

NOAA Technical Memorandum NMFS



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TOWARD A NATIONAL ANIMAL TELEMETRY OBSERVING NETWORK (ATN) FOR OUR OCEANS, COASTS AND GREAT LAKES: WORKSHOP SYNTHESIS REPORT

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**U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
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NOAA Technical Memorandum NMFS

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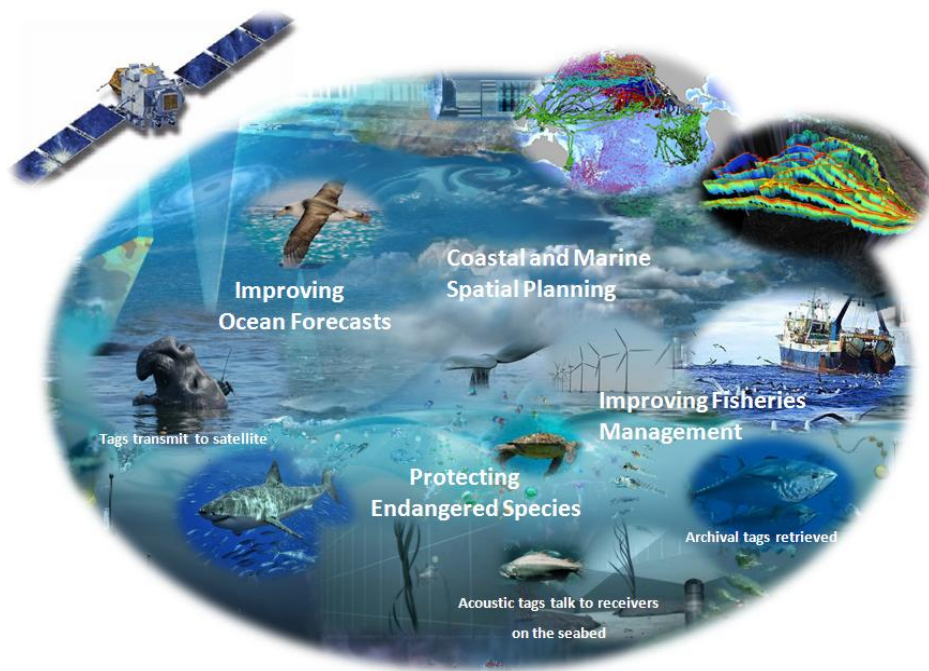
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***Toward a National Animal Telemetry
Observing Network (ATN)
for our Oceans, Coasts and Great Lakes:
Workshop Synthesis Report***



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1. EXECUTIVE SUMMARY

The new National Ocean Policy (NOP) calls for strengthening our capacity to observe the nation's oceans, coastal waters and Great Lakes. The U.S. Integrated Ocean Observing System (U.S. IOOS), a NOAA-led national partnership, is providing a framework for the integration of ocean, coastal, and Great Lakes observing capabilities.

The development of the ocean observing system began with an effort to integrate physical and chemical data on the oceans, and currently an important near-term goal of IOOS is to increase the amount of biological data in the observing system. One valuable addition to the existing US ocean observing capabilities is animal telemetry observations. Animals are often sensitive indicators of environmental trends, and a wide variety of federal, state, tribal, academic and private organizations routinely collect animal telemetry data. Until now, telemetry data have mostly been used in a research context, but in recent years the scale of telemetry activities has greatly increased, and there are now a number of self-organized regional networks making concerted efforts to make these data into an operational part of the ocean observing system. Inclusion of biological resources will provide a science-based source of information critical to advancing most of the National Ocean Policy priority objectives, particularly Ecosystem-Based Management and Coastal and Marine Spatial Planning.

With the goal of establishing a sustainable U.S. Animal Telemetry Observing Network (ATN) and linking observations from this network to the National Ocean Observing System, U.S. IOOS and the NOAA Southwest Fisheries Science Center convened a two-day workshop in March 2011. Through plenary and breakout sessions, workshop participants identified major challenges, opportunities, and “customers” for animal telemetry data. Workshop participants also generated recommendations for implementing an ATN (listed below) and identified potential roles for U.S. IOOS to coordinate the integration of animal telemetry observations into the U.S. IOOS.

The group consensus was that an observing system that monitors animals on a range of temporal and spatial scales will yield both short and long-term benefits, fill knowledge gaps and advance many of the NOP Priority Objectives identified by the Interagency Ocean Policy Task Force (OPTF).

Recommendations

1. Make animal telemetry data and products available to advance National Ocean Policy Priority Objectives.
2. Improve data standards, management, and sharing capability.
3. Collaborate more closely with industry on tag identification coding management, and manufacturing standards.
4. Promote development of new animal telemetry technology.
5. Bring permanence and sustainability to a national network of assets used for biological monitoring.
6. Document and coordinate priority deployment of animal telemetry assets.
7. Expand animal telemetry outreach and education programs.
8. Plan and execute a collaborative project to demonstrate the utility of the ATN to the fisheries and habitat management communities.

2. INTRODUCTION

On July 19, 2010, President Obama signed Executive Order 13547 establishing a National Policy for the Stewardship of the Ocean, our Coasts, and the Great Lakes. That Executive Order adopts the Final Recommendations of the Interagency Ocean Policy Task Force¹ and directs Federal agencies to take the appropriate steps to implement them. The final recommendations call for strengthening the nation's capacity to observe the nation's oceans, coastal waters and Great Lakes. The Integrated Ocean Observing System, IOOS[®], established by law in March of 2009 and referred to in the statute as the Integrated Coastal Ocean Observing System, provides the framework for developing this capacity. The Act establishes federal-regional partnerships for understanding the unique characteristics of the nation's diverse regions, integrating existing information from federal and non-federal sources, and expanding the observation network to fill critical gaps, enhance analyses and understanding, and improve predictive and forecasting capabilities² (Figure 1).



Figure 1. Conceptual model of an Integrated Ocean Observing System². Improved access to integrated ocean information is increasing our ability to understand and predict coastal events, climate change, and ecosystem changes. Graphic: Glynn Gorick for UNESCO Intergovernmental Oceanographic Commission.

Presently, autonomous platforms are the backbone of the National *in situ* ocean observing system. The core mobile platforms include: (1) the Argo array of profiling floats which sample a large fraction of the global ocean, (2) ocean gliders which provide high resolution spatial and temporal sampling in boundary currents, marginal seas, and water mass formation areas.

In the last 25 years, technological advances have made it possible to use animals as platforms to carry remote-sensing devices (i.e. Animal Telemetry). Large animals such as sharks and marine mammals can carry sophisticated tags that sample the environment and report to satellites. In cases where animals return to predictable haul out sites or where recapture rates are high (example, tuna caught around fish aggregation devices – FADs) the tags can be recovered and the entire archived data downloaded. More recently, the decreasing size of acoustic transmitters provides a mechanism to monitor the movements of smaller individuals over great distances using networks of underwater receivers. These developments provide unprecedented insights into the habitat usage patterns of animals helping to revolutionize the way the ocean is sampled and is leading to a partnership between physical oceanographers and biologists³. Animal telemetry complements gliders and other autonomous vehicle products to provide unique data for resource management and ocean modeling and analysis that address Interagency Ocean Policy Task Force's National Ocean Policy Priority Objectives (see Appendix D) as detailed below.

Animal telemetry is defined as the processes of obtaining data remotely and storing it for later retrieval and/or transmittal via satellite or acoustics. Animal telemetry can be conducted in real time (e.g., to track the movements of animals using either acoustic or radio transmissions) or in 'archival mode' wherein tracks are reconstructed from archived data that are either transmitted on a time-delayed basis to satellites or obtained when the animal is recaptured and the tag retrieved. By and large, it is the archival mode that underpins the ability of animals to sample and store information about the characteristics of the water through which they are swimming. The fields of telemetry include number of research approaches, from simple radio or acoustic tags that allow researchers to relocate

telemetered individuals, to complex systems that record and transmit data from multiple environmental sensors. Recent advances in miniaturized sensors, computing power, microprocessors, and global telecommunication systems have provided extraordinary insights into aquatic animal ecology as well as information on their physical and biological environment, such as SST, chlorophyll and salinity that help to identify ocean fronts, eddies and other important features⁴.

Animal telemetry makes it possible to record the fine-scale behavior of individuals for, in some cases, years in the most remote regions of the world's oceans. Animals can provide vertical oceanographic profiles throughout the upper 1000 m of the water column and can travel to regions that are relatively inaccessible to other ocean observing technology, such as the polar oceans beneath seasonal or permanent sea ice⁵ or remote atolls such as those in the Northwest Hawaiian Islands. This technology allows researchers to investigate how animals use their three-dimensional world, quantify important physical and biological aspects of their environments, test potential conservation measures designed to mitigate the effects of adverse human activities and improve ocean forecasting systems that depend to a large extent on reducing ocean model initial condition errors. Animal telemetry continues to develop rapidly, fueled by continuing advances in technology, miniaturization, and data processing⁶, as well as through innovative use of existing technology such as using large marine mammals as mobile acoustic receivers to track smaller tagged animals⁷.

Animal telemetry technologies already have been important in improving fisheries management and conservation. For example, tag-derived movement data helped improve management of Atlantic bluefin tuna and conclusively delineating stock structure⁴. Additional distribution and migration data from other taxa has been overlaid on oceanographic data to develop predictive mapping tools that help the US Navy avoid endangered whales and Central Pacific longline fishers minimize bycatch of protected loggerhead sea turtles (Figure 2)⁸. On the West coast of North America, discoveries about the unexpectedly large extent of green sturgeon movements were used to designate federally-mandated critical habitat for the ESA listed (threatened) southern stock⁹. Similarly, animal telemetry has revealed information critical to salmon conservation in

west coast river systems, e.g., that outmigrant smolt survival through the Columbia River hydropower system was better than previously believed, and that survival through the Sacramento River basin was uniformly poor throughout the river as opposed to concentrated in the river delta^{10,11,12}.

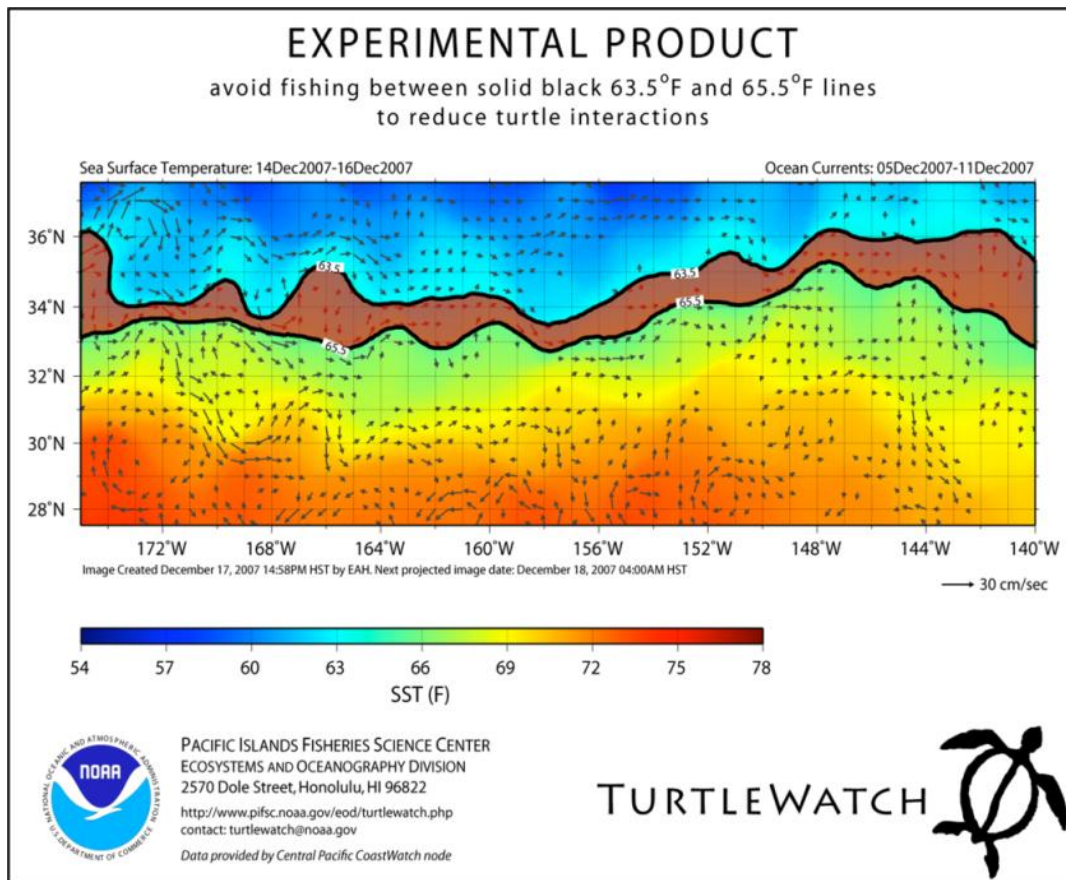


Figure 2. Predicted range of Endangered loggerhead turtles. This is an example of a near-real-time product designed to assist commercial fishers in avoiding bycatch in the Pacific longline fishery⁸. The predicted range of the turtles varies with oceanographic conditions, and a detailed knowledge of loggerhead behavior from tagging makes this product possible.

Animal telemetry programs are conducted in almost all US regions (Figure 3, Table 1 and Appendix C) and species tagged range from from 20-gram salmon smolts to 150-ton whales.

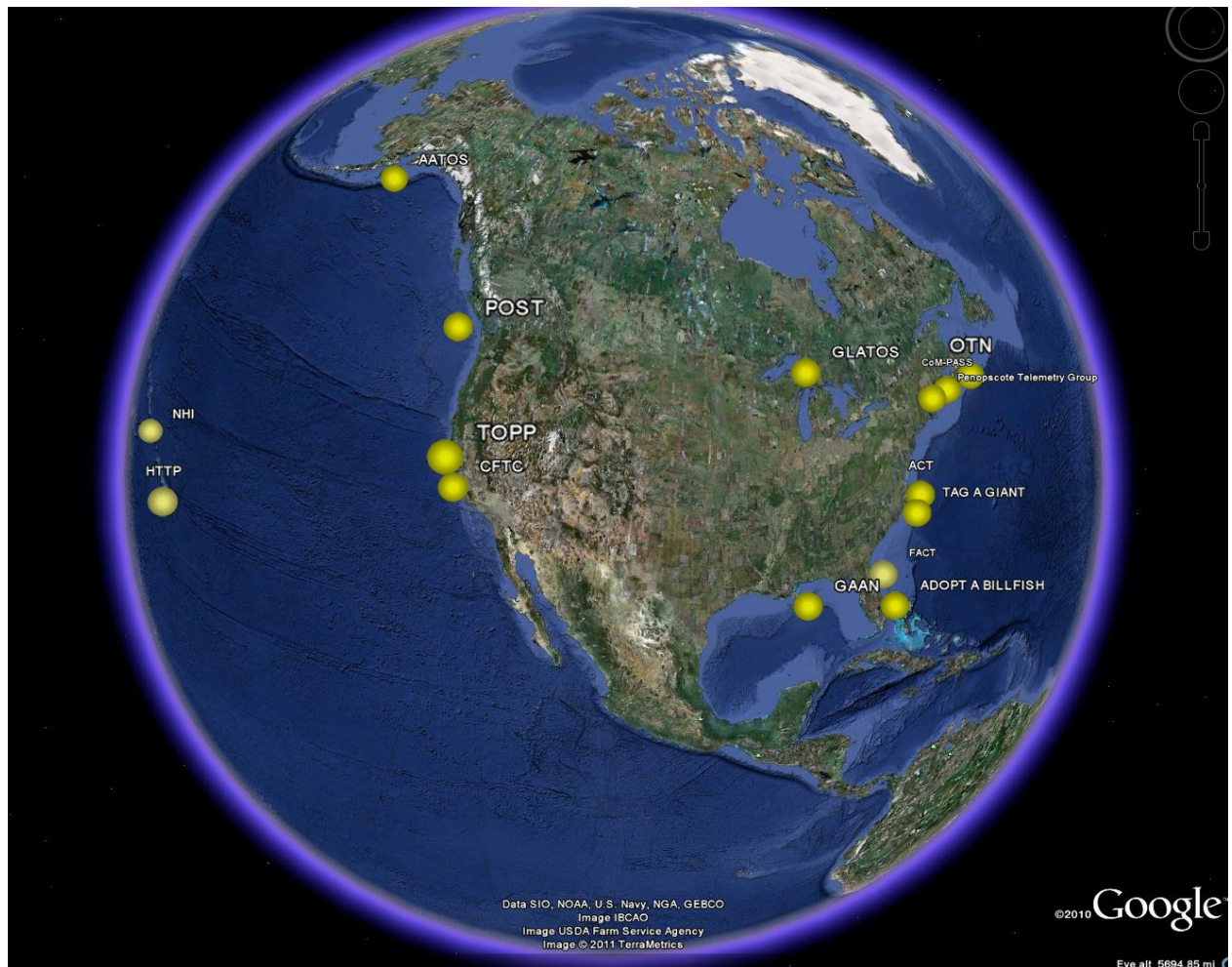


Figure 3. Animal Telemetry programs/projects in North America (yellow dots).

Table 1. A list of the large-scale Animal telemetry programs/projects in North America that were represented at this workshop.

Atlantic Arena

Coast of Maine Passive Acoustic Sensor System (CoM-PASS)
Penobscot Telemetry Group
Atlantic Cooperative Telemetry Network (ACT)
Florida Atlantic Coast Telemetry Project (FACT) ¹³
Adopt a Billfish¹⁴
Tag A Giant Foundation¹⁵

Pacific Arena

California Fish Tracking Consortium (CFTC) ¹⁶
Northwest Hawaiian Islands array
PacIOOS array
Hawaii TunaTagging Project (HTTP)

Large scale Census of Marine Life (COML)¹⁷ projects:

Tagging of Pacific Pelagics (TOPP) ¹⁸
Pacific Ocean Shelf Tracking (POST) ¹⁹

Gulf of Mexico

Gulf of Mexico – wide Acoustic Array Network (GAAN)

Great Lakes

Great Lakes Acoustic Telemetry Observing System (GLATOS)

Alaska

Alaska Animal Telemetry Ocean Observing. (AATOS)

Internationally funded project

Ocean Tracking Network (OTN) ²⁰

An example of a large-scale telemetry program is the Tagging of Pacific Pelagics (TOPP) program, which has deployed over 4,500 electronic tags on sharks (mako, blue, thresher, salmon and white sharks), elephant seals, California sea lions, bluefin and yellowfin tuna, whales, leatherback turtles, squid, black-footed and Laysan albatross, sooty shearwaters humpback and blue whales, and loggerhead and leatherback sea turtles (Figure 4). Animal tracks are overlaid on remotely sensed satellite imagery of oceanographic features, which help define the environmental attributes of biological “hot spots” and provide insights into areas of high biodiversity ^{3,4}.

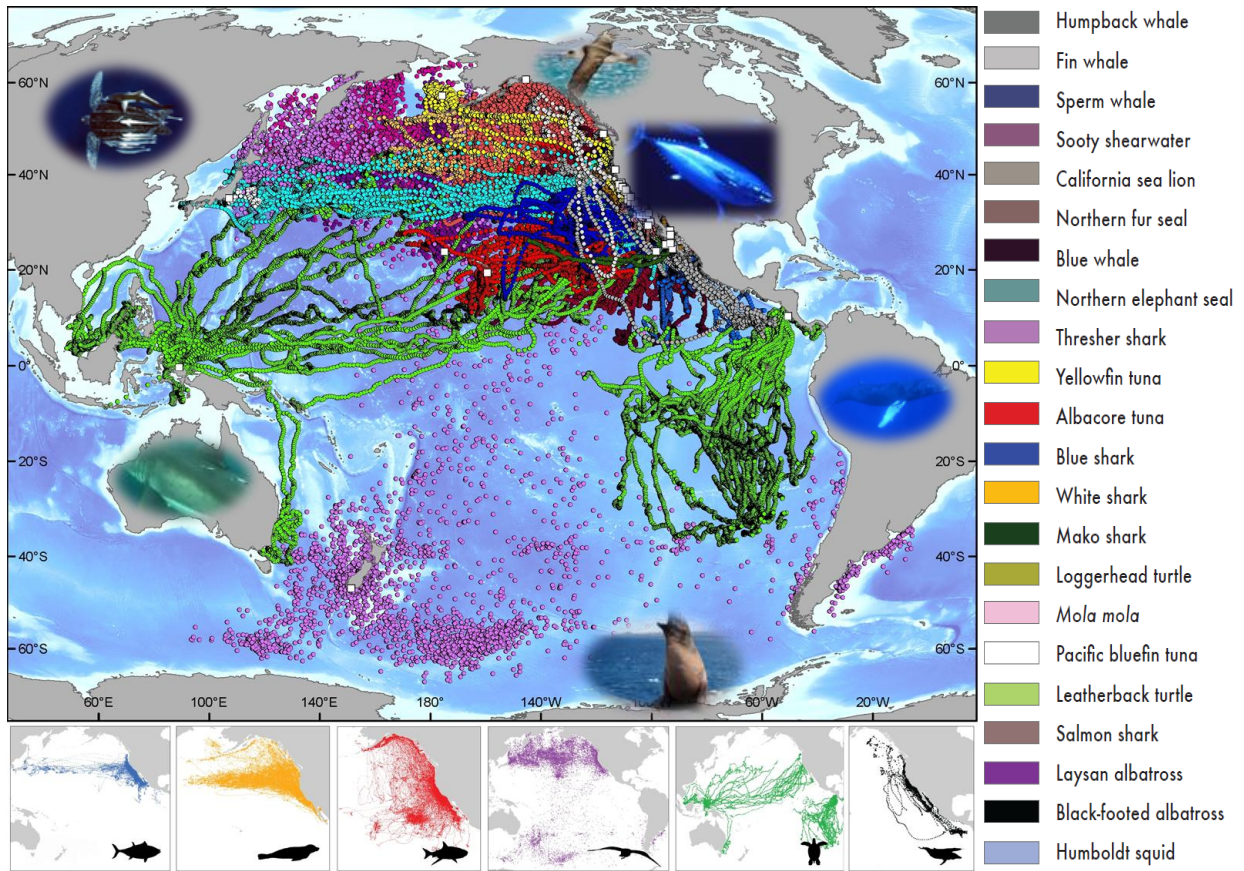


Figure 3: TOPP Program¹⁸ animal tracks from >4500 individual birds, fish, whales, and other others from 2000-2010. The tracks show areas of overlap, common habitat utilization and “biological hotspots” in the vast Pacific Ocean.

In 2010, it became clear to U.S. IOOS managers that the animal telemetry community had reached a critical tipping point. The geographical scale of activity in the telemetry community and the extensive efforts at self-organization and data sharing put it in a position where a relatively small amount of support could bring a large amount of valuable data into the U.S. IOOS network. Inclusion in U.S. IOOS would make the data available to a far larger community of national users and would help to jump-start U.S. IOOS’s biological observing capacity. In fact, fish telemetry is an integral component of the PacIOOS project.

To facilitate the development of an animal observing system a group of 40 scientists and technical managers, including program leaders from several of the largest telemetry programs including TOPP, POST (Pacific Ocean Shelf Tracking Program), OTN (Ocean Tracking Network), as well as senior scientists from NOAA Fisheries, U.S. IOOS, and other federal, state, academic and industry organizations gathered for two days in Santa Cruz, California. Their goal was to focus on providing a framework to develop a sustainable U.S. Animal Telemetry “Network” of observations and link these activities to the U.S. IOOS (See Appendix A, the Workshop agenda). Details on these discussions and the recommendations are contained in the body of this report. A major finding was that the animal telemetry technology has proven to be routinely operational and is ready to incorporate to the National Ocean Observing System. Significant coordination and resources are needed to establish regional networks towards and integrated sustainable U.S. Animal Telemetry Observing Network.

3. TOWARD A NATIONAL ANIMAL TELEMETRY OBSERVING NETWORK.

3.1. Workshop format

In October 2010, IOOS invited a Steering Committee of six academic and federal scientists to develop a national workshop for exploring the concept of integrating telemetry data into the US IOOS. The format included presentations of the current status of telemetry projects from all United States regions, plenary discussions to synthesize findings and small breakout groups to identify major challenges, opportunities, customers for telemetry data, and potential roles for U.S. IOOS in coordinating a national animal telemetry “Network.” The workshop was attended by 40 scientists and computer programmers, representing all U.S coastal regions including the Great Lakes: (Appendix B, workshop participants). The meeting was hosted by NOAA Fisheries Southwest Fisheries Science Center laboratory in Santa Cruz, California. Representatives from two telemetry companies (VEMCO, AMIRIX Systems Inc and LOTEK, Ltd) also participated in plenary and breakout sessions as observers.

3.2. Workshop findings

Breakout groups identified challenges, opportunities, customers and roles of U.S. IOOS towards a coordinated U.S. Animal Telemetry Observing Network identified by workshop participants who responded to a survey prior to the meeting (See Appendix E).

The breakout group outcomes indicated that several challenges exist including: visibility and congressional interest, program funding, data standards and data sharing (unified sharing agreement), identification of available animal telemetry assets and fostering collaboration among research groups in the animal telemetry community. However, there are many opportunities noted by the participants. For example, 1) cyber-infrastructure for archiving and displaying telemetry data has been developed by other programs (i.e. POST, TOPP and OTN) which could be integrated with existing U.S. IOOS protocols; and 2) sharing data products of value to ecosystem based management, resource conservation, military and commercial operations.

An ATN will be critically useful for identification of sensitive “hot spot” areas, high value ecosystems and ecosystem benefits created by Marine Protected Areas (MPAs). For example, TOPP identified an area that is important to loggerhead sea turtles off the coast of Baja California, which was later established as an MPA to protect them ²¹. Additionally, an ATN will help conservation and management of living resources. For example animal telemetry data showed that “shark tourism” operations do not increase risk to coastal ocean users and also have no permanent impact on the behavior of sharks that associate with the tourism sites, which helped the Hawaiian legislature decide not to impose a ban on shark tourism operations ²². Similarly, shark telemetry data caused state agencies to adopt a policy of not culling sharks following shark attacks in Hawaii ²³.

The breakout groups identified several major “customers” of animal telemetry, including: 1) Federal and state agencies; 2) the fisheries conservation and management community; 3) tribal communities; 4) the energy sector, 5) the tourism sector; 6) the general public; 7) educational institutions; 8) private industry and 9) the research community.

The breakout group also synthesized a list of suggested animal telemetry activities that link closely to NOP nine priority objectives (Box. 1).

Box 1. List of ATN activities that link closely to NOP nine priority objectives

1. Ecosystem-Based Management:

- a. Provide the scientific basis for ecosystem-based management (EBM).
- b. Identify ecosystem indicators useful to enable Integrated Ecosystem Assessment and to measure progress towards achieving management goals.
- c. Investigate regional connectivity of resources and integrate ocean observation systems across the region.
- d. Improve oceanographic models, which provide understanding of ecosystem processes and enable prediction of future ecosystem conditions.
- e. Provide near-real-time geospatial data that are integral to realistic parameterization of spatially explicit population and fishery assessment models, and for assessing the habitat requirements of harvested and protected species as it relates to conservation of species and the maintenance of biodiversity.
- f. Provide retrospective data that are useful for understanding the scale of natural variation, identifying human impacts, and predicting future changes.
- g. Monitor and mitigate the impacts of management strategies including protected areas and fisheries regulations.

2. Coastal and Marine Spatial Planning.

- a. Define essential fish habitat (EFH) – this is relevant to many aspects of fisheries management and the design and evaluation of MPAs. On a larger scale, these studies can inform managers about the geographical range and seasonality of the stocks they are charged with managing.
- b. Establish baseline habitat usage studies on potential sites of future anthropogenic disturbance (e.g. aquaculture sites, energy development, military activities, shipping, sewage treatment facilities, and marina development)

- c. Develop maps of sensitive “hot spot” areas and high-value ecosystems, which can be crucial for identifying regions that may warrant special protection status and creation of MPAs to protect critically endangered species and conversely identify development corridors where impacts would be reduced.
 - d. Monitor effectiveness of a MPAs and Special Management Zones (SMZs).
 - e. Identify early warning system- sentinel animals.
3. Inform Decisions and Improve Understanding.
- a. Inform near real time management of fisheries, and management of bycatch of non-target species.
 - b. Improve stock assessments: provide spatial and temporal refinement of natural mortality and harvest susceptibility.
 - c. Link needs of customers (e.g. stock assessments) with end products early in the process .
 - d. Education and outreach:
 - i. From recreational fishers to conservationists animals offer a unique opportunity to catch the attention of the public and educate them about the value and importance of ocean observation.
 - ii. Popular and useful educational products have been created for grades K-12 with telemetry and tracking data.
4. Coordinate and Support
- a. Existing animal telemetry programs and protocols can be leveraged to monitor movements of animals and to collect environmental observations.
 - b. Provide predictive mapping tools and real time data to marine transportation and the US military to avoid endangered species (e.g. protecting whales from ship strikes and sonar).
 - c. The partnership between physical oceanographers and biologists is invaluable for developing a mechanistic understanding of ecosystem structure and function.
5. Resiliency and Adaption to Climate Change and Ocean Acidification

- a. There is a large degree of uncertainty regarding the impacts of ocean warming and acidification and its impact on fishes which provide significant levels of protein globally. Animal telemetry directly measures the response of animals to oceanographic changes, and as such it is extremely important at this delicate moment in the history of the oceans.
 - b. Animal telemetry provides environmental observations (temperature and salinity profiles) from the sea-ice zone and hard-to-reach areas where conventional oceanographic sensing techniques are technologically or economically unfeasible.
 - c. Animal telemetry can provide the foundation for modeling habitat changes in relation to environmental variability.
 - d. Animal telemetry can improve our documentation of natural mortality rates and thereby increase the predictability of boom-bust cycles in the abundance of living marine resources, which is critical to the harvesters and communities that rely on them.
 - e. Animal-carried environmental sensors can identify foraging habitats, migration corridors, and regions of high occupancy, providing critical knowledge about how variable components of marine habitat influence distribution, survival, growth, and reproduction of organisms.
6. Regional Ecosystem Protection and Restoration
- a. Provide baseline habitat usage information of animals to protect and restore damaged essential habitats (e.g. Gulf of Mexico, Alaska).
 - b. Identify sensitive areas that could serve to protect endangered species.
 - c. Prediction of habitat use by animal sentinels: toxic harmful algal blooms and influence on survival.
7. Water Quality and Sustainable Practices on Land
- a. Animal Telemetry can reveal how environmental factors drives animal distributions in nutrient enriched estuaries and coastal areas, to better

understand the impact of the large low-oxygen zones that are now routinely observed off the West coast of US.

- b. Animal Telemetry has been intensively used to gain a better understanding impacts of hydropower dams, water extraction and other freshwater habitat alterations on anadromous fish movements and behavior.

8. Changing Conditions in the Arctic

- a. There are large uncertainties in the rate at which global warming is affecting the polar oceans. Animal-borne environmental sensors can access to remote and difficult areas including pack ice which could provide observations from remote Arctic areas that will increase the availability of temperature and salinity profiles from the sea-ice zone.

9. Ocean Coastal and Great Lakes Observations Mapping and Infrastructure

- a. Integration of animal telemetry assets with U.S. IOOS will mean more observations and more capability of our National Observing System to provide high resolution biological and geo-physical observations key to advancing OPTF NOP Objectives and particularly EBM and Coastal Marine Spatial Planning.

4. RECOMMENDATIONS

Developing, supporting, and educating an integrated approach to the measurement, storage and display of animal and telemetry data gathered by private, academic, local, state and federal institutions will strengthen our national ocean observing capabilities. Stronger ocean observing capabilities will augment our knowledge and understanding of ocean ecosystems and our ability to engage in science-based decision-making and ecosystem-based management. A central goal of the workshop was to discuss options on how to best establish a National Animal Telemetry “Network” (ATN) capable of meeting the challenges of the 21st century for resource management and ocean forecasting.

The workshop generated recommendations and actions items necessary to implement an ATN, as well as identifying the potential role of U.S. IOOS for integrating animal and telemetry observations (Box 2.). Specifically:

1. Synthesize and make animal telemetry products available to advance NOP Priority Objectives. The analytical products derived from animal telemetry data have typically been generated in response to particular local or regional research or management needs, and reside with different groups. The workshop participants recommended that ATN should identify and facilitate synthesis of these products that are relevant to advancing NOP priority Objectives (e.g. undertake a synthesis of products across species and trophic levels relevant to EBM).
2. Improve data management, standards and data sharing capability.

Although significant advances have been made in animal telemetry data management and several large telemetry databases are publicly available online, there are still obstacles in coordinating data sharing among programs. Animal telemetry data that were tailored to the individual missions of those who fund them reside in dozens of federal and state agencies, universities, and private entities. These data are complex and there is no universally agreed upon set of standards for telemetry metadata. The workshop participants strongly agreed that to avoid isolated, individual systems and duplication of efforts, we should foster broad development of common standards and formats that will enhance data sharing. There was also a strong agreement that centralized data management is necessary to allow flexibility in data access, quality control and exploration. The word ‘centralized’ does not connote having all data in one physical location; in fact that is unnecessary and undesirable. The attendees agreed that it was important to leverage existing standards and protocols to advance data sharing and data access. Among other benefits, having those standards and protocols would make a centralized portal possible. The community places a high priority on making animal telemetry data (particularly physical observations by animal oceanographers) accessible in near real time via Global Telecommunications System (GTS). Sharing and maintaining data will help avoid duplication of efforts and ensure data are compatible and accessible for analyses and assimilation by computer models. Better

access to animal telemetry information will improve our ability to provide accurate forecasts and inform ecosystem based coastal and marine spatial planning. This recommendation is key to advancing National Ocean Policy Objective 9-Infrastructure.

3. Collaborate with industry on tag identification and coding management and recommend manufacturing standards.

As the scale of acoustic telemetry has increased, the availability of unique tag IDs has become critical. Some of the early coding schemes had a relatively small number of spaces that have already been exhausted, and difficult to manage. In addition, a handful of other manufacturers reverse engineered the older coding schemes with no visibility into the tag database which threatened to cause duplicate IDs (two or more animals carrying the same ID) which would jeopardize the integrity of all participants' research. Therefore, the workshop participants recommended working closely with industry to develop coding schemes to improve error correction and strong encryption to protect against cloned duplicate tag IDs. This coding scheme could also increase the number of tag ID numbers available, enabling larger tagging studies and maximization of data sharing. Working with industry would also facilitate upgraded and new receiver technology. This will advance NOP objective 4-Coordinate.

4. Promote development of new technology.

The workshop participants recommended investment in development of new sensors (e.g. oxygen and pH sensors) in response to growing concerns about the potential impacts of ocean acidification and hypoxia on marine biological resources and the health of marine ecosystems. This will advance NOP objective 9-Infrastructure. Developing transmitters that facilitate animal to animal communication of data would open up new horizons in understanding ecosystem connectivity.

5. Bring permanence and sustainability to a national network.

Workshop participants emphasized that a successful ATN will not be possible without sustained long-term support for maintenance and deployment of new technology to continue providing continuous biological and geophysical observations critical to advancing NOP objective 9-infrastructure.

6. Document and coordinate priority deployment of animal telemetry assets.

Currently, there is a diverse set of animal telemetry projects taking place throughout the country with different local and regional objectives. The workshop participants represented several large, long-running, and most active telemetry programs in the US, but there are many additional independent telemetry projects around the US that are unaffiliated or only loosely affiliated with the programs that were represented in the meeting. To design a ATN and to integrate with the National Ocean Observing System, the workshop participants recommended that an inventory of the National Animal Telemetry capacity should first be conducted. This inventory will help identify the gaps and optimize the system to address the National objectives. There was much discussion at the meeting of IOOS RA helping provide a structure and venue to bring telemetry community together. This recommendation will advance NOP objective 4-coordinate and 9-infrastructure.

7. Expand animal telemetry outreach and education programs.

Animals are a way to foster a public understanding of the value of the ocean, coasts and the ocean observing systems. The workshop participants recommended that funding should be given to support building products for K-12 with animal and telemetry data. Aquariums offer great opportunities to expose the public to this initiative through education programs and by exhibiting tracks of tagged animals in near real time.

8. Plan and execute a demonstration project in a short time frame.

The process can be initiated by developing a project to demonstrate the utility of the ATN to the fisheries and habitat management communities. The project should preferably leverage existing programs and infrastructure that are well developed. This demonstration project could be realized by a targeted call for proposals for telemetry projects that federal and state resource management agencies indicate would advance the science supporting management policy. This will advance most of the NOP objectives.

Box 2. Roles of U.S. IOOS to coordinate an ATN

- Take the lead on bringing animal data into our national ocean observing system. Begin a dialogue with telemetry data managers from all the regions on how to integrate various types of data, how to begin to understand issues such as data quality standards, interchangeability, and portability. Also, lead a discussion of data sharing guidelines and metadata standards.
- Encourage IOOS Regional Associations to support tagging/telemetry components that could address resource management and spatial planning issues pertinent to their regions.
- Facilitate the organization of local animal telemetry arrays into confederated regional arrays and establish animal telemetry assets in a super-region in collaboration with U.S IOOS regional associations.
- Engage government agencies (as the lead on an interagency effort) to support funding for some of the assets of the ATN.
- Organize the first Super-Regional and National meetings to establish and implement the ATN .
- Establish an inventory of current national telemetry capacity
- Promote development of new sensors (the animal community sees a need for O2 and pH sensor development)

Toward a National Animal Telemetry Observing Network

- Establish rapid sharing of data and data management infrastructure by leveraging existing resources
- Facilitate communications between regional telemetry efforts, and hold regular meetings of the national telemetry community. This will help in many ways, including identification of shared problems and solutions.
- Facilitate delivery/access of animal telemetry data (geo-physical data) through GTS.
- Collect and display telemetry products including publications, data visualization or decision-support tools and other software that may have wide applications.
- Coordinate deployment and maintenance of coastal and ocean arrays
- Support maintenance of infrastructure (possibly in-kind support of ship time)
- Lead education and outreach programs
- Underwrite sessions at various symposia to foster exchange between biologists and physical oceanographers and biologists and regional planners.
- Establish telemetry representatives on the Data Management and Communication (DMAC) steering committee and DMAC Regional Association Data management workshops.

5. REFERENCES AND WEBSITES CITED

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Acknowledgements

This workshop was supported by U.S IOOS and hosted by NOAA Fisheries Southwest Fisheries Science Center in Santa Cruz California. We thank the Steering Committee and the participants of the workshop who all contributed to the success of this work. Special thanks to Daniel Costa, Ron O'Dor and Richard Vallee for the helpful comments they provided on an earlier draft of this report.

6. APPENDICES.

A. Workshop Agenda

IOOS ANIMAL TELEMETRY OBSERVING WORKSHOP AGENDA

NOAA Fisheries - Southwest Fisheries Science Center/
Fisheries Ecology Division, 110 Shaffer Road Santa Cruz, CA

March 2-3, 2011

GOAL: To focus on how to establish a sustainable U.S. Animal Telemetry Network (ATN) of observations and link these activities to the U.S. Integrated Ocean Observations System (IOOS)

Objectives:

- *Identify existing animal telemetry observing in US regions*
- *Identify Challenges/Opportunities (common/ unique)*
- *Identify Customers of animal telemetry data/products*
- *Identify US IOOS roles to coordinate Animal Telemetry Community*
- *Examine options for establishing a National Telemetry Network*

Wednesday, March 2nd

8:00 am **Assemble/Breakfast**

8:30 **Opening Remarks/Welcome**
Churchill Grimes (NOAA/SWFSC), Hassan Moustahfid (NOAA/US IOOS)

8:45 **Introduction to Workshop Goal/Objectives**
Charly Alexander & Hassan Moustahfid (NOAA/US IOOS)

9:15 **U.S. Animal Telemetry Observing Programs/Projects – A Review**
(10 minutes per presentation)

- US Northeast/ NERACOOS Region (John Kocik, NOAA)
- Mid-Atlantic/ MARACOOS (Dewayne Fox, ACT)
- US Southeast and Caribbean/SECOORA/CARA (Eric Prince, NOAA)
- Gulf of Mexico/GCOOS (Behzad Mahmoudi, FWC/FWRI)
- Great Lakes/GLOS (Christopher Holbrook, USGS Via Webex)

Toward a National Animal Telemetry Observing Network

- 10:00 **Break** (coffee, etc.)
- 10:15 ***U.S. Animal Telemetry Observing Programs/Projects (continued)***
- US Southwest/SCCOOS and CeNCOOS (Sean Hayes NOAA)
 - Northwest/NANOOS (John Ferguson, NOAA)
 - Mid Pacific/Hawaii/PacIOOS (Kim Holland, UH/HIMB)
 - Alaska/AOOS (Andy Seitz, UAF)
 - TOPP (Barbara Block, Stanford Univ)
 - POST (John Payne UW)
 - OTN (CoML/Dalhousie Univ)
 - Questions/Discussion
- 12:00pm **Break for lunch**
- 1:00 pm **Introduction to Discussion Phase of Meeting** (Church/Hassan)
- 1:10 **1. Major Challenges and Opportunities Across Regions
(Common/Unique)**
(Barbara Block, John Payne)
- 1:40 Breakout Discussions – Two Groups
- 2:40 Breakout reports/discussion
- 3:00 Break
- 3:30 **2. Customers of Animal Telemetry Data & Products**
(Kim Holland, Dewayne Fox)
- 4:00 Breakout Discussions – Two Groups
- 5:00 Breakout reports/discussion
- 5:30 **Adjourn**
- 6:30 **Group Dinner** – Santa Cruz (location TBD)

Thursday, March 3rd

- 8:00 am **Breakfast**
- 8:30 **Zdenka Willis, U.S. IOOS Director - Remarks, Q&A**
- 9:00 **3. Role for U.S. IOOS in coordination of a National Animal Telemetry
Observing “network”** *(Charly, Church, Hassan)*
- 9:30 Breakout Discussions – Two Groups
- 10:30 **Break**
- 10:45 Breakout reports/discussions

- 11:15 **4. Options for Establishing a National Telemetry Network**
(Church Grimes, John Kocik)
- 11:45 **Break for lunch**
- 1:00pm Breakout Discussions – Two Groups
- 2:00 Breakout reports/discussion
- 2:30 **Identify Action Items and Next Steps**
(Church/Charly/Hassan)
- Possible Time Line for some next steps:
- May-June 2011: Workshop Synthesis posted
 - June-September 2011 – Workshop Summary/Product Presented to NOAA Leadership, Article in journal (e.g. Bioscience, Fisheries, MTS, etc.)
- 3:00 Wrap-Up/Closing Discussion
- 3:30 Adjourn Workshop
- 4:00 Steering Committee Meeting – Workshop Synthesis
- 5: 00 Adjourn Steering Committee

B. Workshop participants



Workshop Participants

Name	Affiliations
Andy Seitz	University of Alaska Fairbanks
Barbara Block (SC)	Tagging Of Pacific Predators (TOPP)
Behzad Mahmoudi	Gulf of Mexico regional ocean observing system (GCOOS)
Bruce MacFarlane	NOAA.Fisheries/SWFSC
Charles Alexander	NOAA//IOOS
Christopher Holbrook	U.S. Geological Survey/Great Lakes (via WebEx)
Churchill Grimes (SC Chair)	NOAA Fisheries/SWFSC-Santa Cruz
Dan Costa	University of California, Santa Cruz
Dan Rudnick	Southern California Coastal Ocean Observing System (SCCOOS) (via WebEx)
Dewayne Fox (SC)	Delaware State University/Atlantic Cooperative Telemetry Network (ACT)
Doug Wilson	NOAA Chesapeake Bay Office (via WebEx)
Eric Prince	NOAA.Fisheries/SEFSC
Hassan Moustahfid	NOAA/IOOS
Heather Kerkering	Central and Northern California Ocean Observing System (CeNCOOS)
Jan Newton	NANOOS (via WebEx)
Jason Smith	IOOS/Alliance for Coastal Technologies (ACT)-Pacific Coast
Jim Bolger	POST/Vancouver Aquarium
John Kocik (SC)	NOAA. Fisheries/ NEFSC-Maine
Jim Bolger	Pacific Ocean Shelf Tracking (POST)
John Payne (SC)	Pacific Ocean Shelf Tracking (POST)
John W. Ferguson	NOAA/NWFSC
Julia Stewart	Stanford University
Kim Holland (SC)	Pacific Islands Ocean Observing System (PacIOOS)
Larry Egan	Lotek wireless, inc
Mark Fornwall	USGS
Michael Feldman	US Census of Marine Life
Michael Weise	Office of Naval Research/MMB (by WebEx)
Rebecca Shuford	NOAA. Fisheries-Silver Spring
Richard Vallee	Vemco , AMIRIX Systems, Inc
Ron O'Dor	CoML/Ocean Tracking Network (OTN)
Scott Miehl	Great Lakes Fishery Commission

Toward a National Animal Telemetry Observing Network

Sean Hayes	NOAA Fisheries/SWFSC-Santa Cruz
Sean Powers	Gulf of Mexico regional ocean observing system (GCOOS)
Shane St. Clair	Alaska Ocean Observing System (AOOS)
Steve Lindley	NOAA Fisheries/SWFSC-Santa Cruz
Steven Bograd	NOAA Fisheries/SWFSC-Pacific Grove
Tom Grotheus	Rutgers University/Institute of Marine and Coastal Sciences
Tom Wadsworth	Central and Northern California Ocean Observing System (CeNCOOS)
William Gilly	Stanford University
Zdenka Willis	NOAA/IOOS

C. Animal Telemetry Programs and Projects

Tagging of Pacific Pelagics (TOPP)

Barbara Block et al. Stanford Univ, Hopkins Marine Station

Background

The Tagging of Pacific Pelagics (TOPP) research program is a collaboration among scientists from the U.S., Australia, Canada, Mexico, Japan, France and the UK, that utilizes electronic tagging technologies to understanding the environmental basis for movements and behaviors of large pelagic animals in the North Pacific. Using a variety of electronic tags, TOPP scientists have followed the migrations of marine fishes, turtles, birds, pinnipeds, whales and squid as they traveled throughout the Pacific basin. The results are answering basic questions about the animals' biology including where they feed and breed, and what migration corridors they use. By integrating these biological data with available oceanographic information, TOPP scientists are learning how the dynamic ocean environment influences these basic life functions. By tagging a broad array of taxonomically diverse species, the scientists are gaining a broader understanding of how the North Pacific ecosystem functions – and are using this information to identify “ocean hotspots” which are key habitat areas within this vast region.

The goals of the TOPP program, to obtain biological and oceanographic information for an array of marine predators, have required the development of new tools. New types of tags have been designed that expand the range of oceanographic parameters that can be measured. Perhaps more significantly, new software systems have been developed to assimilate, access and analyze the terabytes of data coming in from all the TOPP tags, allowing TOPP biologists and oceanographers to explore and analyze this massive dataset in a variety of different ways.

At the completion of its first decade, the TOPP program has deployed 4,306 tags on 23 species in the North Pacific Ocean, resulting in a tracking data set of unprecedented scale and species diversity that covers 265,386 tracking days from 2000 to 2009. TOPP scientists have gained understanding of animal migration pathways, linked ocean features to hotspots and illustrated niche partitioning within and among congener guilds. These results indicate that the California Current large marine ecosystem and the North Pacific transition zone attract and retain a diverse assemblage of marine vertebrates. Within the California Current large marine ecosystem, several predator guilds seasonally undertake north-south migrations that may be driven by oceanic processes, species-specific thermal tolerances and shifts in prey distributions. They have identified critical habitats across

multinational boundaries and demonstrated that top predators exploit their environment in predictable ways, providing the foundation for spatial management of large marine ecosystems.

Challenges

Over its first decade, the TOPP program faced several challenges. In addition to the perpetual issue of generating sufficient funding for such a large and ambitious undertaking, we faced a fundamental challenge of coordinating such a broad and diverse assemblage of personnel into a cohesive, coordinated program. Thousands of tags needed to be purchased, programmed, deployed and recovered from locations all around the North Pacific. And once the tags were deployed, the data from them, which exists in a variety of different formats and delivery modes, had to be assimilated and processed through a common system that would allow TOPP researchers to work with the entire dataset as an integrated whole. The development of this system will remain as an important legacy of the TOPP project, and is now being utilized in several other marine biologging projects.

Opportunities

In addition to providing information about the animals themselves, the data from the tags are providing valuable information to the oceanographic research community. Although modern oceanographic sciences are aided by satellite-based observations, this view from space can only provide information about the oceans' surface. There is a dearth of information about the water column. This lack of data limits scientists' ability to describe ocean dynamics, and has hampered efforts to understand the coupling between the ocean, atmosphere and climate. Understanding of this coupling is a critical component of models that predict changes in the global climate. Since many of the TOPP organisms make repeated dives as they travel, they are continually sampling the water column, effectively "profiling" the ocean along their path.

Who are the major customers for the data?

To date, the primary customers of the TOPP data have been the TOPP researchers and their colleagues, who have benefitted from this dataset and the concomitant publication of over 150 scientific papers. In addition, TOPP data have been accessible to the general public throughout the program, and several efforts are currently under way to integrate the TOPP data into formal (i.e., classrooms) and informal education (e.g., museums, aquariums, science centers) venues.

What role should IOOS play?

The integration of TOPP data into IOOS fulfills one of the long-standing goals of the TOPP program – to demonstrate the utility of animal-derived data for oceanographic observations. By integrating TOPP animal data into IOOS, this collaboration will open the door to the addition of animal-borne sensors to the array of instruments used to monitor and explore the physical ocean. This creates a win-win situation, wherein the oceanographic community can add value to biologically-based observations, and biologically scientists will have enhanced opportunities to deploy more sophisticated tags, capable of collecting high-value oceanographic data.

Tag A Giant

Barbara A. Block, Hopkins Marine Station, Stanford University

The Tag-A-Giant (TAG) campaign was initiated in 1996 by the Tuna Research and Conservation Center (TRCC) of Stanford University and the Monterey Bay Aquarium. Since then, 1,145 electronic tags (700 archival, 445 pop-up satellite) have been deployed to track adolescent and mature bluefin tuna in the North Atlantic Ocean, creating the longest electronic tag time series in the world. Over the 16 years of the TAG program, fishers in the western and eastern Atlantic and the Mediterranean Sea have recovered 140 of the 700 archival tags deployed in the western Atlantic to date (20%), 78 in the western Atlantic, 24 in the eastern Atlantic and 35 in the Mediterranean Sea. A total of 445 satellite tags have been deployed, 80% have transmitted data to satellite, and 9 were recovered by fishers prior to their pop-up dates or from beaches. From these tags recapture records encompassing 1 to 4,938 days (13.5 years) post release and electronic tracks of 4.5 years in length have been obtained. Together, these data provide over 28,000 cumulative days of position and related data on Atlantic bluefin. This extensive dataset forms the basis for in-depth analyses of bluefin tuna distribution, physiology and behavior in the North Atlantic. The data are used by NOAA and the International Commission for the Conservation of Atlantic Tunas (ICCAT) for the development of new population abundance estimates and management strategies.

In the Pacific Ocean, the TRCC initiated a satellite and archival tagging program in 2002 in conjunction with the Tagging of Pacific Predators (TOPP) program. In total, 646 electronic tags (553 archival, 93 satellite) have been deployed to track bluefin tuna in the Pacific Ocean, creating the largest electronic tag time series in the world thanks to tag return rates of over 50%. While the majority of the 315 tag returns were from fish recaptured off Mexico or California, 23 fish have been recaptured near Japan. Individual track lengths range from 3 to 2,307 days with an average of 313 (+330) days. Combining the data from all recovered tags has generated 66,000 days of information on the movements, behaviors and habitat preferences of Pacific bluefin tuna in the eastern Pacific and on their trans-Atlantic journeys. TAG science is being used by NOAA, the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific (ISC), the Inter-American Tropical Tuna Commission (IATTC), and the Western and Central Pacific Fisheries

Commission (WCPFC) to assess the status of the species and prepare for development of a management plan for the North Pacific and California Current region.

The major challenge for the TAG research program is securing a steady source of funding for not just tag purchase and deployment, but also rewards to encourage tag returns. Due to the temporal extent of the TAG dataset, there is a major opportunity to monitor changes in population distribution and abundance over time in response to climate change, exploitation and other forces. In addition, the expansion of acoustic arrays in both oceans now presents an opportunity to double tag fish with an acoustic tag in addition to the archival/satellite tags to provide additional tracking data.

Pacific Ocean Shelf Tracking (POST)

John Payne et al. (University of Washington/POST)

Background

The Pacific Ocean Shelf Tracking Project (POST) began in 2001 as an effort to study the movements and survival of salmon in the ocean, using a large seabed network of acoustic receivers to track individual acoustically-tagged fish. The successful proof-of-concept in Washington and British Columbia, and the fact that compatible receivers and tags were in use by other researchers on the West Coast, helped POST mature and diversify into a complex infrastructure that is now regarded as a valuable tool for understanding the behavior of many marine species that move along the continental shelves. Operationally, POST is an international non-profit program run by an independent board, with board members and staff in both the US and Canada. POST is hosted by the Vancouver Aquarium. The POST board views POST's role as supporting research, rather than doing research. POST's mission is to facilitate the development of a large-scale acoustic telemetry network along the entire length of the West Coast of North America, working with contractors and partners who deploy the array, and through collaborative relationships with independent principle investigators who conduct their own research projects using the array. POST maintains a public database where currently over 9 million detections of over 16,000 tags and 18 species are securely stored, and may be searched and shared by anyone. There are about 50 PIs from federal, state, private and tribal organizations who use POST on a regular basis.

At present, we're funded on a relatively bare-bones budget for the next year, so maintenance is our main priority.

Major Challenges

- 1) Funding, of course.
- 2) Maintenance of infrastructure. POST is asset-heavy. Our lines have up to 10% equipment loss in some years. Tag and receiver technology changes constantly. Some upgrades are required (for example, Vemco's switch to a new coding scheme requires us to upgrade the firmware in our entire receiver network); others are desirable as new technology opens new opportunities. For example, new, smaller, high-frequency tags make it possible to tag species that were too small to be tagged in the past, but those tags require a new generation of receivers which must be spaced closer together in lines, to achieve the same detection rates as current receiver lines get.
- 3) Collaborative relationships need constant attention. Priority-setting must be ongoing in an environment where funding is short-term, and funders have diverse needs. Data sharing involves both technical challenges and social challenges.

Major Opportunities

Interdisciplinary research teams. Far too much tagging has been done with a single, limited goal – to see where animals go. Tagging can be the glue that holds other research together: if you know where an animal goes, you can start to figure out how it interacts with the environment (physiology, nutrition, disease, navigation) and how it interacts with other species. To make this a reality, projects have to be bigger and have to include many different technologies.

Technological breakthroughs. Double-tagging has potential in several areas; full-life cycle tagging is coming closer to being possible; and Ron O'Dor has championed the idea of an implantable life-long data logger that would communicate with external devices. The use of receivers on mobile platforms (animals, seagliders) has potential for beginning to scratch the surface of inter-species interactions and for using larger animals to report on species that are too small to carry sophisticated tags.

Integration of data from multiple sources (tag deployments, oceanographic data, etc.) still has much to offer us. Analytical techniques can be improved and pre-packaged so that it is easier to use them.

Who are the major customers for the data?

I view the answer to this question as a “major opportunity” because better marketing of animal telemetry data to end-users has the potential to improve our funding. Customers include people who extract energy or resources from the ocean, people who live or recreate on the coastline, military and civilian shipping, coastal jurisdictions (federal, state, local and

tribal) that need to plan development, and a much larger community that benefits from ocean “services” such as uptake of CO₂, climate regulation, and production of oxygen and protein. Can we come up with products that are scalable from small localities to a region to the nation, or that can be useful to more than one customer? Making data relevant to customers basically means helping with decision support, but decision support can take many forms:

- Near-real-time data can be useful for resource management. Examples include models for sea turtles that predict their location so that fishermen can avoid them, or shark alerts that affect beach closures, or knowing the return timing of endangered salmon runs to help managers protect those runs. These solutions are usually specific, local and expensive. Can we come up with models that make them more general, portable and copy-able?
- Habitat use data can be vital for planning by everyone from ocean energy projects to local jurisdictions, marine protected areas, shipping, and the military. Is there a way to package habitat use data that makes it more universal (combines species or integrates it with data on oceanography and climate change?)
- Long-term time series are useful for understanding the scale of natural variation, identifying human impacts, and predicting changes. These studies are difficult to fund, but absolutely critical. For example, POST researchers are building up a long-term database of salmon survival and migratory routes that is becoming a rich source of information on ocean conditions. Similarly, extremely long-life tags (10-20 years) may become important for population studies. How do we market the value of this kind of longevity? What customers are going to care about indicator studies/indicator species? How do we ensure continuity of funding and methods?
- Interdisciplinary studies can be invaluable for developing a mechanistic understanding of the ecosystem and the services it provides. However, such studies tend to be expensive and the results are sometimes not directly applicable to resource management. Can these studies be sold to the larger public?

What role should IOOS play?

Obviously, the most valuable role IOOS could play would be as a source of stable, core funding for some of the telemetry activities. Other possibilities:

- Facilitate communications between regional telemetry efforts: hold regular meetings of the national telemetry community. This will help in many ways, including identification of shared problems and solutions.

- Take the lead on bringing animal data into our NOOS. Begin a dialogue with telemetry data managers from all the regions on how to integrate various types of data, how to begin to understand issues such as data quality standards, interchangeability, and portability. Also, lead a discussion of data sharing guidelines (POST and TOPP have different but not identical sharing guidelines, for example).
- Serve as a voice for the telemetry community. Collect and display (perhaps under the IOOS brand) telemetry products including publications, data visualization or decision-support tools and other software that may have wide applications. Also, and simultaneously, push the telemetry community to think bigger and more collaboratively about potential products. As an example of the latter, IOOS could sponsor white papers on 1) the uses of telemetry data in stock assessments, 2) potential uses of telemetry-derived habitat use data, 3) the potential uses of long time series derived from telemetry.

Ocean Tracking Network

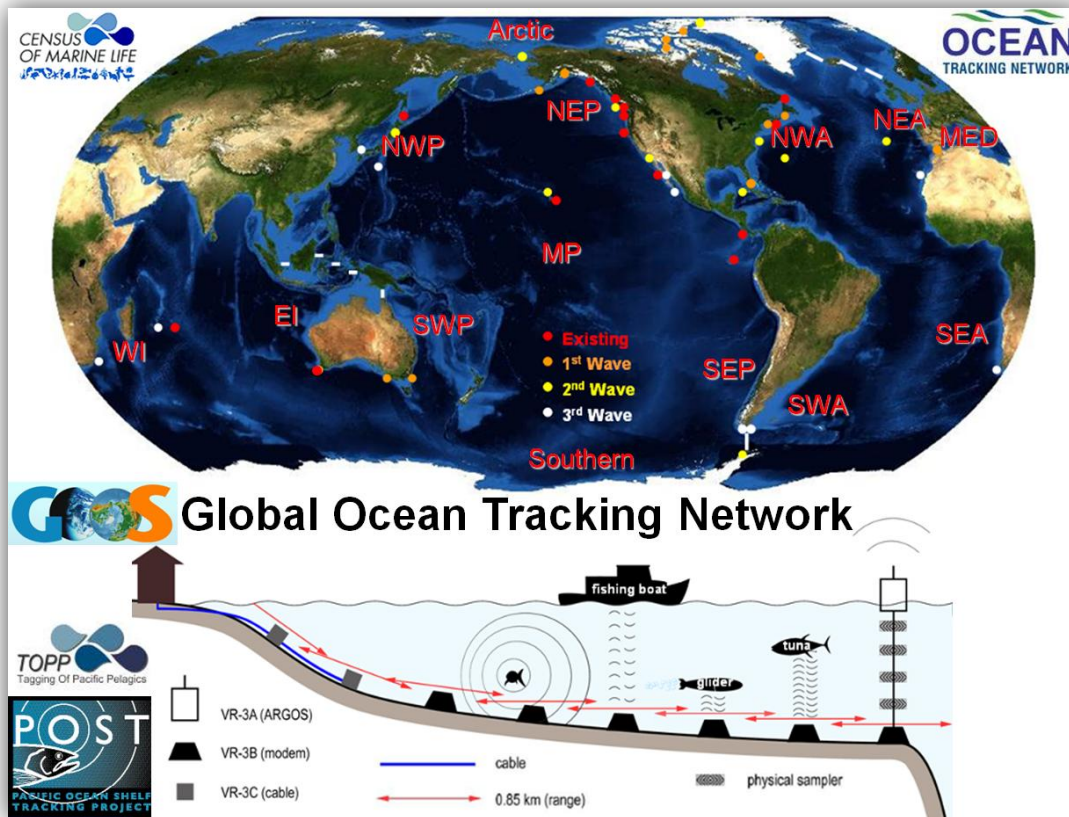
Ron O'Dor (Census of Marine Life/Dalhousie University, NS Canada))

The Ocean Tracking Network (OTN) began as a Census of Marine Life Affiliated Project sponsored by Census Canadian National Implementation Committee. It combines the global database concepts of Census Ocean Biogeographic Information System (OBIS) with the Census animal tracking technologies developed by the Pacific Ocean Shelf Tracking (POST) and the Tagging of Pacific Predators (TOPP) projects. Its original concept was to merge their small animal, acoustic tracking and large animal, satellite tracking technologies as a part of the UN Intergovernmental Oceanographic Commission's (IOC) Global Ocean Observing System (GOOS) with goals similar to IOOS. In addition to showing where animals from 10g salmon smolts to 100MT whales go during migrations, the large diving animals can transmit physiochemical oceanographic profiles via satellite and the lines of acoustic receivers can also collect long-term physiochemical data on site at the sea bottom. Both provide information needed to model ocean patterns that are becoming increasingly rare as routine oceanographic cruises decline in number.

OTN's core sponsors are the Canada Foundation for Innovation, the Canadian Natural Science and Engineering Research Council and Social Sciences and Humanities Research Council and Fisheries and Oceans Canada, who have together committed nearly \$50M to developing the global system. When OTN's global partners have committed an additional \$100M. One issue OTN raised at this meeting was, "Can IOOS play a role in identifying optimal partnerships in the US that will maximize the value of OTN's investment for delivering both physiochemical and biological information?" OTN core

funding for central operation and maintenance costs extends through 2017, and assumes that international partners will cover costs of collecting data and tagging animals regionally to solve their own local problems. Naturally, GOOS would like to see the system considered so valuable that it would be maintained globally in perpetuity, and IOOS has similar goals within US waters.

OTN also reported recent progress on its “Bioprobe” technology that will allow larger animals like seals to carry acoustic receivers to detect smaller acoustically tagged species to help understand interactions between predators and prey in the open ocean to advance Ecosystem-Based Management. The seal bioprobes have detected salmon and tuna in the region of Sable Island where they were tagged. Plans are underway to allow bioprobes to relay their data to satellites in real time in 2012, which would provide a lot more flexibility in who could be used as a bioprobe. Current technology requires that the receivers be recovered to recover data, so the Sable Island seals that routinely return to their breeding ground are the best candidates, but other species that could communicate with satellites would make this approach much more flexible and rewarding.



Alaska Animal Telemetry Ocean Observing Activities

Andy Seitz, University of Alaska Fairbanks

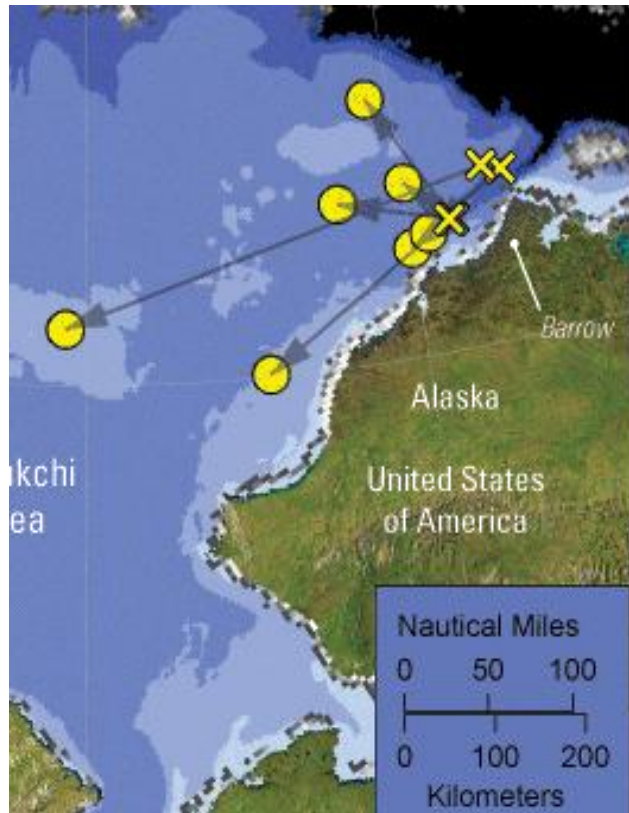
Shane St Clair, Alaska Ocean Observing System

There is a wide array of animal tagging and tracking activities in Alaska conducted by government and non-government agencies, academia, and private consulting companies. These tagging activities have been conducted on mammals, fishes and birds. The common goal of all of these research projects is to understand the distribution and movement of these animals for delineation of marine resource management areas, model transfer of biomass among management areas in stock assessments and population structure analyses, determine potential and realized impacts of human development and design marine protected areas.

Although these tagging and tracking studies have yielded considerable ecological information about Alaska's marine organisms, undertaking these studies presents several challenges. The marine waters of Alaska are huge, with the state accounting for greater than half of the entire US coastline. The Alaskan coast has relatively few population centers to support marine research and therefore much of Alaska's waters are extremely remote. In addition to being remote, Alaska's waters have inclement weather for much of the year and face near-total darkness during winter months. Because of these conditions, accessing animals for tag deployment and recovery is very expensive, logistically difficult and potentially dangerous.

Although there are several challenges associated with tagging and tracking animals in Alaska's marine waters, there are also several opportunities for future tagging projects. First, rural residents such as Native Alaskan subsistence hunters and fishers may provide longterm traditional ecological knowledge for assisting in tag deployment, retrieval and data interpretation. Additionally, several new technologies offer solutions to some of the aforementioned challenges.

Developing these opportunities for tagging and tracking animals is critically important because several constituents are interested in the movement of marine organisms off of Alaska. The constituents include a wide variety of groups including scientists, management agencies, private industry (i.e., oil and gas, shipping, and commercial fishing), subsistence users, sport anglers and children in grades K-12. To effectively develop these opportunities, a concerted effort must be made to coordinate projects and provide a central distributor of tagging and tracking data that is accessible to the public. Several investigators are interested in coordinating projects and the Alaska Ocean Observing System aims to distribute data to the public.



USGS Study on walrus by Jay & Fischbach

Great Lakes Animal Telemetry Observing Systems Activities

By Christopher Holbrook (U.S. Geological Survey/Great Lakes), Charles Krueger (Great Lakes Fishery Commission) and Thomas Binder (Great Lakes Fishery Commission).

Background

The Great Lakes Fishery Commission (GLFC) and USGS are currently in early stages of developing of a Great Lakes Acoustic Telemetry Observing System (GLATOS). GLATOS is currently in its initial phase: three independent projects are being conducted to build regional telemetry expertise, raise awareness of the technology among researchers and the public, and begin developing a common database. During the next three years, permanent monitoring sites will be established for long-term multi-species monitoring.

Acoustic telemetry activities

- Several research projects funded by the GLFC through funds obtained via the Great Lakes Restoration Initiative. Currently 327 Vemco VR2W Receivers and 9 Vemco VR3-UWM receivers are shared among projects.
- Specific project info (species, time frame, location technology, contact)
 - Lake trout; Lake Huron; 2010-2013; Vemco; Dr. Thomas Binder, Great Lakes Fishery Commission, Hammond Bay Biological Station, Millersburg, MI, tr.binder@gmail.com
 - Sea lamprey; Lake Huron and tributaries; 2010-2013; Vemco; Chris Holbrook; USGS, Hammond Bay Biological Station, Millersburg, MI; cholbrook@usgs.gov
 - Walleye; Lake Huron, and tributaries, Lake Eerie and tributaries; Dr. John Dettmers, Great Lakes Fishery Commission, Ann Arbor, MI; jdettmers@glfc.org

Gulf of Mexico Animal Telemetry Observing Activities

By Sean P. Powers (University of South Alabama), Matthew Ajemian (University of South Alabama) and Behzad Mahmoudi (Florida Fish and Wildlife Research Institute)

Several investigators in the northern Gulf of Mexico employ acoustic and satellite telemetry in their research studies. To date no network has been formally established. Informal data sharing has occurred via personal communications and limited exchange of codes and hydrophone detections. For example, the coastal Alabama acoustic array (CAAMP) was established to examine movements of elasmobranchs (sharks and rays) in Alabama waters; however, the CAAMP array has also contributed to large-scale distribution behavior of gulf sturgeon tagged in Florida waters (USFWS), with 23 different individuals detected in Alabama waters from 2009-2010. Similarly, researchers at the Gulf Coast Research Lab (GCRL) have detected elasmobranchs from Mobile Bay in their array. These various exchanges across states have involved multiple agencies and have lead to the proposal of a Gulf of Mexico – wide acoustic array network (GAAN). This network would synthesize the various current tagging efforts and provide an opportunity for researchers to broaden the scale of their investigations (Figure 1). A meeting of some of the potential GAAN cooperators will occur on March 18 in Mobile, Alabama in conjunction with the 40th Marine Benthic Ecology Meeting.

- Animal telemetry observing activities in your region?

Figure 1 summarizes information on activities by species in the Gulf of Mexico. The information should not be viewed as complete, but more as a representative sample of activities. We are attempting to gather a more comprehensive data base.

- Challenges and opportunities in your region?

The majority of acoustic tagging has focused on estuarine/coastal species (i.e. state managed species) or species with fairly high site fidelity (red snapper and grouper). The challenge is to coordinate the coastal areas into a cooperative network that shares information and address standardization and compatibility issues (Lotek, Sonotronic and VEMCO equipment is routinely used). Coastal migratory species are important fisheries species and little is known about their movements and migrations. The vast number of oil and gas platforms in the western Gulf of Mexico may provide excellent platforms for expanding an array. However, these platforms are not permitted in the eastern Gulf. Adding networks to sensor in offshore waters would greatly enhance our telemetry capacity in the Gulf of Mexico.

- Customers of animal telemetry observations data in your region?

Table 1 gives a wide range of University, State and Federal Agencies, and NGO customers that could use the information. In addition, the NRDA process for the Deepwater Horizon Oil Spill is utilizing telemetry as part of their assessments.

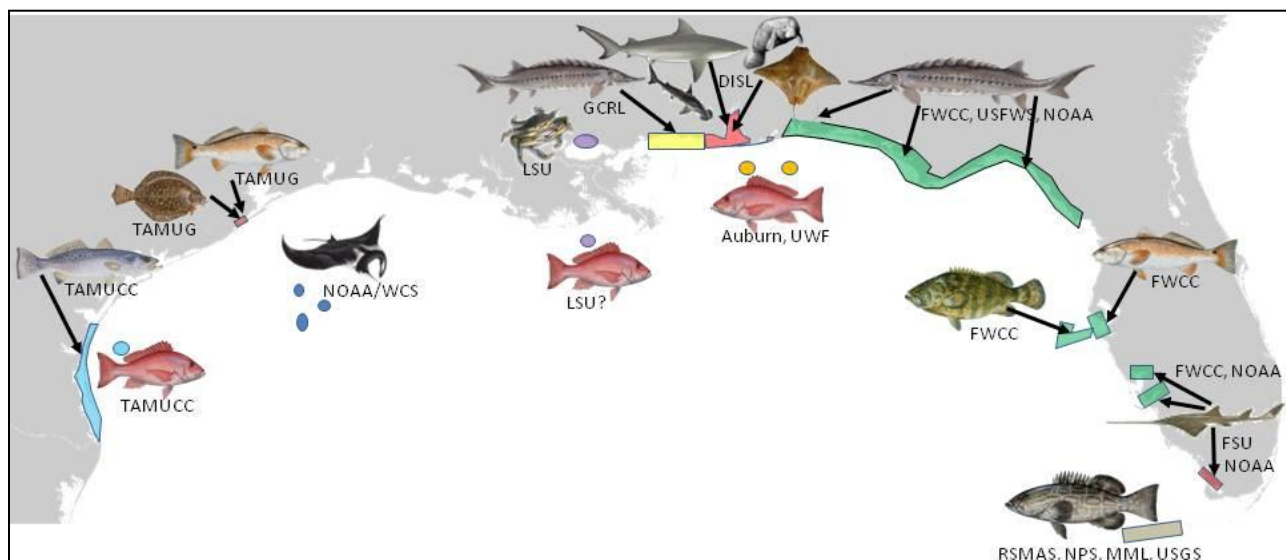


Figure 1 – Distribution of active acoustic monitoring studies, coverage zones, species tagged and participating agencies across the US Gulf of Mexico (current as of February 2011). Tagged species fall into several categories of fisheries importance (recreational, commercial) and IUCN conservation status (endangered, vulnerable, data deficient, etc.). Acronym explanation below:

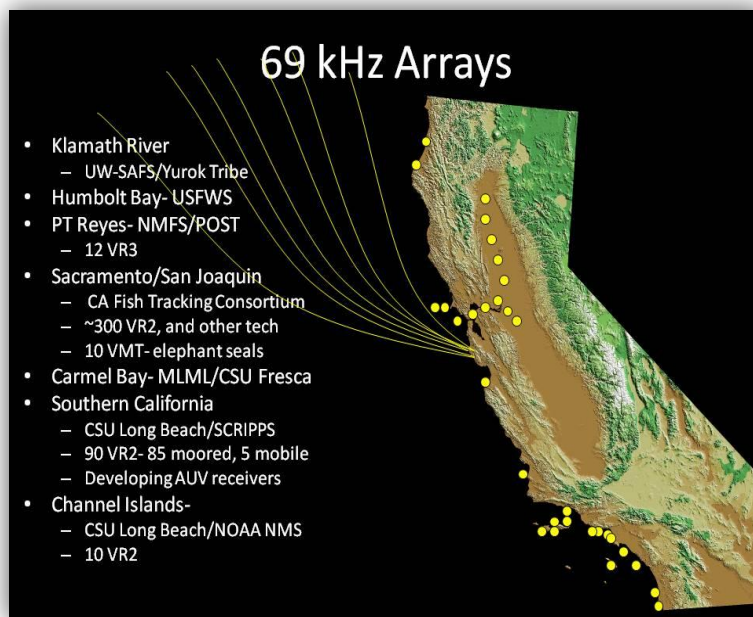
California Animal Telemetry Observing Activities

Sean Hayes et al. (NOAA. Fisheries, Santa Cruz)

The use of acoustic telemetry in California marine waters has seen an explosion of activity in the last ten years. While there are a variety of manufacturers and technologies, at this point, most of technology being used in California marine waters appears to be 69 kHz tags, originally developed by Vemco. The majority of the tags are deployed on salmonids (~1000-1500/yr) for tracking movement and survival through freshwater, estuarine, and marine portions of the Sacramento River outmigration corridor (~300 receivers operated by the California Fish Tracking Consortium). However, hundreds of tags have been deployed on more than a dozen species, including fish (osteichthyes and chondrichthyes), Humboldt squid, and pinnipeds. These are tracked through a series of independent and/or grassroots networks of coastal receivers. There is a 'curtain' style array of VR3 receivers (~10), perpendicular to the coast at Pt. Reyes established by a joint NOAA SWFSC and POST collaboration, and maintained by SWFSC.

There are a few isolated VR2 type receivers along river mouths and bays in Northern California. Perhaps the most extensive marine coverage is in southern California, with a network for roughly 85 moored VR2s between Morro Bay and Tijuana River, and another 10 around the Channel Islands. These are operated through collaborations

between CSU Long Beach, Scripps, and NOAA Sanctuaries. Some work on moving receivers is being done as well. NOAA SWFSC and UCSC are deploying the Vemco Mobile Transceivers (VMT) carried by northern elephant seals on their migrations across the northeastern Pacific. In addition NWFS and SWFSC have been deploying the VMT's on their oceanographic and net sampling gear during ocean surveys. Similar to this, CSU Long Beach has been providing VR2's to 'party fishing boats' to deploy while on anchor during charter trips, and is exploring the use of AUV based receiver technology.



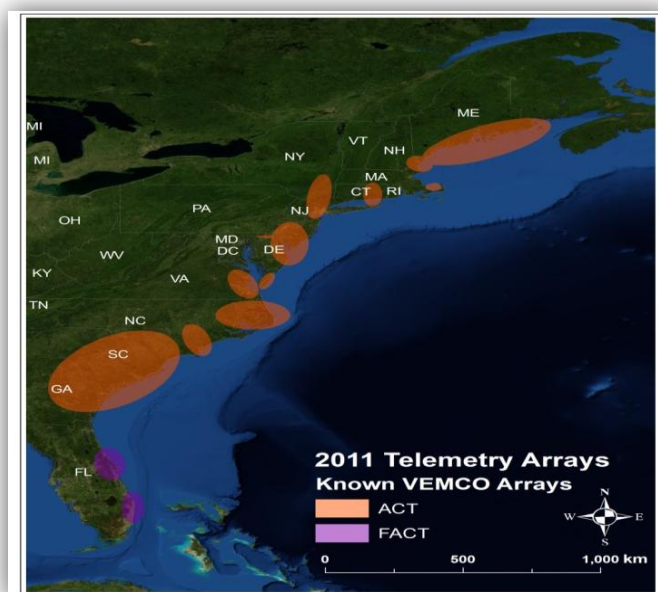
The Atlantic Cooperative Telemetry Network (ACT) and Florida Acoustic Cooperative Telemetry (FACT)

ACT formally began to take shape in 2006 during an Atlantic States Marine Fisheries Commission – Atlantic Sturgeon Technical Committee Meeting. As researchers began utilizing acoustic telemetry technology more extensively along the eastern coast of the United States, the potential benefits of collaborating in order to share telemetry data from existing arrays beyond those in their own system became apparent. What started with 15 researchers that year has expanded to over 65 from Maine to Florida (with collaboration in the Canadian Maritimes as well), including the addition of the FACT group in 2008.

Researchers maintain their own arrays, so transmitters deployed and array sizes are often dependent on grant-based funding. It is up to the individual researchers to provide information regarding transmitters that they have deployed to the network, and to date each researcher provides as much or as little information as they feel necessary. This way, researchers can maintain a level of involvement in the network that is appropriate for their needs; from just sharing general tag code information to collaborating with other researchers and leveraging other arrays to gain additional funding. Currently there are over 5000 known transmitters deployed since 2004, with over 1000 deployed in 2010 alone. This corresponds to 49 identified species currently being studied along the east coast.

As we continue to develop and enhance the ACT network, we hope to make exchanging information about “unknown” transmitter codes simpler and more straightforward, further strengthen collaboration. One of the main challenges ACT faces as we continue to expand is developing and maintaining standards in data collecting and sharing, so as we grow, we will be able to incorporate our telemetry data with other physical/environmental information systems, further enhancing potentials.

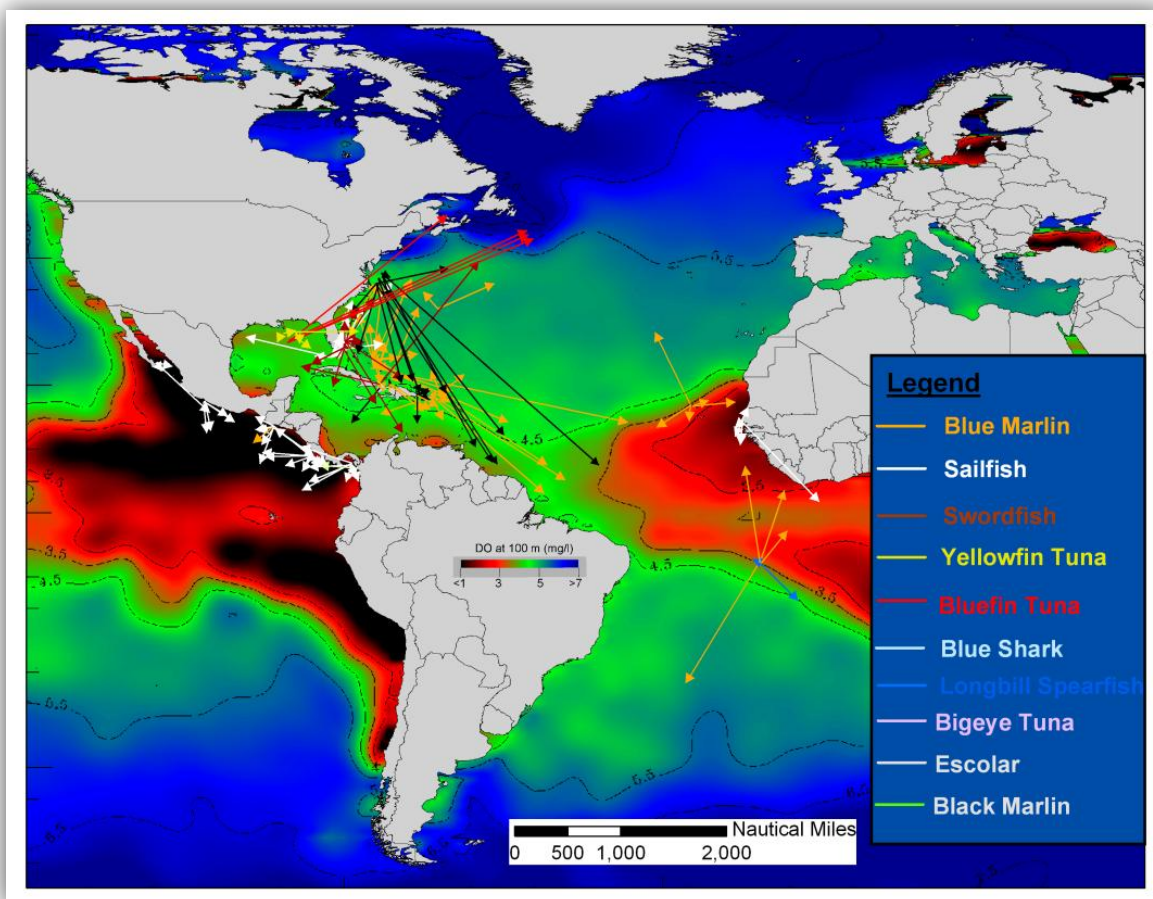
Current known VEMCO Array along the Eastern United States. Orange indicates the ACT Network collaborators and purple indicates those researchers also involved with FACT.



US Southeast and Caribbean

Adopt a Billfish

Eric Prince (NOAA Fisheries, Miami)



Central Pacific Tracking Activities Based at the Hawaii Institute of Marine Biology, University of Hawaii

Tracking activities carried out by Kim Holland and colleague Carl Meyer at the Hawaii Institute of Marine Biology (HIMB) can be divided into two main categories – tracking of pelagic species such as tuna and billfish and tracking of reef-associated species including top predators such as sharks, giant trevally and grouper but also smaller species such as parrotfish and goatfish. In many cases, a combination of acoustic telemetry, data logging archival tags and satellite linked telemetry is used to answer management related questions. These questions include defining the size of the ecological unit (“catchment area”) that supports Hawaii-based fisheries that exploit pelagic species, defining the home ranges of ‘coastal’ sharks such as Galapagos, hammerhead and tiger sharks and evaluating the effectiveness of Marine Protected Areas (MPAs) as management tools for conserving commercially important species such as groupers and goatfish.

Geographically, these activities can be divided into those that focus on the remote Northwestern Hawaiian Islands (and the recently created Papahānuamokuākea Marine Monument) and those that focus on the Main Hawaiian Islands – principally Oahu and the Big Island of Hawaii. Of course, some species, such as tiger sharks have been shown to travel widely throughout the Hawaiian archipelago. Activities around Oahu are being integrated with and supported in part by the Ecosystem Stewardship component of PacIOOS and, in other PacIOOS related activities, we are providing material support to nascent shark tracking activities in Palau. In a project supported in part by Monterey Bay Aquarium, we are using a combination of acoustic telemetry and satellite telemetry to quantify the open ocean movement patterns of adult hammerhead sharks that use Kaneohe Bay as a pupping ground. These data will be used to enhance our understanding of the energy budget of Kaneohe Bay and similar tropical estuaries.

Among other management-related outcomes, our work has been used to inform deployment strategies for deepwater fish aggregating device (FAD) networks, shape public policy regarding responses to shark attacks and the operation of shark ‘ecotourism’ activities, elucidate the role of shark predation on endangered Hawaiian monk seals and identify optimum sizes and locations for coastal MPAs.

U.S. Northeast region

John Kocik, NOAA. Fisheries Northeast Fisheries Science Center

The Northeast Fisheries Science Centers Atlantic Salmon Telemetry Estuary and Coastal Assessment focuses on the estuaries, bays and Gulf of Maine Atlantic salmon. Beginning 2005 NEFSC attached receivers to each Gulf of Maine Ocean Observing System (GoMOOS; www.gomoos.org and <http://neracoos.org/>) buoys. In 2010, receivers on three GoMOOS buoys recorded 350 detections from 49 transmitters belonging to nine different research organizations. NOAA contributes data from the GoMOOS array to the Ocean Tracking Network (OTN; www.oceantrackingnetwork.org) headquartered out of Dalhousie University (Halifax, NS). Additionally, NEFSC has maintained part of a coastal array at the mouths of the Union and Narraguagus Rivers since 2008. In 2010, the outer receiver in the Narraguagus array recorded multiple detections from an Atlantic sturgeon tagged by University of Maine researchers in the Penobscot River. The NEFSC also deploys drifters that map ocean surface currents (<http://www.nefsc.noaa.gov/drifter/>). NOAA telemetry crews deployed fourteen drifters in 2010, six of which had telemetry receivers attached. Two Atlantic salmon smolts and one Atlantic sturgeon were detected by two receivers. NEFSC began a pilot project working with local fisherman called Telemetry Monitors on Lobster Traps (tMOLT) in 2010. Researchers cooperate with local lobster fishermen to deploy receivers on their lobster gear. Nine receivers were deployed in 2010 and recorded 416 detections from 39 individual transmitters belonging to seven different research organizations. Multiple species have been collected on these platforms -Atlantic salmon, Atlantic sturgeon, alewives, striped bass, winter flounder, and spiny dog fish and connections made with researchers throughout New England and the east coast as far as Florida. Cooperative monitoring of the Coast of Maine Passive Acoustic Sensor System (CoMPASS) has established offshore grids, estuary networks in the Kennebec, and coastal estuary coverage for 150 km of rivermouths.

The Penobscot Telemetry Group is an informal consortium of researchers from NOAA Fisheries Northeast Fisheries Science Center, US Geological Survey Co-Op Unit, University of Maine, and Maine Department of Marine Resources. USGS and Umaine monitor freshwater sections of the Penobscot River and NOAA covers estuary and bay. NEFSC has used ultrasonic telemetry to monitor Atlantic salmon (*Salmo salar*) smolt behavior and survival in Maine's salmon rivers since 1997. Since 2006 NMFS has maintained a hydroacoustic array in Penobscot Estuary and Bay ranging from 75 to 104 hydroacoustic receivers. During that period NMFS tagged 768 Atlantic salmon smolts from different rearing strategies (hatchery or naturally reared) to study estuary movements. USGS has tagged similar numbers to study dam passage and estuary survival of smolts. The

University of Maine tagged both shortnose sturgeon and Atlantic sturgeon and arrays of both the Penobscot Telemetry Group and CoMPASS have facilitated understanding of between river movements. The use of hydroacoustic receivers to passively monitor smolts has provided many useful insights into migration dynamics within Penobscot Bay. Researchers have been able to identify preferred migration corridors for emigration, tidal behaviors, migration swim speed patterns, and survival.

APPENDIX D. Nine National Ocean Policy Priority Objectives

1. **Ecosystem-Based Management:** Adopt ecosystem-based management as a foundational principle for comprehensive management of the ocean, our coasts, and the Great Lakes.
2. **Coastal and Marine Spatial Planning:** Implement comprehensive, integrated, ecosystem based coastal and marine spatial planning and management in the United States.
3. **Inform Decisions and Improve Understanding:** Increase knowledge to continually inform and improve management and policy decisions and the capacity to respond to change and challenges. Better educate the public through formal and informal programs about the ocean, our coasts, and the Great Lakes.
4. **Coordinate and Support:** Better coordinate and support Federal, State, tribal, local, and regional management of the ocean, our coasts, and the Great Lakes. Improve coordination and integration across the Federal Government and, as appropriate, engage with the international community.
5. **Resiliency and Adaptation to Climate Change and Ocean Acidification:** Strengthen resiliency of coastal communities and marine and Great Lakes environments and their abilities to adapt to climate change impacts and ocean acidification.
6. **Regional Ecosystem Protection and Restoration:** Establish and implement an integrated ecosystem protection and restoration strategy that is science-based and aligns conservation and restoration goals at the Federal, state, tribal, local and regional levels.
7. **Water Quality and Sustainable Practices on Land:** Enhance water quality in the ocean, along our coasts, and in the Great Lakes by promoting and implementing sustainable practices on land.
8. **Changing Conditions in the Arctic:** Address environmental stewardship needs in the Arctic Ocean and adjacent coastal areas in the face of climate-induced and other environmental changes.
9. **Ocean, Coastal, and Great Lakes Observations, Mapping, and Infrastructure:** Strengthen and integrate Federal and non-Federal ocean observing systems, sensors, data collection platforms, data management, and mapping capabilities into a national system, and integrate that system into international observation efforts.

RECENT TECHNICAL MEMORANDUMS

SWFSC Technical Memorandums are accessible online at the SWFSC web site (<http://swfsc.noaa.gov>). Copies are also available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161 (<http://www.ntis.gov>). Recent issues of NOAA Technical Memorandums from the NMFS Southwest Fisheries Science Center are listed below:

- NOAA-TM-NMFS-SWFSC-472 Historical occurrence of coho salmon (*Oncorhynchus kisutch*) in streams of the Santa Cruz Mountain region of California: response to an Endangered Species Act petition to delist coho salmon south of San Francisco Bay.
B.C. SPENCE, W.G. DUFFY, J.C. GARZA, B.C. HARVEY, S.M. SOGARD, L.A. WEITKAMP, T.H. WILLIAMS, and D.A. BOUGHTON
(February 2011)
- 473 Comparison of real-time and post-cruise acoustic species identification of dolphin whistles using ROCCA (Real-time Odontocete Call Classification Algorithm).
Y. BARKLEY, J.N. OSWALD, J.V. CARRETTA, S. RANKIN, A. RUDD, and M.O. LAMMERS
(February 2011)
- 474 Global review of Humpback whale, (*Megaptera novaeangliae*)
A. FLEMING and J. JACKSON
(March 2011)
- 475 Status review update for Pacific salmon and steelhead listed under the Endangered Species Act: Central California Coast Coho Salmon ESU.
B.C. SPENCE and T.H. WILLIAMS
(March 2011)
- 476 U.S. Pacific marine mammal stock assessments: 2011.
J.V. CARRETTA, K.A. FORNEY, E. OLESON, K. MARTIEN, M.M. MUTO, M.S. LOWRY, J. BARLOW, J. BAKER, B. HANSON, D. LYNCH, L. CARSWELL, R.L. BROWNELL JR., J. ROBBINS, D.K. MATTILA, K. RALLS, and M.C. HILL
(June 2011)
- 477 Osteological specimens of tropical dolphins (*Delphinus*, *Grampus*, *Lagenodelphis*, *Stenella*, *Steno* and *Tursiops*) killed in the tuna fishery in the tuna fishery in the eastern tropical Pacific (1966-1992) and placed in museums by the Southwest Fisheries Science Center.
W.F. PERRIN and S.J. CHIVERS
(May 2011)
- 478 Ichthyoplankton and station data for surface (Manta) and oblique (Bongo) plankton tows for California Cooperative Oceanic Fisheries Investigations Survey cruises in 2007.
S.R. CHARTER, W. WATSON, and S.M. MANION
(May 2011)
- 479 Passive acoustic beaked whale monitoring survey of the Channel Islands, CA.
T.M. YACK, J. BARLOW, J. CALAMBOKIDIS, L. BALLANCE, R. PITMAN, and M. McKENNA
(May 2011)
- 480 Determining transmitter drag and best-practice attachment procedures for sea turtle biotelemetry studies.
T.T. JONES, B. BOSTROM, M. CAREY, B. IMLACH, J. MIKKELSEN, P. OSTIFACHUK, S. ECKERT, P. OPAY, Y. SWIMMER, J.A. SEMINOFF, and D.R. JONES
(May 2011)
- 481 Ichthyoplankton, paralarval cephalopod, and station data for surface (Manta) and oblique (Bongo) plankton tows for California Cooperative Oceanic Fisheries Investigations Survey and California Current Ecosystem Survey cruises in 2008.
W. WATSON and S.M. MANION
(May 2011)