are the implications of a lost time series? Who are the correct people to develop those fundamental questions - is it the end users? Do the questions need an explicit connection to the managers, or other end users?

ATN and OTN are working on bottom-up organization to increase collaboration and coordination and to address some of the questions outlined above. Acoustic monitoring groups seem to be in an exploratory phase of figuring out how to coordinate and collaborate. MBON is attempting a more top-down organizational approach to understanding the key questions and long-term time series that can help to answer those questions. Perhaps ATN and MBON can learn from each other—MBON can learn about data interoperability and data management from ATN, and ATN can learn how to build consensus around the grand challenges that the telemetry community can help to answer.

Group 2: Improving Ocean Observations and Forecasts for Ecosystem Change Detection and Response

Observing systems need to be designed with a sustainable framework that can last for decades. We need flexibility to adapt systems' missions - for example, an observing system that will continuously collect data from a time series (along the lines of PACOOS in terms of encompassing the entire West Coast) with a focus on the open ocean.

ERRDAP has been a valuable tool for data collection—a way to link multiple databases, a tool that allows users to read

multiple databases to reduce redundancy. Data training for data providers can help to assess who is doing what and where with information length of time series.

ATN and MBON can bring individual researchers and their data formats into a common framework to develop integrated products. We can consider conducting a survey of the manufacturers that are producing these data, thereby interacting with manufacturers instead of individual researchers. We are constantly hearing about new receivers of listening devices; this intercoordination is very important.

Group 3: Improving Fisheries and Marine Resources Management

Biology that crosses management boundaries (fisheries regions, MMPA, ESA regions, etc.), once identified, can be used to establish "listening gates" to know who crosses those boundaries and when. Boundaries and managed spaces and their authorizing mandates and legislation can help to incentivize community coordination and observation standardization.

When targeting species, we must ensure that baseline data about the animal are available. Acoustic data collection possibly can piggyback information around these sensors. Developing connectivity across regional boundaries is important—having a broader dialogue across these borders, even when borders include our mandates (acts, legislation).

ATN is working from the bottom-up while MBON is taking key issues and determining why we need to measure them. It is important that these two communities to work together; the challenge is when the two groups inherently work in different styles.

Group 4: Defining Essential or Critical Habitats and Species

Coordination will require buy-in from enough of the community that it catches on so everyone knows about it and participates. Data must be discoverable to network participants and others.

Data wranglers and coordination bodies are needed to engage in the data management and data aggregation capacity. MBON has not yet identified the need for a data wrangler, but it has emerged as a gap during this workshop. What is role of an IOOS Regional Association in supporting an MBON data wrangler?

Data providers need training opportunities such as technical workshops to get their data into the correct data format and metadata standards that are OBIS compliant.

The research community must identify fundamental questions that are critical into the foreseeable future and that help inform asset needs and network structure. The network design needs a framework that is sustainable for decades but also has flexibility to adapt as its mission adapts. Then you can determine the observational needs to support the fundamental questions.

DAY 3: PLENARY SESSION

Vision for a West Coast Observing System

U.S. IOOS has a strong legacy of supporting physical and chemical oceanographic measurements and coordination, but we need to do better with biology. Currently there is no single, clear mechanism that helps us to coordinate and demonstrate the benefit of engaging in the network to researchers, private-sector, and managers at the local level.

During the plenary session, a nascent vision for the West Coast biological observations network was presented. The proposed collaborative observing network would integrate the spectacular array of biology-focused scientific activities in the West Coast Region to better serve regional stakeholders. A key goal of the network is to deliver more consistent observation and delivery of biology and ecosystem data, building on foundations in physical and biogeochemical work. A small steering team was established to continue the energy and enthusiasm developed at the workshop and to define the mechanism through which the west coast community will implement this community-driven effort.

The network will aim to deliver a suite of fit-for-purpose indicator products that incorporate near real-time data on an ongoing basis and encompass local-to-global perspectives on ecosystem assessment priorities. The network also will continually help us engage other organizations to collaborate and strategize effective partnerships to maximize ongoing prioritization and indicator development activities. Strategic partnerships will become increasingly important as the network advances through leveraging and support. In addition to its many collaborators representing key federal, state, local, and regional interests, the network is working closely with the West Coast Ocean Alliance and Point Blue Conservation Science to prioritize and understand ocean indicators.

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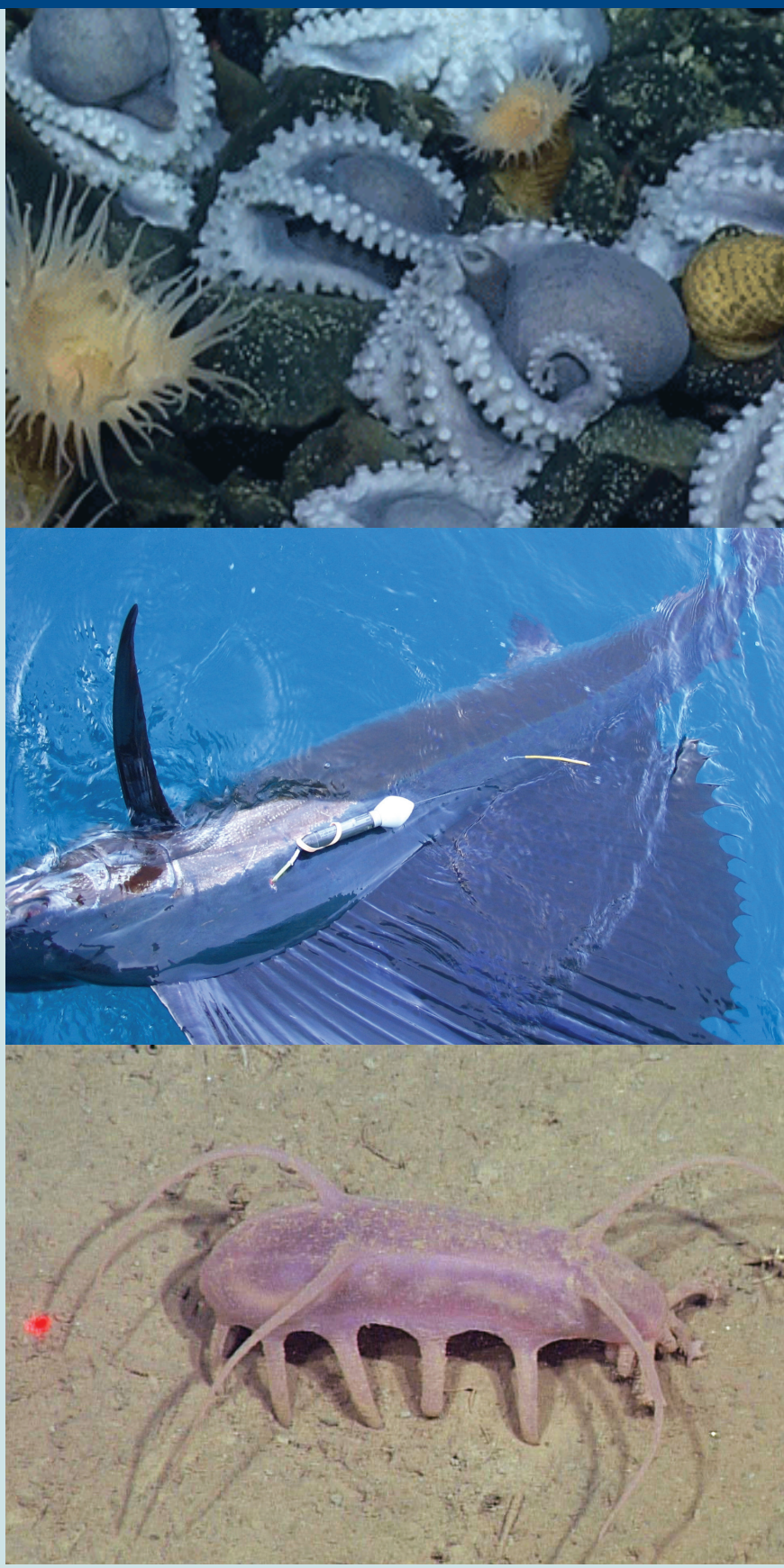

Top: Deep-sea octopuses discovered near Davidson Seamount at 3300 meters. Photo Credit: Ocean Exploration Trust/NOAA. Middle: Tagging and placing tracking device on large billfish. Photo Credit: Derke Snodgrass. Bottom: Scootplanes globosa sea cucumbers on the seafloor at Station M off the Central California Coast. Photo Credit: © 2015 MBARI

A North Puget Sound gray whale (one of the Sounders) taken off of Everett, Washington. Photo Credit: Ian Flynn-Thomas, Cascadia Research Collective (NMFS Scientific Research Permit #21678 to John Calambokidis)