NOAA Technical Memorandum NMFS-NE-265

Opportunistic Acoustic Telemetry Platforms: An Update on the Northeast Fisheries Science Center's Collaborative Monitoring Program in the Gulf of Maine, 2005-2018

by Graham S. Goulette[1], James P. Hawkes[1], John F. Kocik[1], James P. Manning[2], Eric Matzen[2], Sofie Van Parijs[2], Neil Pettigrew[3], John Wallinga[3], Gayle B. Zydlewski[3], Catlin Ames[3]

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[1] *NOAA Fisheries Service, Northeast Fisheries Science Center, Maine Field Station,*
17 Godfrey Drive - Suite 1, Orono, Maine 04473

[2] *NOAA Fisheries Service, Northeast Fisheries Science Center,*
166 Water Street, Woods Hole, Massachusetts 02543

[3] *University of Maine, School of Marine Sciences, Orono, Maine 04473*

US DEPARTMENT OF COMMERCE
Wynn Coggins, ActingSecretary
National Oceanic and Atmospheric Administration
Benjamin Friedman, Acting Under Secretary
National Marine Fisheries Service
Paul Doremus, Acting Administrator for Fisheries
Northeast Fisheries Science Center
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ABSTRACT

Researchers frequently study the ecology of marine animals by using acoustic telemetry to collect information on behavior, habitat use, and survival. Many studies use acoustic telemetry to monitor marine animals at a local level to answer specific questions (i.e., swim speeds or mortality bottlenecks). It can be difficult to collect data for migratory species that exhibit extensive movements covering broad spatial distributions outside "home arrays" for 2 reasons: the cost of offshore deployments (ship time and mooring costs) and awareness/accessibility of distant water detections. To address both issues, we work in research partnerships to both deploy receivers and share data. First, we utilize a number of opportunistic platforms: oceanographic buoys, commercial fishing gear, drifters, passive acoustic moorings, gliders, and coastal moorings to expand coverage while lowering costs. Then, after receivers are downloaded and we assure data quality, we actively contact tag owners to report detections and/or make these data available through the Ocean Tracking Network data portal. These platforms provide novel data and have generated over 369,000 detections from over 1,100 transmitters released by 50 researchers (34 organizations). These opportunistic platforms prove to be a low-cost method able to collect valuable data benefiting the science community. The information gained from these data helps researchers fill in data gaps, leads to novel findings on expanded species distributions, develops new research partnerships, and supports collaborative studies of migratory marine species behavior and survival.

INTRODUCTION

Acoustic telemetry is an established method for tracking fish and other marine animals across variable spatial and temporal distributions. Information collected via acoustic telemetry provides insight into the behavior, habitat use, and survival of these animals (Hussey et al. 2015). Traditional study designs often use systematic receiver deployments sometimes referred to as gates (or curtains) to monitor migration dynamics within riverine, estuarine, and bay environments (Kocik et al. 2009; O'Dor et al. 2009) or grids to monitor movements within a defined area (Heupel et al. 2006; McDougall et al. 2013). We refer to these traditional study designs as "home arrays". Monitoring migratory animals in deeper offshore waters outside these "home arrays" can be costly for individual projects because more resources are required to deploy equipment as the spatial coverage increases. Additionally, acquiring detections that are made in distant waters on existing arrays can be difficult for researchers if they are unaware that these arrays exist or if they are unable to access these data. Sharing data across arrays and between researchers benefits individual projects, and it also will benefit the many species being studied as information collected can also help shape management decisions (Crossin et al. 2017; Dunn et al. 2019).

We use a combination of traditional deployments in rivers, estuaries, and bays to study Atlantic salmon (*Salmo salar*). However, these fish are a highly migratory species and spend a majority of their lifecycle outside our seasonally deployed arrays. As management needs expanded, our focus also expanded to include monitoring Atlantic salmon, in the freshwater, estuarine, and bay areas, as well as in the larger ecosystem of the marine environment. Knowing we lacked the resources and logistical support to construct offshore acoustic telemetry arrays, we began investigating alternative platforms for deploying receivers to expand our coverage for Atlantic salmon monitoring. Utilizing existing infrastructure and partnering with various entities, we have been able to create a network of opportunistic deployments (Figure 1) that have collected invaluable data for Atlantic salmon research.

These opportunistic deployments have proven to be a low cost and effective method for collecting data on numerous migratory species in the marine environment. Additional information collected from these deployments serves to strengthen existing projects and provide additional data and perspective. While these deployments cannot replace traditional networks, they do provide insights into species behavior and migrations not captured by “home arrays.” Much of the data we are able to provide can help fill in temporal and spatial gaps for these migratory species. Principal investigators have the opportunity to expand the scope of their work and learn more about the individuals they have tagged because of these distant waters detections. Some of the researchers we are able to share these data with may not even be aware of these detections until we contact them. Ultimately, our model for utilizing opportunistic platforms assists numerous researchers with constructing a more complete picture of their tagged animals’ behavior and migration patterns.

The Northeast Fisheries Science Center’s collaborative efforts began in 2005 when we partnered with the University of Maine’s Physical Oceanography Group (PhOG) to attach our receivers to their oceanographic observing buoys. That initial effort led to additional opportunistic platforms including lobster gear and drifters being added in subsequent years. Goulette et al. (2014) describes the various methods used and synthesized the detection data collected for the years 2005 – 2012. During that period our opportunistic platforms provided novel data from 265 individual transmitters to 18 different organizations. Oceanographic observing buoys and lobster gear provided the majority of detections while drifters provided very few and were also not as easily recovered. Hence, we continue to use the oceanographic observing buoys and lobster gear as platforms but no longer deploy drifters. Additionally, we have added glider missions, passive acoustic moorings and coastal moorings, and acoustic releases as platforms (Table 1). Essentially, we are always looking to actively partner on new platforms in our area of focus if we can attach a receiver without compromising the utility of that platform. Preference is given to platforms that are longer term offshore deployments or methods that will cover a large geographical area. Through 2018, all platforms combined have detected over 1,100 transmitters belonging to 50 different researchers (34 different organizations) and provided valuable detection data that assists in studying fish migration and behavior in the marine environment. This technical memo will highlight the new methods utilized and summarize synthesized data collections for years 2005 – 2018. Our goal is to provide an update every 5 years and to include new methods we may incorporate and to provide both a synthesis of detection data and a citable reference of these deployments for partners that use these data.

METHODS

Ocean Observing Buoys

The University of Maine’s Physical Oceanography Group (PhOG) maintains a series of moored oceanographic buoys referred to as the University of Maine Ocean Observing System (UMOOS). UMOOS is a part of the larger Northeastern Regional Association of Coastal Ocean Observing System’s (NERACOOS) that monitors environmental variables in the Northwest Atlantic Ocean. In 2005, the Northeast Fisheries Science Center (NEFSC) began a partnership with PhOG to attach acoustic receivers (InnovaSea) on the oceanographic buoys deployed in the Gulf of Maine. Telemetry monitoring has been continuous since that time. We conducted laboratory tests prior to deployment to ensure the acoustic receivers would not interfere with the electronics and sensors of the buoys and vice versa (Goulette et al. 2014). Additionally, we developed custom hardware to attach the acoustic receivers to the buoy's mooring line. Initially (2005 – 2011) acoustic receivers were attached to the anchor line at 10 m below the surface with the hydrophone oriented downwards towards the ocean floor. In 2012, acoustic receiver position was relocated to 50 m deep (Figure 2) with the hydrophone oriented towards the surface, which increased the number of detections received per transmitter. Acoustic receivers are deployed and retrieved by the PhOG team during routine buoy maintenance which generally occurs at 6 – 18 month intervals.

Telemetry Monitoring on Lobster Traps

There are nearly 3 million lobster traps deployed by Maine lobstermen annually (https://www.maine.gov/dmr/science-research/species/lobster/licenses-tags.html). Working with volunteer lobstermen, we formed the Telemetry Monitoring on Lobster Traps (tMOLT) project modeled after Manning and Pelletier's (2009) innovative Environmental Monitoring on Lobster Traps (eMOLT). The goals of this project were to (a) explore the efficacy of a new platform and (b) strengthen relationships will local fishermen. The NEFSC team distributes preprogrammed acoustic receivers to lobstermen who deploy them with commercial gear by affixing them to their lobster traps (Figure 3). When the lobstermen deploy their gear (usually late spring/early summer) they record the deployment date, time, and location. Each time the gear is tended and relocated, new deployment information is collected. Acoustic receivers are returned to us for download once the lobstermen's gear is retrieved for the season (mid/late fall). The tMOLT project began in 2010 and continued through 2016 before resources needed to be reallocated to other projects. The project will be back in the water in 2019 with 8 receivers deployed by 4 lobstermen.

Passive Acoustic Moorings

The NEFSC's Passive Acoustics Research Group frequently uses passive acoustic monitoring (PAM) to study marine animal vocalizations and anthropogenic impacts in the Northwest Atlantic (Van Parijs et al. 2009, 2015). PAM involves the deployment of acoustic recorders which can either be moored to the sea floor (bottom mounted), floating freely (drifters), or propelled by autonomous vehicles (gliders) (Figures 4 and 5). Acoustic recorders collect information on underwater sounds mostly ranging from 10Hz to 100 kHz. These recordings are used to identify spatial distribution and temporal patterns of the occurrence of acoustically active species such as marine mammals, fish, and invertebrates. In addition, the specific sounds used and the timing thereof can provide information on species behavior (e.g., mating, feeding, migration). These data are likewise used to assess the presence and degree of anthropogenic sounds such as vessel noise, echo sounders, sonar, and seismic exploration or pile driving. PAM data collection can take place over long periods of time (months to years) and over large spatial scales. Over the course of several years, acoustic receivers were supplied for attachment to various PAM recorders. Acoustic receivers were deployed on bottom mounted recorders both on the shelf and on the shelf break, as well as in deep water within the sound fixing and ranging (SOFAR) channel. In addition, acoustic receivers were attached to multiple gliders aimed at simultaneously collecting information on tagged Atlantic cod (*Gadus morhua*) and their spawning sounds as well as other tagged fish or sharks.

Acoustic receivers were attached in a number of different ways: using cable ties to affix to the side of the Marine Autonomous Recording Units (MARUs), integrated within the VR2AR acoustic release system for the SoundTrap (ST) deployments, or top mounted on gliders. When the passive acoustic recorders are retrieved (via acoustic release or simple collection of the unit for gliders), the acoustic telemetry receivers are retrieved simultaneously.

Gliders

Slocum gliders (autonomous underwater vehicles) are often used in the Northwest Atlantic Ocean to collect data on a number of oceanographic variables. These subsurface vessels can be programmed to execute a specific path and have the capability to be deployed long term (e.g., months). We have partnered with a number of researchers using the Slocum gliders and provided them with acoustic receivers to attach to their vessels (Figure 5). Detection data collected by the acoustic receivers can be paired with the location data from the glider's GPS unit. Together they provide the location, date, and time of any transmitters encountered during the glider's deployment. Preprogrammed environmental sampling variables collected onboard the glider (including dissolved oxygen, temperature, depth, density, and salinity) can also be attributed to locations of transmitter detections for habitat description. PhOG deploys Slocum gliders retrofitted with a dorsally mounted acoustic receiver with the goal of detecting tagged Atlantic sturgeon (*Acipenser oxyrinchus*) in coastal Maine. The collaboration with PhOG is planned to continue into 2020, with seasonal deployments of gliders in and off the coast of the Gulf of Maine. Additionally, we have partnered with the Woods Hole Oceanographic Institution as well as members of NEFSC's Passive Acoustics Research Group to outfit gliders in the Gulf of Maine and Massachusetts Bay.

Coastal Moorings

Our seasonal (April – November) "home arrays" are traditionally deployed in rivers, estuaries, and bay environments. These deployments are for our acoustic telemetry studies occurring in a specific river for a given year. However, for a number of years we deployed additional receivers mounted on our traditional concrete moorings or with acoustic releases in several estuaries where we were not releasing transmitters. We termed this array of receivers the "Coastal Array," as it was not specific to any one project but provided detection data from any species that ventured into the estuaries being monitored. This project ran from 2008 through 2017 peaking in 2016 with 23 units deployed.

Data Processing, Management, and Distribution

We download receiver data from all platforms with the most current version of the InnovaSea software, VUE. Data quality control and assurance are identical for each platform. We consider single detections at a station valid only if we can corroborate them with ancillary information (e.g., detections at neighboring sites, past track history (Goulette et al. 2014)). For transmitters that we release, we cross-reference and enter all detections into our database. If unassigned transmitters are noted, raw data files are sent to InnovaSea for reconciling with other researchers. InnovaSea then notifies the researchers that we have detections for their transmitters. If researchers contact us, we exchange our detection and location data with their basic information, such as the species tagged, and enter that information into our database. If a transmitter remains unassigned, we search 2 databases: the Atlantic Cooperative Telemetry Network (ACT; http://www.theactnetwork.com/) and the Ocean Tracking Network (OTN; www.oceantrackingnetwork.org/). If no resolution is made, these transmitters are designated as unknown. Once ownership is assigned, we import and enter all data into a Microsoft Access relational database with 4 core tables: location, deployment, detections, and primary investigator. Transmitter codes are a primary key that link these tables, and our format follows standard Ocean Tracking Network database design and nomenclature. Metadata for each project and associated files are uploaded to the OTN where researchers can locate their transmitter detections if they have not already started a dialog with us and received them. Our OTN PlatOpus related projects presently include Gulf of Maine (GMG) and Gulf of Maine Estuary Network (GMEN).

RESULTS AND DISCUSSION

At the end of our 2012 season, PlatOpus had detected 265 individual transmitters implanted in 11 species for a total of 15,185 detections. Eighteen different organizations were able to learn more about their study animals from the detections provided by the project. PlatOpus now totals 369,871 detections and has increased the number of individual transmitters detected to 1,102 and the different number of species to 23 (Tables 2 and 3). More importantly, these detections have benefitted 50 researchers from 34 different organizations (Table 4). Utilizing the resources of the OTN, ACT, and InnovaSea's customer support, we have been able to identify owners of 97.5% of the transmitters detected in PlatOpus.

Three species, Atlantic salmon, Atlantic sturgeon, and Atlantic cod, account for over two thirds of the total number of transmitters detected (Table 2). Because this program primarily originated to provide the NEFSC with additional detections of our tagged Atlantic salmon outside our home arrays, it is not surprising Atlantic salmon has the highest number of individuals detected (n = 312). Additionally, when partnering with PhOG and the University of Maine- Atlantic sturgeon were a priority. A high number (n = 202) of Atlantic sturgeon transmitters are detected through PlatOpus because of their long migrations covering a large area. Another 5 species (American eel [Anguilla rostrate], American shad [Alosa sapidissima], sea run alewife [Alosa pseudoharengus], spiny dogfish [Squalus acanthias], and striped bass [Morone saxatilis]) each represent between 1.2 and 8.6% of all transmitters and collectively amount to 25.5% of the total. The remaining 15 species, totaling less than 5% of all transmitters, each account for 1% or less of the total with the remaining 2.5% of all transmitters being unidentified (Table 2). The top 3 species tagged by the most organizations are Atlantic salmon, striped bass, and Atlantic sturgeon (Figure 6).

Because of the poor recovery rate, we ceased using drifters as a deployment method for PlatOpus after 2011. In addition to our original PlatOpus methods (oceanographic buoys and commercial lobster gear), we have been able to incorporate passive acoustic moorings, gliders, acoustic release units and coastal moorings through partnerships with other researchers (Tables 1 and 5). The PhOG oceanographic buoys have detected the highest number of individual transmitters with the most diversity – 692 unique transmitters belonging to 17 different species. Passive acoustic moorings have detected 245 unique transmitters implanted in 14 different species, and the commercial lobster gear has detected 10 different species and a total of 169 unique transmitters (Table 5). Monthly coverage and deployment location play an important role in the number of unique transmitters detected by each platform (Table 6.)

The remaining gear types (acoustic release, drifters, gliders, and coastal moorings) have detected 6 or fewer different species, though individual transmitter ID numbers are high for some platforms. The high number of unique transmitters for a platform that has detected relatively few species tends to be the result of receivers being deployed in an area for a specific project. For example, gliders have detected only 6 different species but a total of 211 unique transmitters. Nearly 96% of these unique transmitters belong to a single species – Atlantic cod (Table 5). The high number of Atlantic cod detected on gliders is the result of several glider missions taking place in an area where an Atlantic cod spawning study was occurring.

Out of the 34 different organizations that have deployed transmitters detected by PlatOpus, more than half (n = 19) of them have 4 or more individuals detected on our arrays. Many of the data collected through PlatOpus have provided valuable information to researchers who have been able to utilize them to cover a broad spectrum of studies. Several researchers have incorporated detections from the PlatOpus program into migration studies to help draw a more complete picture of their species marine movements (Babin et al. 2019; Collatos 2018; Dadswell et al. 2016). While these detections may be ancillary to the researchers' original study design, they provide valuable data identifying previously unknown migration corridors, alternative strategies, or new habitats. These data are also contributing to stock assessments (ASMFC 2017), mortality estimates (Block et al. 2019), and behavior studies (Lilly et al. 2019) for different species. They have also been used to identify safer time frames for industrial projects (e.g., tidal power, dredging) to reduce impacts on certain species (Wippelhauser et al. 2017). Additionally, novel data from PlatOpus are helping to depict a more holistic portrayal of what may be required for successful restoration efforts (Gahagan and Bailey 2019) of threatened or endangered species or species of concern. Being able to provide the amount of data that PlatOpus generates to such a large number of researchers with limited resources is a huge gain to the science community as a whole. While PlatOpus efforts on their own do not support an original study, they provide an innovative mechanism to collect meaningful data for a broad range of research studies.

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TABLES

Table 1. Annual receiver deployments according to gear type. Some deployments span more than one calendar year but are only represented in the year they were deployed. Receiver deployments are not entered into the database until they have been retrieved, therefore not all deployments to date are represented in the table. NOTE: Goulette et al. 2014 indicated there were 8 Telemetry Monitoring on Lobster Traps (tMOLT) deployments in 2011. However, one of these receivers failed upon retrieval and no data was recovered from the unit, so it is not included in this table.

Year	Acoustic Release	Drifter	Glider	Lobster Gear	Mooring	Oceanographic Buoy	Passive Acoustic Monitoring	Total
2005						20		20
2006						16		16
2007						20		20
2008					14	13		27
2009					4	15		19
2010		7		9	4	9		29
2011		6		7	8	11		32
2012				4	4	10		18
2013				4	4	12		20
2014				6	16	9	6	37
2015	2		2	8	18	7	11	48
2016	2		1	8	21	7	1	40
2017	3		1			3		7
2018						3	1	4
Total	7	13	4	46	93	155	19	337

Table 2. Total number of transmitters for each species detected on PlatOpus for all years combined.

Species Name	# Transmitters
American eel (*Anguilla rostrata*)	95
American lobster (*Homarus americanus*)	3
American shad (*Alosa sapidissima*)	14
Atlantic bluefin tuna (*Thunnus thynnus*)	7
Atlantic cod (*Gadus morhua*)	229
Atlantic salmon (*Salmo salar*)	312
Atlantic sturgeon (*Acipenser oxyrinchus*)	202
Black sea bass (*Centropristis striata*)	1
Blue shark (*Prionace glauca*)	1
Blueback herring (*Alosa aestivalis*)	3
Dusky shark (*Carcharhinus obscurus*)	1
Haddock (*Melanogrammus aeglefinus*)	4
Porbeagle shark (*Lamna nasus*)	1
Sand tiger shark (*Carcharias taurus*)	1
Sandbar shark (*Carcharhinus plumbeus*)	5
Sea run alewife (*Alosa pseudoharengus*)	81
Shortnose sturgeon (*Acipenser brevirostrum*)	8
Spiny dogfish (*Squalus acanthias*)	34
Striped bass (*Morone saxatilis*)	57
Summer flounder (*Paralichthys dentatus*)	1
UNKNOWN	28
White shark (*Carcharodon carcharias*)	12
Winter flounder (*Pseudopleuronectes americanus*)	1
Winter skate (*Leucoraja ocellata*)	1
Total	1,102

Table 3. Number of transmitters for each species by year from initial deployments through 2018. Many transmitters (n = 211) were detected in multiple years; therefore, the total number of transmitters is much higher than the total number of 1,102 unique transmitters detected across all years. NOTE: Some numbers in this table differ from Goulette et al. 2014 because some previously UNKNOWN transmitters have since been identified, some transmitters have been detected in different years, and multiple transmitters in some animals have been discovered.

Species Name	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total
American eel (*Anguilla rostrata*)								1			1	50	43		95
American lobster (*Homarus americanus*)													3		3
American shad (*Alosa sapidissima*)								1			2	5		6	14
Atlantic bluefin tuna (*Thunnus thynnus*)								1	1	2	3	3			10
Atlantic cod (*Gadus morhua*)						1	1	8	16	113	144	104	3		390
Atlantic salmon (*Salmo salar*)	10	11		5	10	10	24	51	55	4	16	58	9	49	312
Atlantic sturgeon (*Acipenser oxyrinchus*)				6	3	30	15	24	46	31	46	80	28	23	332
Black sea bass (*Centropristis striata*)														1	1
Blue shark (*Prionace glauca*)										1					1
Blueback herring (*Alosa aestivalis*)									3						3
Dusky shark (*Carcharhinus obscurus*)														1	1
Haddock (*Melanogrammus aeglefinus*)											4	1			5
Porbeagle shark (*Lamna nasus*)											1				1
Sand tiger shark (*Carcharias taurus*)												1			1
Sandbar shark (*Carcharhinus plumbeus*)														5	5

Sea run alewife (*Alosa pseudoharengus*)					2					23	54		2		81
Shortnose sturgeon (*Acipenser brevirostrum*)						2				3	1	3	2		11
Spiny dogfish (*Squalus acanthias*)					4	12	17	3	1					1	38
Striped bass (*Morone saxatilis*)		1	1	3		9	6	5	4	3	3	11	6	7	59
Summer flounder (*Paralichthys dentatus*)														1	1
UNKNOWN				2	1	1	2	1	3	3	3	7	1	7	31
White shark (*Carcharodon carcharias*)								4	1	1	2		1	4	13
Winter flounder (*Pseudopleuronectes americanus*)					1										1
Winter skate (*Leucoraja ocellata*)														1	1
Total	10	12	1	16	21	65	65	99	130	184	280	323	98	106	1,410

Table 4. Number of transmitters by research organization. Total number of individual researchers whose transmitters our platforms have detected is 50, but multiple researchers from within an organization may be working on different projects.

Organization	#Transmitters
Acadia University	9
Atlantic Salmon Federation	57
Coastal Carolina University	1
Delaware State University	4
Department of Fisheries and Oceans	4
DNREC Delaware Division of Fish and Wildlife	2
East Carolina University	32
Maine Department of Marine Resources	50
Massachusetts Division of Marine Fisheries	270
Ministère des Forêts	2
National Marine Fisheries Service	125
New Hampshire Fish and Game	3
Normandeau Environmental Consultants	43
Northeastern University	7
NY State Department of Environmental Conservation	3
Ocean Tracking Network	1
Ocearch	1
Parks Canada	1
Smithsonian Environmental Research Center	1
Stanford University	6
Stony Brook University	11
Monmouth University	10
United States Fish and Wildlife Service	3
United States Geological Survey	27
Unites States Department of the Navy	1
University of Maine School of Marine Sciences	69
University of Maryland Center for Environmental Science	7
University of New Brunswick	3
University of New England	52
University of New Hampshire	1
University Southern Maine	32
UNKNOWN	28
USGS Massachusetts Cooperative Fish and Wildlife Research Unit	2
USGS Maine Cooperative Fish and Wildlife Research Unit	233
Wildlife Conservation Society	1
Total	1,102

Table 5. Number of transmitters by species by gear type through 2018. Many transmitters are detected in multiple years (n = 211); therefore, the total number of transmitters in this table is much higher than the total number of 1,102 unique transmitters detected across all years.

Species Name	Acoustic Release	Drifter	Glider	Lobster Gear	Mooring	Oceanographic Buoy	Passive Acoustic Monitoring	Total
American eel	89			2		9		100
American lobster						3		3
American shad						14		14
Atlantic bluefin tuna				3		8	1	12
Atlantic cod			202	2		91	203	498
Atlantic salmon		2	1	50	42	224	3	322
Atlantic sturgeon	16	1	2	94	51	218	13	395
Black sea bass							1	1
Blue shark						1		1
Blueback herring				2		1		3
Dusky shark							1	1
Haddock			4			2		6
Porbeagle shark						1	1	2
Sand tiger shark			1					1
Sandbar shark							5	5
Sea run alewife					77	4	3	84
Shortnose sturgeon	2			1	6	3		12
Spiny dogfish		1		6		32	1	40
Striped bass		1	1	3	1	51	4	61
Summer flounder							1	1
UNKNOWN				3	5	19	4	31
White shark				3		10	3	16
Winter flounder						1		1
Winter skate							1	1
Total	107	5	211	169	182	692	245	1,611

Table 6. Monthly timeline of coverage from PlatOpus deployments according to gear type. Not all gear types are utilized each year.

Year	January	February	March	April	May	June	July	August	September	October	November	December
Acoustic Release	■	■	■	■							■	■
Drifter					■	■	■	■				
Glider				■	■	■	■	■	■	■	■	
Lobster Gear					■	■	■	■	■	■	■	
Mooring				■	■	■	■	■	■	■	■	
Oceanographic Buoy	■	■	■	■	■	■	■	■	■	■	■	■
Passive Acoustic Mooring	■	■	■	■	■	■	■	■	■	■	■	■

Figures

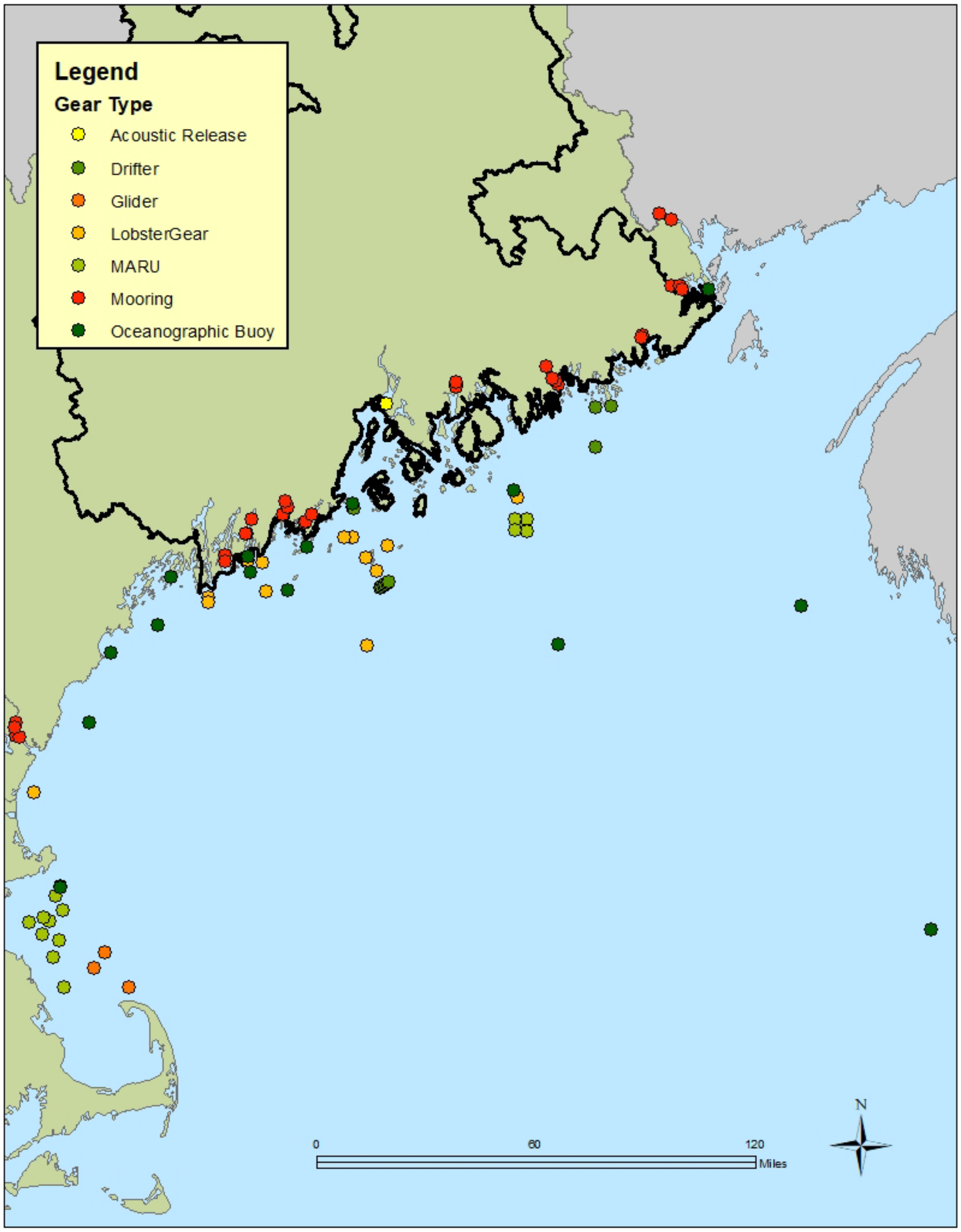


Figure 1. PlatOpus receiver deployment locations from 2005 – 2018. Not all locations were utilized each year. Marine autonomous recording unit (MARU) is part of the passive acoustic monitoring program.

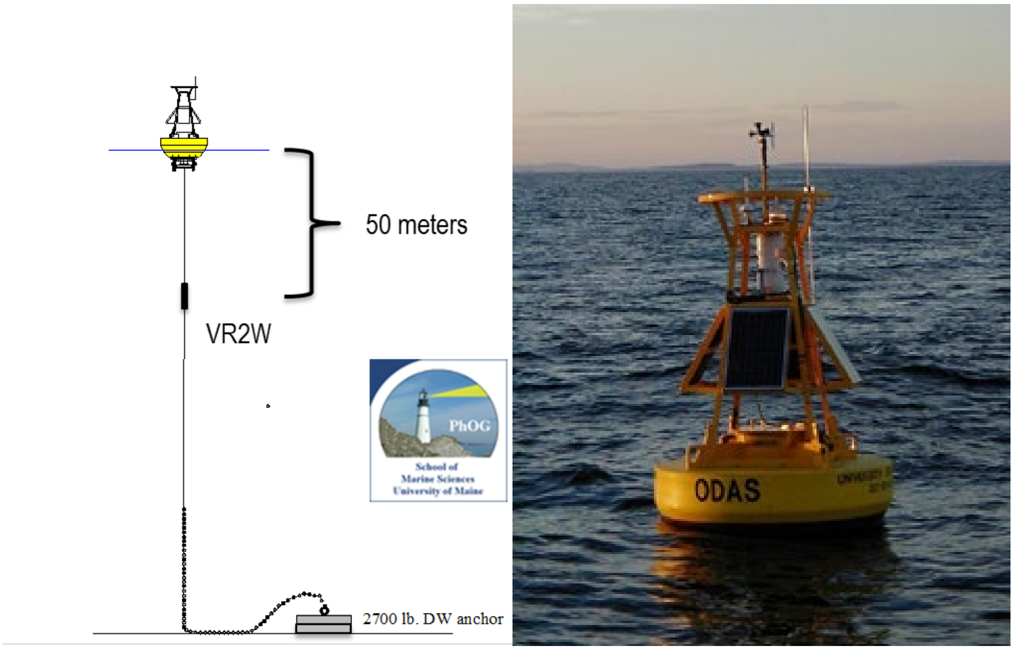


Figure 2. An image of an ocean observing system buoy maintained by the University of Maine's Physical Oceanography Group (PhOG). The diagram on the left illustrates the deployment design utilized since 2012 with the receiver (VR2W) attached to the mooring cable 50 meters below the surface.

Figure 3. An acoustic receiver (VR2W) attached to a lobster trap – ready for deployment. Photo Credit – John Melquist Sr.

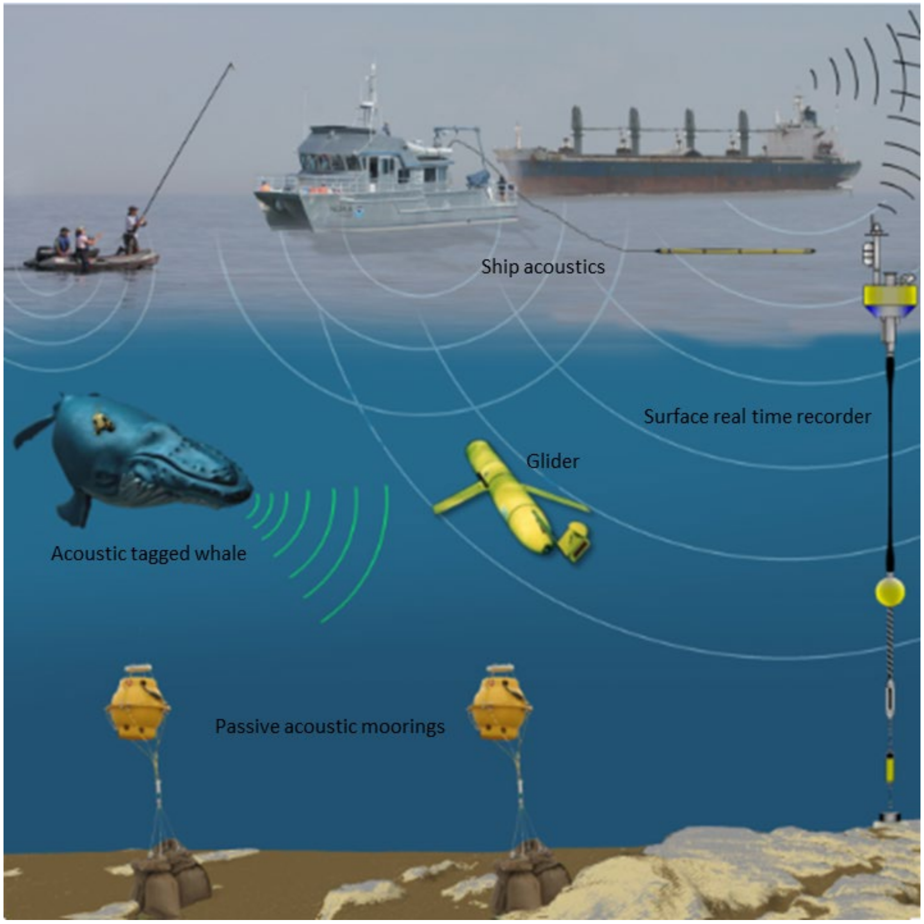
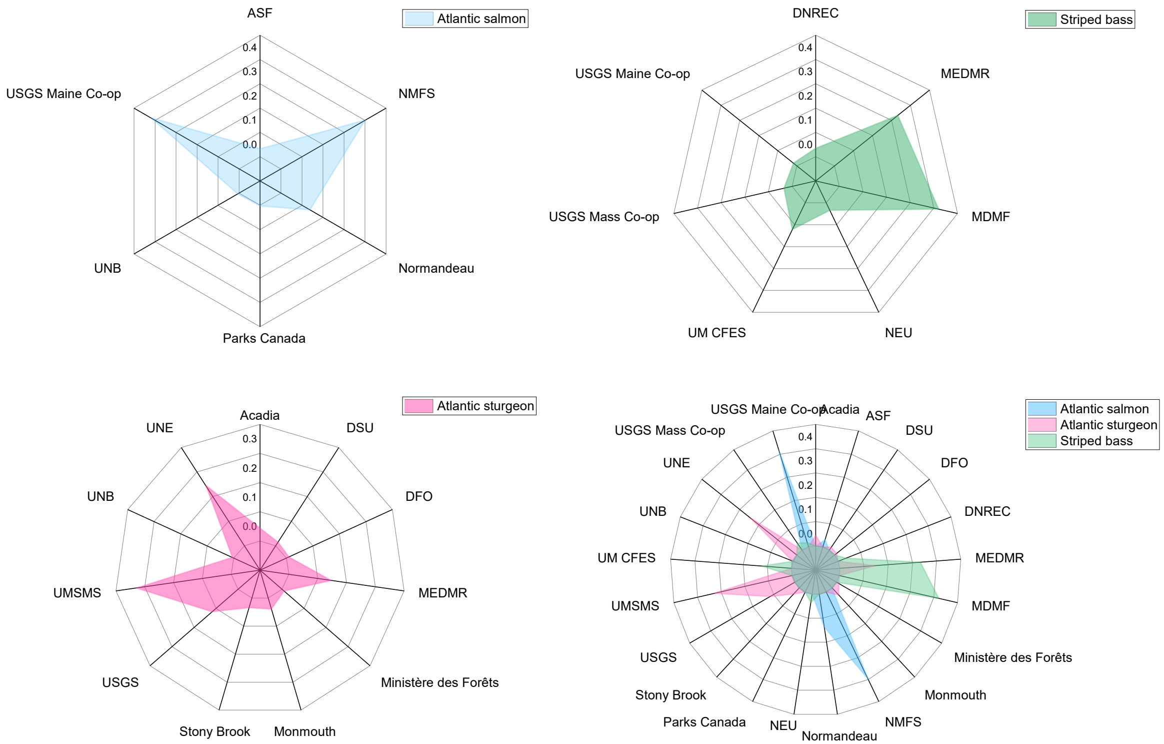


Figure 4. Depiction of the different types of passive acoustic technology that are used for data collection. These types include bottom mounted recorders, surface real time recorders, and autonomous vehicles called gliders, in addition to acoustic arrays towed behind a ship and acoustic tags placed on animals. The first 3 instruments are those typically used for the deployment of acoustic telemetry receivers. Figure Credit – Mike Thompson NOAA/Stellwagen Bank National Marine Sanctuary.

Figure 5. A G2 Teledyne Webb Slocum glider retrofitted with an InnovaSea VR2W receiver before deployment off of Northeast Harbor, ME.



Acronym	Organization
Acadia	Acadia University
ASF	Atlantic Salmon Federation
DSU	Delaware State University
DFO	Department of Fisheries and Oceans
DNREC	DNREC Delaware Division of Fish and Wildlife
MEDMR	Maine Department of Marine Resources
MDMF	Massachusetts Division of Marine Fisheries
Ministère des Forêts	Ministère des Forêts
Monmouth	Monmouth University
NMFS	National Marine Fisheries Service
Normandeau	Normandeau Environmental Consultants
NEU	Northeastern University
Parks Canada	Parks Canada
Stony Brook	Stony Brook University
USGS	United States Geological Survey
UMSMS	University of Maine School of Marine Sciences
UM CFES	University of Maryland Center for Environmental Science
UNB	University of New Brunswick
UNE	University of New England
USGS Mass Co-op	USGS Massachusetts Cooperative Fish and Wildlife Research Unit
USGS Maine Co-op	USGS Maine Cooperative Fish and Wildlife Research Unit

Figure 6. The top 3 species tagged by the highest number of organizations: Atlantic salmon (*Salmo salar*), striped bass (*Morone saxatilis*), and Atlantic sturgeon (*Acipenser oxyrinchus*). Not all organizations tagged each of the 3 species. A table of acronyms and full names follows the figure.

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