BIOTELEMETRY OPTIONS FOR TRACKING AND MONITORING MARINE ORGANISMS IN PRINCE WILLIAM SOUND AND THE COPPER RIVER DELTA REGION

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Purpose

This paper is intended to provide a brief overview of the rich and developing field of biotelemetry, or remote sensing of mobile organisms, with specific reference to those organisms that reside within and migrate through the Gulf of Alaska and the Prince William Sound and Copper River delta ecosystem. This paper can serve as an initial reference for those unfamiliar with the field of biotelemetry and as a bridge to additional information for those interested in furthering their understanding. This paper includes a series of appendices with greater detail on specific aspects of the field of biotelemetry including a glossary of biotelemetry terms (Appendix A); a listing of telemetry studies within the Gulf of Alaska (Appendix B); a listing of larger acoustic telemetry programs (Appendix C); and information on biotelemetry manufacturers (Appendix D).

Introduction

In 2005, the North Pacific Research Board (NPRB) and Prince William Sound (PWS) Oil Spill Recovery Institute (OSRI) both completed comprehensive science plans for marine research needs in the Gulf of Alaska (GOA) and PWS (NPRB 2005; PWS OSRI 2005). The NPRB Science Plan has eight primary research categories - lower trophic level productivity, fish habitat, fish and invertebrates, marine mammals, seabirds, humans, other prominent issues, and integrated ecosystem research programs. The first six represent major components of the marine ecosystem, while integrated ecosystem research is considered the most critical category, and is exemplified by studies that cut across disciplines and build upon issues raised in other themes (NPRB 2005). The goal of the PWS OSRI is to combine hypothesis-driven long-term research with short-term process studies to understand mechanisms underlying long-term dynamics between the major coastal currents of the GOA, the coastal ocean, and the fauna and flora of PWS. Of particular interest is understanding the predominant causes of ecological variability (PWS OSRI 2005).

Information on migration patterns and habitat use of fish and invertebrates, marine mammals, and seabirds are needed to make ecologically sound and effective management decisions. At the same time, determining numbers and rates of animal movement can help elucidate trophic characteristics of the marine regions being studied. Many marine fish exhibit large seasonal movements that influence overlap of predator and prey, as well as seasonal availability of fish to commercial fisheries. Some species are almost entirely independent of benthic habitat, they may be closely dependent on particular bottom structure, or require overwintering areas along the outer shelf and shallow waters for spawning. Similarly different critical life stages may be associated with particular habitats, as well as connectivity between them. There is also a need to elucidate migration patterns for seabirds and marine mammals, especially as they relate to variations in the ocean environment. How will these migration patterns be impacted by climate change? To what extent do migrations and foraging activities overlap the presence of major commercial fisheries? What are the pelagic distribution and abundance of seabirds and marine mammals? Research in this category may also help explain contaminant loads. For example, harbor seals have lower levels of persistent organic polychlorides (POPs) in PWS than specimens from the Pacific Northwest. Some fur seals from St. Paul have shown higher concentrations than ringed and bearded seals from the Bering Sea or from PWS. Such results may result from large migrations that occur to areas far south of Alaska where contaminant loads are much higher (NPRB and PWS OSRI 2007 Priorities).

The field of biotelemetry encompasses a growing number of disciplines ranging from medical telemetry for patient monitoring and human research to studies on fish and wildlife that address natural history and resource management issues. Unprecedented advances in electronics and telecommunications are providing new approaches and tools for scientists in these fields. These advances can substantially enhance the ability to meet research or management goals, yet it is quite challenging to keep up with the available technology. The marine waters of the Northeast (NE) Pacific including the GOA with its size, remote nature, and abundant migratory fish and wildlife make it an ideal region for a variety of biotelemetry applications.

Overview of Telemetry Technology

Biotelemetry is the remote measurement (telemetry) of biologically relevant data, including behavioral, physiological, or environmental data. Data is telemetered through the use of electronic tags. Electronic tags can be divided into three basic categories to include transmitting, data storage or archival, and transponding. All of these systems operate on the premise of transmitting information from an organism to researchers in the form of sound energy transmission, either in radio (20 to 400 MHz), acoustic (or ultrasonic) (20-300 kHz), or satellite (UHF 401.650 MHz) frequencies. See Appendix A for a glossary of telemetry terms and Appendix B for discussion of telemetry studies in the GOA.

A transmitter emits or sends information (data) to a receiver. This transmission most typically occurs by means of acoustical waves in water and by radio waves through air or by optical emitters. Acoustic telemetry is used in brackish and saline water or in deep bodies of freshwater such as lakes and reservoirs. Radio telemetry is used for transmission in air or through shallow depths of freshwater. Satellite telemetry uses a platform transmitter terminal (PTT) attached to an animal which sends an ultra high frequency signal to satellites (Argos). An archival tag is a recording device that stores (archives) sensor data on some recording medium or in solid state (electronic) memory for later retrieval. Also called a data recorder or data storage tag (DST). The DST must be recovered to collect data stored in memory. Another version of this tag type is the pop-up satellite-transmitting archival tag (PSAT). The PSAT can be used for large fish and other animals that do not remain at the surface for long periods of time. The PSAT collects and stores data throughout its deployment. It releases itself from the animal and floats to the surface on a user-specified date. Data are then transmitted to the Argos system.

Transmitters can include sensors to detect light intensity, water pressure, water temperature, salinity, internal body temperature, respiration, and heart activity. Archival tags may function simply as data loggers that measure temperature and water depth or as programmable devices capable of recording direct estimates of the geographical position of a fish at regular intervals over periods of months to years. Archival tags can record environment parameters such as temperature, depth, salinity, pressure, light and chemical and physiological indicators at set intervals.

Transponders are typically known as passive-integrated-transponder (PIT) tags. PIT tags are miniaturized radio-transmitters encapsulated in a small glass cylinder. The PIT tag does not contain any power source, therefore known as "passive," but is instead energized by the electric current induced in a very small, densely wound coil. All other electronic tags are known as “active” tags as they have their own power source.

Transmitter selection and attachment methods for birds and mammals (and fish) should follow the guidelines suggested by Mech et al. (1965): minimum weight, minimum effect on the animal, maximum protection for the transmitter, permanence of the attachment, and maximum protection of transmitter from animal mortality factors such as predation and accident.

Although biotelemetry offers advantages few other technologies have, it still presents technological challenges for researchers investigating small organisms. The rule of thumb is that to minimize stress and effects from tagging and tag burden, such as increased energetic expenditure, altered behavior, and reduced fitness, a telemetry tag should weigh 2% or less of the body weight of the subject (Winter 1983; Cooke et al. 2004). For small animals, size and mass of sensors limits the kind or number of variables that can be measured. Battery size is also a constraint. Batteries tiny enough for small animals might be exhausted so quickly by the continuous transmission of data that records are too short to be useful and the power produced by such a small battery reduces the transmission range of the tag often by one-half or more from the next largest tag. The smallest acoustic tags currently used for fish studies range from 0.6 g to 1.6 g. The smaller tag can be used in salmon smolts as small as 30 g (approximately 90-100 mm) while the larger tag can be used in salmon of 80 g (approximately 180 mm or larger). The life span of the smaller tag is 14-21 days while the larger tag is 85-90 days. Even with these small tags, to date there have been no acoustic tracking studies of marine forage fish such as Pacific herring, sand lace, or smelt.

Attachment methods for fitting transmitters to birds vary widely. Examples include transmitters with whip antennas fitted to backpacks with attachment loops under the wings; loops meeting near the breast, or loops under the legs; loop-antenna harness-chest packs; whip antennas adhered directly to tail feathers; collars, neck band mounts, or necklaces; and leg-band transmitters. Other methods include suture-only attachments; adhesive-only attachments; suture and adhesive attachment; patagial band mounts; and surgical implants (Mech and Barber 2002).

Collars have traditionally been used to fit transmitter packages on mammals with prominent necks, large ears, or horns/antlers since these structures help prevent the collar from slipping over and off the head of the animal. Some mammals do not retain collars well since they do not have prominent necks, mammals such as dolphins have instead been fitted with backpack harnesses (Jennings and Gandy 1980). Tail harnesses have also been used to fit animals with short stocky necks such as manatees (Priede and French 1991). Some alternatives to applying collars or harnesses on mammals include ear-tag transmitters and transmitters fixed with adhesive or suction directly onto the mammal such as seals and killer whales (Hastings et al. 2001; Rehberg and Small 2001; Baird et al. 2005). Surgically implanted transmitters such as subcutaneous transmitters or abdominal transmitters represent other attachment alternatives used in aquatic mammals such as river otters and sea otters (Reid et al. 1986; Ralls et al.1989).

Transmitter attachment methods in fish can be internal or external. Internal attachment is considered invasive (especially in smaller animals), requiring surgical implantation or gastric insertion in certain situations. External attachment is often used with archival tags. This attachment method (usually on the dorsal side of the body) is being used in a number of species, size and age classes (Block et al. 2002; Seitz et al. 2003; Walker et al. 2005; Wilson et al. 2005), but it may cause more complications. Externally attached tags may cause increased drag and affect swimming speed and energy expenditure. They may also cause abrasions or snag on objects and dorsally attached tags can disrupt balance (Winter 1983). Internal implantation avoids some of the problems associated with external attachment, but results in its own set of complications. The best option for internal implantation is surgical, but these procedures are invasive, take longer to perform, require more handling, require anesthesia and longer recovery periods, and bring the risk of infection, especially in warm water (Winter 1983; Thorsteinsson 2002).

The range of detection of transmitters varies between terrestrial and freshwater systems, in which radio frequencies travel well, compared with ocean and estuarine waters, in which ultrasound is used. Radio signals can be heard kilometers (km) to tens of km from the transmitter. Animals (fish and wildlife) can be tracked using fixed receiving stations (land/water) or by mobile (manual) tracking where animals can be tracked by air (plane), land (car), or water (boat). Satellite tracking employs a much higher-powered transmitter attached to an animal. The signal is received by satellites and the animal's calculated location is sent to a researcher's computer. By contrast, acoustic transmitters achieve a much smaller range – from 100 meters (m) up to a maximum of 1 km (much lower range with background noise) and suffer from strong attenuation and reflection or refraction of signals (multipath). Animals can be tracked using underwater (moored or fixed) receivers and by mobile tracking by boat. The terms "passive" acoustics refers to the use of moored receivers and "active" acoustics refers to manual tracking, as opposed to use of "passive" and "active" as power sources in tags. New applications include linked receiver networks allowing tracking of organisms in three-dimensions (horizontal and vertical position) using either radio or acoustic telemetry (O'dor et al. 1998 and 2001; Steig 1999; Grothues et al. 2005); and tracking marine animals over great distances using acoustic "curtains" or lines of linked or single receivers at key migration points (Welch et al. 2003; Stark et al. 2005; Heupel et al. 2006a).

Acoustic telemetry was first used for study of fish movement as early as 1955 when the National Marine Fisheries Service attached 132-kHz tags to adult chinook and coho salmon (Trefethen 1956). Radio telemetry has been used to study wildlife since 1963 (Mech and Barber 2002), while satellite telemetry has been used to study wildlife and pelagic fish since the early 1980's (Seegar et al. 1996) . A recent innovation is the creation of combined acoustic and radio telemetry (CART tag) where transmitters can oscillate between radio in freshwater to acoustic in saltwater (Niezgoda et al. 1998). Since these initial studies, these telemetry types have been used worldwide to track movements of many fish and wildlife species, from invertebrates such as squid and crabs (Stone et al. 1993; Stark et al. 2005), to fishes, most notably salmonids (Thorsteinsson 2002), marine mammals such as sea lions, whales, and manatees (Reid et al. 2001, Block et al. 2002), reptiles such as sea turtles (Keinath and Musick 1993) and numerous terrestrial wildlife species (Mech and Barber 2002). The use of internal tags, especially PIT tags, has become increasingly popular since their introduction in the early 1980s. PIT tags are used to identify hundreds to millions of individual fish passing through fish bypass systems on the Columbia River (PSMFC 2000).

The use of electronic tags can be organized by the type of telemetry, by the ecotype to be studied, and by the type of organism occupying that ecotype (**Table 1**). Ecotypes correspond to general ecosystem types used by major animal groups – aerial – bird migration; terrestrial – mainland and island areas used by birds and mammals; freshwater – anadromous and freshwater fishes and aquatic mammals; estuarine tidally-influenced areas with brackish waters - anadromous and marine fishes, marine invertebrates, and marine mammals; nearshore marine shoreline areas to 20-m depth (photic zone) – benthic invertebrates, anadromous and marine fishes, marine mammals; pelagic offshore waters beyond nearshore – anadromous and marine fishes, marine mammals, and benthic invertebrates: seabirds are considered under terrestrial and aerial zones.

The sound properties of each telemetry type in air, freshwater, brackish and saltwater dictates where that type can be used. Radio and satellite telemetry can be used with any organism that spends time in air – on land or water, or in shallow freshwater. Acoustic telemetry can be used in brackish and marine waters and in larger/deeper freshwater areas. CART tags can be used in all environments. Archival tags can be used in most any environment but require collection of the tag. Automatic detection of PIT tags requires that the animal be routed through an antenna system to energize the tag.

Table 1. General telemetry types available for use by ecotype and major category of organism: archival tags are considered effective in all conditions.

Ecotype	Organism	Satellite	Radio	Acoustic	Combined Radio/Acoustic (CART)	Passive Integrated Transponder (PIT)[a]
Aerial	Bird	Yes	Yes	No	No	No
Terrestrial	Bird	Yes	Yes	No	No	No
	Mammal	Yes	Yes	No	No	No
Freshwater	Fish	No	Yes	Possible	Yes	Yes
	Mammal	Yes	Yes	Possible	Yes	No
Estuarine	Invertebrate	No	No	Yes	Yes	Yes
	Fish	Yes	Possible	Yes	Yes	Yes
	Mammal	Yes	Yes	Yes	Yes	Yes
Nearshore	Invertebrate	No	Possible	Yes	Yes	No
	Fish	Yes	No	Yes	Yes	No
	Mammal	Yes	Possible	Yes	Yes	No
Pelagic	Fish	Yes	No	Yes	Yes	No
	Mammal	Yes	Possible	Yes	Possible	No

a. PIT-tag application using automated receiver where the organism moves through a transceiver. Any organism can be recaptured and scanned for tag so all organisms can be PIT-tagged.

Previous and Ongoing Telemetry Studies in the Gulf of Alaska

There is a rich history of telemetry studies in the GOA and PWS. Studies have been conducted using all telemetry types in all ecotypes and for all major organism types. These studies include single studies by individual researchers and ongoing telemetry programs managed by university, tribal, state or federal agencies. Appendix B provides a detailed listing of available studies and programs found through web and library searches. Following is a brief summary of selected studies.

More than any other group, biotelemetry has been used to assess the impacts of the Exxon Valdez oil spill on seabirds and migratory birds. These studies have been conducted over the past 15 years using radio and satellite telemetry tags or pop-up satellite tags (PSAT). The total mortality of dead seabirds was directly assessed through radio tracking of carcasses following the spill (Ford et al. 1996). One of the most unanticipated and revealing impacts of the spill on seabirds was exhibited by harlequin ducks- they suffered acute mortality during the spill and had continuing injury at the population level for years after the spill. Radio tracking revealed higher mortality rates in adult females that overwinter on heavily oiled Knight Island and Green Island than on unoiled Montague Island (Esler et al. 2000a, 2000b, and 2002). Outside of the specific assessment of oil spill impacts, radio telemetry has been used to determine and evaluate the movements, foraging areas (relation to forage fish), reproduction, survival and habitat use of a wide range of seabirds, migratory birds and shorebirds including – pigeon guillemot, golden plover, western sandpipers, black-legged kittiwake, tufted puffin, spectacled and common eider, brandt, Canada, emperor and white-fronted geese. These studies include ongoing radio telemetry programs through the Gulf Apex and Predator Prey (GAP) program, Western Hemisphere Shorebird Reserve Network (Copper River Delta), and the U.S. Geological Survey Banding and Radio Telemetry, and Seabirds, Forage Fish, and Marine Ecosystems programs (see Appendix Table B-1 for details and other references).

Satellite telemetry has been used to study other GOA long-range migratory birds including - red-throated, yellow-billed and common loons, common and thick-billed murres, tufted puffins, sandhill cranes, common, king, spectacled and Steller's eider, Barrow's and common goldeneye, oldsquaw, common and red-breasted merganser, surf and white scoters, and tundra swans. Studies have looked at the comparative ecology of loons, season movement and pelagic habitat use of murres and puffins, and migration of Steller's eider and threats from oil spills. The Seaduck Joint Venture (http://www.seaduckjv.org/index.html) is one major program that includes many of the seabirds monitored through satellite telemetry (see Appendix Table B-1 for details and other references).

Unlike seabirds, radio telemetry has not been used as extensively in the study of marine mammals. In the GOA, harbor seals have been studied to assess the reasons for the sharp population declines in PWS and to develop quantitative models of foraging behavior. Radio telemetry was also used to determine the survival of sea otters following the Exxon Valdez spill and to assess the success of California sea otter relocations (Ralls et al. 1992; Bodkin et al. 2002; Ballachey et al. 2003). Satellite telemetry has been the predominate telemetry technique to study large marine mammals in the GOA including Stellar sea lions, harbor and elephant seals, Beluga and humpback whales. This method has been applied to determine the recovery success of rehabilitated harbor and elephant seals, the local and long-distance migration of humpback whales from Hawaii to the GOA, and the wintering grounds of beluga whales providing information to assist in evaluating mercury bioaccumulation and for sustainable harvest (see Appendix Table B-2 for details and other references).

In the GOA, archival tags have been used or evaluated by the USGS in Pacific halibut (with PSAT) and post-smolt hatchery coho salmon (with DST), by NMFS with Steller sea lions (PSAT), and by University of Alaska and ADFG for harbor seals (PSAT). In fish studies, the PSAT tag proved useful for the study of halibut, one of the fish applications with demersal fish, with measurement of geographic position, temperature, and depths over an extended period of time (Seitz et al. 2003). In the study of coho salmon, researchers hope to document critical marine habitats (location, depth, time) and their relationship to the health and survival of salmonids in their first year at sea (Wilson et al. 2005). In the study of harbor seals, a variation of the DST is used called the time-depth recorder (TDR) or satellite-transmitted TDR (STDR). The harbor seal study is part of the GAP study (Harper and Wynne 2005) (See Appendix Tables B-2 and B-3 for details and other references).

A priority of the NPRB is to study factors affecting western Alaska salmon stock dynamics, mortality, and migration. The North Pacific Anadromous Fish Committee has funded tagging of Pacific salmon with DST tags in the NE Pacific and Bering Sea since 1998 to gather information on daily behavior and the range of temperatures fish encounter (Walker et al. 2000). Since 1998, hundreds of salmon have been tagged in the Bering Sea. Recovery rates from 1998-2004 ranged from 2.9-19.1 percent with an average return rate of 9.1 percent. Results have shown clear differences in behavior of salmon species, with sockeye and pink salmon remaining in near surface waters, chum salmon undergoing large daily vertical migrations, and Chinook showing an unusual holding pattern in deep, cold water (Walker et al. 2005) (See Appendix Table B-3 for details and other references).

Radio telemetry has been used to study the migration and habitat use of adult Chinook salmon, coho salmon smolts, and adult cutthroat trout in the Copper River delta and mainstem. These studies were undertaken to develop a long-term monitoring program to improve fisheries management of the salmon stocks, identify critical delta habitat for smolts, and to assess the impact of road crossings on upstream fish passage of trout (Smith et al. 2005; Jurica et al. 2005; Saiget 2005). Radio telemetry has been the primary biotelemetry method in studying the movements and habitat use of freshwater fishes around the world. In large rivers and lakes, acoustic and radio telemetry are often used (Thorsteinsson 2002; Reine 2005). Both methods are used often in tandem with PIT tags to evaluate the effectiveness of fishways, channel modifications, and flow manipulations in maintaining or improving the migrations of salmon and trout in Pacific Northwest rivers. Using data from these studies, mortality risk models have been developed to predict the likelihood of migration success depending on river flow and temperature conditions and to predict the consequences of climate change (Cooke et al. 2004).

Satellite telemetry has played a prominent role in the study of salmon sharks, an apex predator, in PWS. The Tagging of Pacific Pelagics (TOPPs) program is an initial project of the Census for Marine Life (CoML) intended to study the migrations of large migratory mammals and fish (Block et al. 2002; and Appendix C). The study of salmon sharks is a prominent component of the TOPP program. The management issue driving the research is the unknown effects of increasing sport fisheries, that more information is needed on the annual and seasonal movements of these sharks. Since 2002, over 51 sharks have been marked with satellite tags – single and dual tags of Argos and PSAT – documenting the shark range. Some sharks migrated rapidly southeast to Canada, while others remained to overwinter in the PWS and the GOA (Hulbert et al. 2005). In combination with the foraging range data, other methods identified that while salmon is the primary prey from July to December, these sharks are opportunistic, feeding on a wide variety of prey items. These foraging habits may explain the varying migration routes (Hulbert et al. 2005, Weng et al. 2005).

In PWS, there have been few acoustic telemetry studies of anadromous and marine fishes, despite the rapid evolution of acoustic technology and developing world wide applications. GOA and PWS studies have included: evaluating impacts of seafood waste discharge in Orca Inlet by tracking fish-heads, tracking ling cod and rockfish use of marine protected areas, and documenting the migration of adult steelhead into and out of Alaska rivers (see Appendix Table B-3 for details and other references).

The study of anadromous and marine fishes and mammals in nearshore and pelagic areas has undergone a minor revolution over the past 15 years with the major advances in acoustic telemetry technology. These changes include the development of miniaturized transmitters (Voegeli et al. 1998), three-dimensional tracking systems (Niezgoda et al. 1998; O'Dor et al. 1998, 2001; Steig 1999), low-cost receivers and acoustic curtains (Stark et al. 2005; Heupel et al. 2006a and 2006b), and evolution of multi-scaled marine observing programs (local, regional, national, and international) to include passive acoustics in a bundled telemetry system (Grothues et al. 2005; Ocean Tracking Network – See Appendix C). Outside PWS, the Pacific Ocean Shelf Tracking (POST) project is a pilot project of the CoML to develop a continental-scale acoustic telemetry network allowing monitoring of ocean migrations of a wide variety of species (Welch et al. 2003). The POST project has deployed one acoustic "curtain" off Graves Harbor, Alaska and has documented continental shelf migration tracks through the GOA for British Columbia and Washington salmon and steelhead smolts (see Appendix C for more details on POST).

The study of marine invertebrates through acoustic telemetry is a relatively new and lesser used technique compared to the longer history of fishes and marine mammals. In the GOA, telemetry has been used to study benthic invertebrates - the giant octopus in intertidal areas, and red king, tanner, and Dungeness crab in nearshore and pelagic waters (see Appendix Table B-4). Alaska Pacific University conducted a study of giant octopus in response to concerns that the Exxon Valdez oil spill had reduced the harvest of these animals: octopuses are part of subsistence lifestyle and numbers of appeared to decline after the spill (http://marine.alaskapacific.edu/Marine/MAR%20Facilities.php). The seasonal movements and habitat used by red king and Dungeness crab have been studied in waters of SE Alaska through the NMFS Auke Bay lab (Stone et al. 1993; Stone and O'Clair 2001), while tanner and Dungeness crab were to be monitored in an evaluation of marine reserves in Glacier Bay (Taggart et al. 2002) (See Appendix Table B-4 for details and other references).

Biotelemetry Advantages and Disadvantages

In a review of the field of biotelemetry, Cooke et al. (2004) stated that biotelemetry technology has great potential to advance research in basic and applied ecology studies, that incorporation of biotelemetry into broader ecological programs should bring new information that has previously been difficult to near impossible to collect from migratory animals using traditional methods, and that biotelemetry will certainly enhance research in the assessment of animal responses to anthropogenic perturbations and the development of life-history models and life-time energy budgets. Biotelemetry is particularly interesting to researchers because of the accuracy of the data collected and the speed at which it can be done.

Even with all the promise it holds, biotelemetry should not be considered a stand alone technology, but rather a complementary method to other existing and developing techniques: examples include intrinsic genetic and chemical tags (body hard parts), external passive tags, internal passive tags, and transponders. In some cases, biotelemetry is not yet even a viable method, mainly when the animal of interest is too small for tagging - forage fish in PWS are a current example of this case, although continuing miniaturization of tag components should ultimately permit tagging these fish. In other cases, it cannot, on its own, answer all the questions arising in a study project, but it can greatly facilitate the application of other study and measurement tools. **Table 2** provides a detailed list of the benefits, limitations and challenges from biotelemetry techniques.

Biotelemetry has both a proven and developing track record as an accurate technique to assess a variety of ecological questions and anthropogenic actions (stressors and protections) with examples such as:

- Natural History – all telemetry types have been effective at identifying the distribution, migration patterns and habitat use of a variety of marine organisms.
- Predator Prey relationships – telemetry studies can establish distribution overlaps, identify numbers and rates of movements of predators and selected prey item, examples in GOA - biotelemetry is a prominent study component of the Gulf Apex Predator Prey (GAP) project, and the TOPPs program has provided detailed information on the movements and foraging behavior of salmon sharks.
- Physical and Biological Coupling – the development of biophysical ocean observing systems opens a whole new realm of linked ecological studies, i.e., migration and climate change, etc. (see Appendix C).
- Commercial Fisheries and Marine Reserves – acoustic and satellite telemetry is being used around the world to evaluate the impact of commercial fisheries on local populations and mixed stock areas. Acoustic telemetry provides an accurate method to evaluate movements of marine fishes and invertebrates in and around marine reserves.
- Contaminant loading – telemetry studies are being conducted on flatfish use of contaminated sites in Puget Sound (M. Moser, NMFS, pers. comm.). Telemetry is one of several techniques being used to evaluate sources of mercury uptake in Beluga whales in the NE Pacific.
- Oil Spill Assessment – PWS and the Exxon Valdez oil spill provide the greatest evidence of the effectiveness of biotelemetry techniques used in direct and indirect evaluation of acute and chronic impacts.

The marine waters of the NE Pacific including the GOA with its size, remote nature, and abundant migratory fish and wildlife make it an ideal region for a variety of biotelemetry applications. Implementation plans for the NPRB and PWS OSRI in 2007 emphasize the need for improved census methodologies and assessment techniques including means to track predator and prey fish migrations in relation to commercial fisheries. New and existing biotelemetry methods of tagging and tracking marine organisms may offer the means to develop strategies to address multiple aspects of the NPRB and PWS OSRI Science Plans.

Table 2. Benefits, limitations and challenges of Biotelemetry research (adapted from Cooke et al. 2004).

Benefits

- *Allows linking of fields* – Behaviors of free and wide ranging animals can be linked directly to external environmental conditions, geolocation and oceanographic, or internal physiological conditions.
- *Individual based* - Possible to characterize the variation among individuals and to recognize the range of responses.
- *Continuous, real-time* - Continuous data streams eliminate unknowns during periods when animals are not monitored and facilitate the detection of trends through time. Data can be collected on a diel basis and in harsh environmental conditions for extended periods without requiring continuous human support. Most traditional mark and recapture studies are limited to collection of two data points: release location and capture location.
- *Multi-scale* – Opportunity to focus on behavior and physiology at a variety of scales (temporal, spatial or system).
- *Energetic equivalents* - Energy is a common currency in ecology and is essential for inferring the bioenergetic costs of different behaviors. Enables estimation of metabolic rate in the field.
- *Unrestrained animals* - In nature, animals face a suite of site-specific biotic (e.g. predation or habitat heterogeneity) and abiotic (e.g. weather) conditions that cannot be adequately replicated in a laboratory. Monitoring of unrestrained free-ranging animals in their own environment eliminates laboratory artifacts
- *Potential to study endangered animals* - Enables data collection without further imperilment from animals the populations of which are threatened with extinction; can eliminate the need for laboratory confinement.

Limitations and Challenges

- *Understanding patterns in the data* – Produces large volumes of data and interpreting patterns can be extremely difficult; is most powerful when coupled with other techniques, including detailed visual and/or video observations, combining multiple sensors – such as acoustic and archival tags.
- *Unfamiliarity with technological options* - Most researchers are unfamiliar with options that modern microelectronics has provided for transmitting and receiving behavioral, physiological and microenvironmental variables. Greater communication and collaboration among researchers working in different fields and on different taxa might promote effective use of biotelemetry
- *Cost* - Cost can be high, in some cases leading to low sample sizes. However, must be contrasted with the benefit derived from data that cannot be collected using other techniques.
- *Accuracy of measurement* - Some forms of monitoring might fail to estimate accurately the geolocation, environmental conditions, rate of energy expenditure etc.
- *Need for calibration* - Generally desirable to calibrate transmitters (usually to some energetic or environmental equivalent) and to verify their proper function using parallel lab techniques or additional environmental sensors.
- *Statistical analysis and interpretation of auto-correlated time series* - Because data can be collected in real time, there is the danger of collecting data sets that are difficult to manage. Because time series represent the repeated sampling of data from the same individual, data are nonindependent and could require complex statistical techniques that are poorly suited to these types of data. Can be addressed by monitoring large numbers of individuals with repeated measure designs, although larger budgets are then required.

- *Burden on animal or Size Matters* - Battery size and longevity continue to limit research on small organisms or long-term monitoring and also limits the complexity (mass) of the required circuitry – see the 2% rule. The types of transmitter and sensor, and the biology of the organism of interest will determine whether telemetry devices will be fully implantable or require the use of transcutaneous connections. Where possible, transcutaneous connections should generally be avoided owing to potential for damage or dislodging of transmitters and sensors, and possibility of infection.
- *Specialized skills* - Biotelemetry requires an understanding of basic electronics as well as a more specialized understanding of the fundamental biological variable being measured (i.e. use of heart-rate telemetry requires a basic understanding of cardiovascular physiology). Surgical implantation requires specific training that might require enlisting veterinarians for higher vertebrates.
- *Ethical issues or Permit Requirements* - It is usually necessary to obtain ethical or permit approval for invasive techniques on higher vertebrates.
- *Translation to ecological scale problems* - Some researchers whose work focuses on populations, communities, or ecosystems could find it difficult to view individual-based physiological, environmental or behavioral data in the context of broader ecological scale problems
- *Availability and/or customization* - The lack of commercial suppliers for many uses of biotelemetry can impede new researchers from adopting these techniques, so efforts must be taken to share technology among researchers. Where commercial equipment is available, the costs are high and will remain so until more researchers start using these technologies and/or unless they require manufacturers to produce competitive products with lower costs.

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APPENDIX A

Glossary of Biotelemetry Terms

A **detailed glossary** of telemetry, technology and technical terms can be found on the website of Texas A&M Laboratory for Applied Biotelemetry & Biotechnology at the Department of Marine Biology at Texas A&M University Galveston. A selection of telemetry terms from that glossary and other sources is included below. http://www.tamug.edu/labb/technology/Glossary.htm

Acceleration is a change in rate or direction of motion. Linear acceleration occurs when the rate of motion (speed) along a straight line changes; there are separate measures of centripetal (circular) and angular acceleration.

An ***accelerometer*** is a device that senses acceleration expressed in m/s^2. Modern accelerometers are typically micro-machined silicon **sensors.** **Time-depth-recorders** (**TDR**) are a form of accelerometer.

Acoustic telemetry (or ultrasonic) uses **transmitters** to send data through water where the data is logged by acoustic **receivers**. Acoustic telemetry is used in brackish and saline water or in deep bodies of freshwater such as lakes and reservoirs: **radio telemetry** is limited to transmission in air or through shallow depths of freshwater. **Acoustic** tags are used in the sea because sound is transmitted over long distances in salt water, whereas radio waves are attenuated (weakened) very rapidly. Frequencies of 30-300 kHz are used in acoustic telemetry with most transmitters in the 30-80 kHz range. An acoustic "**curtain**" is a series of receivers aligned to create a tracking line at key points in larger study areas – see **POST (Appendix C).**

The ***accuracy*** of a measurement is an indication of how close the value of a single measurement is likely to be to the real value (the physical property to be measured). **Accuracy** depends on a number of parameters, including the **resolution** of a sensor output digitizing system, if used, **repeatability** of measurements and **hysteresis**, as well as how sensitive a measuring system is to changes in other variables. Frequently the term **resolution** is frequently mistaken for **accuracy** in digital telemetry.

An ***archival*** **tag** is a recording device that stores (**archives**) sensor data on some recording medium or in solid state memory for later retrieval. Also called a **data recorder** or **data storage tag** (**DST**). Another version of this tag type is the **pop-up satellite-transmitting archival tag** (**PSAT**).

Argos is a **satellite**-based location tracking system that also has limited data transfer capability from mobile, **Argos compatible transmitters**. Access to the Argos system is available as a commercial service by Service Argos Inc. The Argos system was established jointly by the French Space Agency CNES with the U.S. agencies NASA and NOAA. The Argos system operates from receiving platforms located aboard NOAA satellites. Argos-compatible transmitters are available from a variety of manufacturers (see **Appendix D**) for biological and marine applications. Argos tracking accuracy is limited (ranging from +/-0.5 to +/-2.5 km), and data transmission bandwidth is restricted.

Biotelemetry is the remote measurement (**telemetry**) of biologically relevant data, including behavioral, physiological, physical or environmental data.

Depth measurement is the inverse of elevation. In biotelemetry, depth relates to the depth in a body of water, and is indicated in (positive) meters. **Pressure sensors** are commonly used to measure the depth of aquatic organisms.

Electronic tags are classified as **active** (with internal power source to record data electronically) or **passive** (without internal power). Electronic tags can be divided into three basic categories to include **transmitting**, **archival** or **data storage**, and **transponding** tags. Transmitting tags include **acoustic/radio/satellite transmitters** and **transponding** tags include **PIT tags**. These tags can be used to measure animal behavior, physiology and environmental parameters. Electronic tags can be divided into three basic categories to include transmitting, data storage or archival, and transponding. All systems operate on the premise of transmitting information from fish to researchers in the form of sound energy transmission, either in radio (20 to 300 MHz), ultrasonic (20-300 kHz), or satellite (UHF 401.650 MHz) frequencies.

Geolocation is the determination of the geographical location by geographic coordinates (latitude and longitude) of an object. The location determination can be accomplished by a number of means, including satellite telemetry (see **Argos**), **GPS** signal reception, or geolocation by analysis of light levels (i.e. with **archival** tags). For the latter, sunrise and sunset times are determined through the measurement of light levels. Within constraints, the determination of day length delivers information on latitude, and the determination of sunrise and sunset times (in reference to GMT) delivers information on longitude.

GPS- Global Positioning System is a satellite-based system for the determination of geographical location. GPS tracking is based on a **radio receiver** (rather than a **transmitter**) in an animal's collar. The receiver picks up signals from a special set of satellites and uses an attached computer to calculate and store the animal's locations periodically (e.g. once/15 minutes, once per hour, etc.). Locations are determined in a GPS receiver based on information transmitted from GPS satellites. GPS satellites transmit time-coded data. Distances from receiver to satellites can be computed by the receiver, and from this information location can be calculated. A primary difference to other possible satellite-based **geolocation** services available for biotelemetry (e.g. **Argos**) is in the far greater accuracy than most other systems and in the fact that location data is calculated in the receiver that is at the site of location of interest, rather than remotely as in the Argos system.

PIT tags or Passive Integrated Transponder Tags are miniaturized radio-transmitters encapsulated in a small glass cylinder. These tags can be as small as 8 mm long by 2 mm in diameter. The device does not contain any power source (hence it is **passive**), but is instead energized by the electric current induced in a very small, densely wound coil. To energize a tag, an external alternating electromagnetic field needs to be applied. This is typically done with a handheld or stationary reader or interrogator. Typical ranges for commercially available units are 2 to 5 cm, maybe up to 25 cm with very large interrogators; recently detection range has been expanded from centimeters to meters for field antennas. If a PIT tag is placed in such a field, an electric current is induced in the tag, and the tag becomes activated. An integrated circuit is then used to transmit a very weak radio signal which contains an individual ID code programmed into each PIT tag. This weak radio signal is then detected by the reader / interrogator unit, and displayed.

A ***pressure sensor*** or ***pressure transducer*** is a device used to measure either absolute pressure, or a pressure differential. Old-fashioned mechanical **sensors** have been replaced by modern, solid-state **electronic sensors** and **transducers.**

Radio telemetry uses **transmitters** to send data through air to radio **receivers** that log the data. Radio telemetry is limited to transmission in air or through shallow depths of freshwater. **Acoustic telemetry** is used in brackish and saline water or in deep bodies of freshwater such as lakes and reservoirs. Radio tags are useful in freshwater because radio waves are less affected by physical obstacles, turbidity, turbulence and thermal stratification than acoustic (non-electromagnetic) waves. Radio signals also radiate through the water surface (into the air) and can be detected at great distances because there is little loss of signal strength in air. Receivers can be fitted in boats, aircraft or land-based listening stations. The commonest frequency ranges used for VHF tracking are 148-152 MHz, 163-165 MHz, and 216-220 MHz.

A ***receiver*** is a device that collects (**receives**) information (data) emitted from a transmitter. Radio waves, acoustic waves or optical pulses are used for such data exchange.

Repeatability of a measurement - sometimes also called **precision** - is an indication of the likelihood of repeatedly obtaining the same result with a measurement system for identical values of measurement parameters. Repeatability is sometimes defined as either exclusive or inclusive of external changes in parameters that might affect the **accuracy** of a system, such as temperature in a depth recorder. If it is used as an inclusive term, then the range of conditions (e.g. temperature ranges) affecting the repeatability has to be indicated. The likelihood refers to repeatable results in a series of measurements under constant or defined conditions. Repeatability is expressed as the maximum difference between output readings, as a percentage of full scale.

Resolution is defined as the smallest discernible step in a measurement system. Resolution should not be (but unfortunately frequently is) confused with **accuracy**. In digital systems, the resolution can be obtained by dividing the full scale **sensor** or **transducer** range by the number of steps delivered by the number of bits of the A/D conversion system. For example, a 12-bit system is capable of delivering 4096 steps. For a digital depth measuring system with a 1000 m transducer depth span, resolution will be 1000 m / 4096 or about 25 cm. Accuracy will depend on how stable the power supply of the A/D system is, and how well temperature compensated the **pressure sensor** may be for dealing with ambient pressure changes. The **repeatability** of measurements will give an indication of how well the data acquisition system will deal with internal variability and produce repeatable results in a series of measurements under constant conditions.

Satellite telemetry utilizes a **platform transmitter terminal** (**PTT**) attached to an animal which sends an ultra high frequency (401.650 MHz) signal to satellites (**Argos**). The satellites calculate the animal's location based on the Doppler effect and relay this information to receiving/interpreting sties on the ground. PTTs are attached by collars, harnesses, subdermal anchoring, harpooning with a connected float, or by fur bonding.

A ***sensor*** is a device that is responsive (**sensitive**) to changes in a particular quantity. Examples are physical quantities such as temperature, pressure, motion (acceleration or speed) or biochemical quantities such as a substrate (lactate, glucose) or antibody. In response to changes in the quantity, the sensor changes a property of its own.

A ***tag*** is used to mark animals. Some of the most commonly used tags are metal coded wire tags (CWT) inserted into the nose of juvenile hatchery salmon, in marine mammals an interdigital skin flaps are attached near the base of a flipper (pinnipeds). Leg-bands and wing-bands are commonly used tags on birds. Most tags have numbers or are color-coded for easy identification. Recent high-tech developments include **electronic** tags such as **acoustic/radio/satellite transmitters**, **archival** tags, and **PIT tags**. These tags can be used to measure animal behavior, physiology and environmental parameters. Tags can be classified as **active** (power source to record data electronically) or **passive** without internal power).

TDR is an acronym that stands for any one of these terms: **Time Depth Recorder**, **Time-at-Depth Recorder**, and **Timed Data Recorder**. Originally, the acronym was used to refer to Time Depth Recorders. Such devices are data **recorders** that store information on the **depth** in a water column where the device is located at a given time. Strictly speaking, many types of TDRs record depth (pressure) values, but not time, which is why some of the name permutations have come up. More recent depth recorders have become much fancier devices that in addition to depth as the baseline data can record many other parameters, hence the name Timed Data Recorder.

Telemetry is remote measurement or the remote collection of data. Telemetered data can be physical, environmental or biological data. Telemetry is typically used to gather data from distant, inaccessible locations, or when data collection would be dangerous or difficult for a variety of reasons. In telemetry, specialized instruments perform measurements of physical quantities, and store or transmit the resulting signal - sometimes after some initial signal processing or conversion.

Thermistors are semiconductors that exhibit a change in resistance that is proportional to changes in temperature of the semiconductor material. This permits the use of thermistors as effective **temperature sensors.**

Tracking is the most basic type of **telemetry** that involves determining where an animal is located spatially (sometimes referred to as locational or positional telemetry). Using fixed **receiving** stations, it is possible to determine fine-scale movement and activity patterns.

A ***transducer*** is a device that converts the output of a **sensor** (in response to a change in quantity the sensor is responsive to) into a useful format, typically a voltage or current which changes proportionally to the sensor response.

A ***transmitter*** is a device that **transmits** (emits) information (data) to a **receiver**. This transmission most typically occurs by means of **radio** waves through air and by **acoustical** (ultrasonic) in water or by optical emitters. Types of transmitters include **coded** or **pulsed** tags. For **pulsed** tags, a simple pulsed signal, a familiar "beep-beep-beep" is transmitted at a selected pulse rate. **Coded** tags operate by emitting a distinct and unique numerical code that differentiates it from all other tags.

APPENDIX B

Listing of Telemetry Studies in Alaska

Appendix Table B-1. Radio and satellite telemetry studies of migratory birds and seabirds in Alaska specifically the Gulf of Alaska & Prince William Sound: see next page for additional details on researchers, publications, and websites.

Telemetry Type Vendor	Organism	Research Objectives or Issue	Region	Location	Organization, Program or Project
Radio	Seabird Carcasses	Total mortality of seabirds after Exxon Valdez Spill	Gulf of Alaska	Prince William Sound	Outer Continental Shelf Environ Assessment Program
Radio	Harlequin Ducks	Oil spill assessment on survival, mark-recapture analysis of annual survival	Gulf of Alaska	Prince William Sound	US Geological Survey
Radio	Golden Plover Western Sandpipers	Copper River Delta Shorebird Reserve Network - assessment of shorebird use of Copper River delta, areas within and without of Delta Shorebird Reserve	Prince William Sound	Copper River Delta	Western Hemisphere Shorebird Reserve Network, Prince William Sound Science Center
Radio	Black-legged Kittiwake	Kittiwake - bio-indicators of marine conditions GAP - trophic relationships between Steller sea lions, prey, predators, near Kodiak Island	Gulf of Alaska	Kodiak Island	Gulf Apex Predator Prey (GAP) Project University of Alaska Fairbanks
Radio	Tufted Puffin	Tufted Puffin - foraging distribution, diet, and breeding; GAP - trophic relationships between Steller sea lions, prey, predators, near Kodiak Island,	Gulf of Alaska	Kodiak Island	Gulf Apex Predator Prey Project University of Alaska Fairbanks
Radio	Black-legged Kittiwake -	Foraging areas, ranges, rates, competition, relation to forage fish	Gulf of Alaska	Prince William Sound	Variety - USFWS researchers, Exxon Valdez Oil Spill Restoration funding.
Radio	Spectacled Eider	At sea distribution, and annual survival	Bering Sea		US Geological Survey (USGS)
Radio/Satellite, and Banding	Seabirds and Migratory Birds	Program of Banding/Radio Telemetry to study ecology of seabirds, forage Fish, marine ecosystems	Alaska	Gulf of Alaska and other areas	USGS
Radio	Brandt	Effects of Bands and Radio Transmitters on Bird reproduction and migration	Alaska		USGS
Radio	Canada Geese, Emperor Geese, and White-fronted geese	Movements, survival, and reproduction of waterbirds	Alaska		USGS
Radio	Common Eider	Movement, ecology, and demographics	Alaska		USGS
Satellite	Red-throated Loons, Yellow-billed Loons, Common Loons	Comparative ecology of loons - develop hypotheses on limiting factors on populations during non-breeding seasons	Prince William Sound	Copper River Delta; Kuskowin Delta, North Slope	USGS
Satellite	Common Murres, Thick-billed Murres, and Tufted Puffins	Seasonal movement/pelagic habitat use by Murres/Puffins	Alaska	Gulf of Alaska; Chukchi Sea	USGS
Satellite	Sandhill Cranes	Migration ecology	Alaska	Upper Cook Inlet, Yukon-Kuskokwim Delta, Tanana Valley, Alaska Pen, Bristol Bay, Kenai	Alaska Dept of Fish and Game
Satellite	Steller's Eider	Migration, survival, side fidelity, annual survival	Alaska Peninsula		USGS
Satellite	Common/King/ Spectacled Eider; Goldeneye - Barrow's, Common; Bufflehead; Oldsquaw; Harlequin Duck; Merganser - Common, Red-breasted	Recommendations for Monitoring Distribution, Abundance, and Trends for North American Sea Ducks	Alaska	Various Areas	The Seaduck Joint Venture http://www.seaduckjv.org/index.html
Satellite	Pacific Common Eider	Migration and threat from oil spills	Alaska	Beaufort Sea	Environment Canada, Canadian Wildlife Service
Satellite	Surf Scoters, White Scoters	Migration ecology	Alaska		Alaska Dept of Fish and Game
Satellite	Tundra Swans	Satellite Tracking of Longs Point Tundra Swan	Alaska	Various Areas - Gulf of Alaska	Multiple Organizations

Additional Information on Migratory Bird and Seabird Biotelemetry References from Gulf of Alaska.

Telemetry Category	Organism	Information Source	Lead Investigator	Email	Phone	Publication and/or Research Interest
Radio, Satellite, and Banding	Seabirds and Migratory Birds	Web	Program			http://www.absc.usgs.gov/research/Banding/banding_program.htm; http://www.absc.usgs.gov/research/seabird_foragefish/index.html
Radio	Spectacled Eider	Web and Scientific Articles	Petersen, M.R.,	margaret_petersen@usgs.gov	907-786-3530	Petersen, M.R., Larned, W. W., and Douglas, D. C. 1999. At-sea distribution of spectacled eiders: A 120-year-old mystery resolved. Auk 116:1009-1020.; http://www.absc.usgs.gov/research/speimod/
Radio	Harlequin Ducks	Web and Scientific Articles	J.A. Schmutz	joel_schmutz@usgs.gov	907-786-3518	Oil Spill impact - most unanticipated and revealing impact of the oil spill on a marine bird was that exhibited by harlequin ducks- suffered acute mortality during the spill, had continuing injury at population level for several years. Radio tracking revealed higher mortality rates in adult females that overwinter on heavily oiled Knight Island and Green Island than unoiled Montague Island 1995-1998. Articles -Esler, D., J. A. Schmutz, R. L. Jarvis, and D. M. Mulcahy. 2000. Winter survival of adult female harlequin ducks in relation to history of contamination by the Exxon Valdez oil spill. J. Wildl. Manage. 64:839-847.; Esler, D., D. M. Mulcahy, and R. L. Jarvis. 2000. Testing assumptions for unbiased estimation of survival of radio-marked harlequin ducks. Journal of Wildlife Management 64:591-598.; .
Satellite	Stellar's Eider	Web and Scientific Articles	Paul Flint	paul_flint@usgs.gov	907-786-3608	Flint, P. L., M.. R. Petersen, C. P. Dau, J. E. Hines, and J. D. Nichols. 2000. Annual survival and site fidelity of Steller's eiders molting along the Alaska Peninsula. J. Wildl. Manage. 64:261-268
Satellite	Common Murres (Uria aalge), Thick-billed Murres (U. lomvia), and Tufted Puffins (Fratercula cirrhata)	Web and Scientific Articles	Scott Hatch	scott_hatch@usgs.gov	907-786-3529	Hatch, S. A., P. M. Meyers, D. M. Mulcahy, and D. C. Douglas. 2000. Seasonal movements and pelagic habitat use of murres and puffins determined by satellite telemetry. Condor 102(1):145-154; Meyers, P. M., S. A. Hatch, and D. M. Mulcahy. 1998. Effect of implanted satellite transmitters on the nesting behavior of murres. Condor 100: 172-174
Radio	Canada Geese, Emperor Geese, and White-fronted geese	Web and Scientific Articles	Jerry Hupp; J.A. Schmutz; Craig Ely	jerry_hupp@usgs.gov; joel_schmutz@usgs.gov; craig_ely@usgs.gov	907-786-3303; 907-786-3518; (907) 786-3526	Hupp, J. W., G. A. Ruhl, J. M. Pearce, D. M. Mulcahy, and M. A. Tomeo. 2003. Effects of abdominally-implanted radio transmitters with percutaneous antennas on behaviors of Canada Geese. Journal of Field Ornithology, 74(3):250-256; Schmutz, J. A. and J. A. Morse. 2000. Effects of neck collars and radio transmitters on survival and reproduction of emperor geese. Journal of Wildlife Management 64:231-237; Ely, C.R. 1990. Effects of neck bands on the behavior of wintering greater white-fronted geese. Journal of Field Ornithology 61:249-253
Radio	Brandt	Web and Scientific Articles	David Ward	david_ward@usgs.gov	907-786-3525	Ward, D. and P. L. Flint. 1995. Effects of harness-attached transmitters on premigration and reproduction of Brant. Journal of Wildlife Management 59:39-46.
Radio	Common Eider	Web and Scientific Articles	Petersen, M.R.	margaret_petersen@usgs.gov	907-786-3530	Petersen, M. R. and P. L. Flint. 2002. Population structure of Pacific common eiders breeding in Alaska. Condor 104:780-787
Band Recovery	Common Merganser as Example	Web and Scientific Articles	John M. Pearce	john_pearce@usgs.gov	907-786-3893	Pearce, J. M., J. A. Reed, and P. L. Flint. 2005. Geographic variation in survival and migratory tendency among North American Common mergansers. Journal of Field Ornithology, 76:109-216
Satellite	Red-throated Loons, Yellow-billed Loons, Common Loons	Web and Scientific Articles	J.A. Schmutz	joel_schmutz@usgs.gov	907-786-3518	Migration Ecology of Loons - Little information exists concerning non-breeding distribution and ecology of loons. To enable generation of tenable hypotheses concerning whether non-breeding periods may be limiting populations, we first need basic information on where and when these populations go when not on Alaskan breeding grounds. We have been acquiring such information by implanting satellite transmitters into the abdominal cavities of breeding adults.; http://www.absc.usgs.gov/staff/WTEB/jschmutz/jschmutz.htm#Publications
Satellite	Tundra Swans	Web	Dr. Scott Petrie			Thirty-gram neck-collar-attached transmitters were more effective for monitoring long distance movement of Tundra Swans than 95-gram backpack-harness-attached transmitters; http://www.bsc-eoc.org/lpbo/swans/swans.html
Satellite	King Eider	Web	Laura Phillips	steffen.oppel@gmx.net	907-474-1949	migration ecology and breeding biology of King Eiders nesting on the North Slope of Alaska; objective to identify where King Eiders reside 10 months outside of breeding season; http://mercury.bio.uaf.edu/kingeider/KIEI_Home.htm
Satellite	Surf Scoters and White Scoters	Web	Dan Roserberg; Mike Petrula	dan_rosenberg@fishgame.state.ak.us; mike_petrula@fishgame.state.ak.us		http://www.wc.adfg.state.ak.us/index.cfm?adfg=waterfowl.scoter_home; Rosenberg, D.H. and M.P. Petrula. 1998. Scoter Satellite Telemetry. Internet WWW page, at URL: http://www.wildlife.alaska.gov/index.cfm?adfg=waterfowl.surf.
Satellite	Sandhill Cranes	Web				Information on latest Crane telemetry results - http://www.wc.adfg.state.ak.us/index.cfm?adfg=waterfowl.craneupdate; Overall crane research with telemetry - http://www.wc.adfg.state.ak.us/index.cfm?adfg=waterfowl.crane
Satellite	Pacific Common Eider	Web		Environment Canada, Canadian Wildlife Service		http://www.mb.ec.gc.ca/nature/migratorybirds/eider/index.en.html
Satellite and Radio	Eider - Common, King, Spectacled, Eider; Goldenee - Barrow's, Common; Bufflehead; Oldsquaw; Harlequin Duck; Merganser - Common, Red-breasted, Hooded	Web and Report				Recommendations for Monitoring Distribution, Abundance, and Trends for North American Sea Ducks - Example - Dan Esler, Erika Lok, John Takekawa. 2005. Spring Migration of Surf Scoters Along the Pacific Coast: Important Habitats and Energetic Implications. Sea Duck Joint Venture Annual Project Summary for Endorsed Projects.
Radio - Fixed Station and Mobile Tracking from Boat, Advanced Telemetry Systems	Black-legged Kittiwake - Rissa tridactyla	Four Articles - Listed under Research Column; more are available but not listed here	Robert M. Suryan and David Irons	robert_suryan@fws.gov David_Irons@fws.gov	907 786-3444 (907) 786-3376	Foraging areas, foraging ranges, foraging rates, were determined by radio telemetry - prey forage fish. D.G. Ainley, R.G. Ford, E.D. Brown, R.M. Suryan, and D.B. Irons. 2003. Prey resources, competition, and geographic structue of Kittiwake colonies in PWS. Ecology 84(3):709–723; Suryan, R. M., D. B. Irons, M. Kauffman, J. Benson, P. G.R. Jodice, D. D. Roby, and E. D. Brown. 2002. Short-term fluctuations in forage fish availability and the effect on prey selection and brood-rearing in the Black-legged Kittiwake (Rissa tridactyla). Marine Ecology Progress Series 236:273–287.; Ostrand, W.O., G.S. Drew, R.M. Suryan, and L.L. McDonald. 1998. Evaluation of radio-tracking and strip transect methods for determining foraging ranges of Black-legged Kittiwakes. Condor 100:709-718. Irons DB (1998) Foraging area fidelity of individual seabirds in relation to tidal cycles and flock feeding. Ecology 79:647–655
Radio - Advanced Telemetry Systems (ATS); Tag - ATS model 3PN; Fixed receiver	Black-legged Kittiwake - Rissa tridactyla	Web and Scientific Report	S. Dean Kildaw Katie M. Murra	ffdsk@uaf.edu kate.wynee@uaf.edu	907.486.1517	GAP's primary goal is to document trophic relationships between Steller sea lions, their prey, predators, and potential competitors in waters near Kodiak Island, an area of continued sea lion declines and extensive commercial fishing; Kildaw, S.D., K.M Murra, C.L Buck. 2005. Black-legged kittiwakes as bio-indicators of marine conditions in the western Gulf Of Alaska. Pages 173-205 in Gulf Apex Predator-prey Study (GAP) Final Report FY2001-2003 NOAA Grant NA16FX1270 University of Fairbanks, School of Fisheries and Ocean Science. http://www.sfos.uaf.edu/gap/publications/annual_reports.htm
Radio - Advanced Telemetry Systems (ATS); Tag - ATS model 3PN; Fixed receiver	Tufted Puffin	Web and Scientific Report	S. Dean Kildaw Katie M. Murra	ffdsk@uaf.edu		GAP's primary goal is to document trophic relationships between Steller sea lions, their prey, predators, and potential competitors in waters near Kodiak Island, an area of continued sea lion declines and extensive commercial fishing; C.T. Williams, S.D. Kildaw, C.L Buck. 2005. Foraging distribution, diet, and breeding biology of tufted puffins In Chiniak Bay, Alaska. Pages 225-241 in Gulf Apex Predator-prey Study (GAP) Final Report FY2001-2003 NOAA Grant NA16FX1270 University of Fairbanks, School of Fisheries and Ocean Science. http://www.sfos.uaf.edu/gap/publications/annual_reports.htm
Radio	Golden Plover Western Sandpipers	Web and Articles	Mary Bishop Copper River Delta Institute and Prince William Sound Science Center	mbishop@pwssc.gen.ak.us	907-424-5800 x228	Radio telemetry work by Dr. Bishop found that Controller Bay, Beaufort River Delta is the first landfall for many migrant Pacific flyway shorebirds arriving to the Copper River Delta. In addition, Bishop's aerial surveys have found that almost 25% of the shorebirds observed each spring occur in Controller Bay. Johnson, O.W., N. Warnock, M.A. Bishop, A.J. Bennett, P.M. Johnson, and R.J. Kienholz, 1997. Migration by Radio-Tagged Pacific Golden Plovers from Hawaii to Alaska, and the Subsequent Survival. Auk 114(3): 521-524. Iverson, G.C., S.E. Warnock, R.W. Butler, M.A. Bishop, and N. Warnock. 1996. Spring Migration of Western Sandpipers Along the Pacific Coast of North America: a Telemetry Study. Condor 98:10-21. http://www.manomet.org/WHSRN/viewsite.php?id=31
Radio	Seabird Carcasses	Web Abstract and Report	RG Ford			Ford, RG; Bonnell, ML; Varoujean, DH; Page, GW; Carter, HR; Sharp, BE; Heinemann, D; Casey, JL. Total direct mortality of seabirds from the Exxon Valdez oil spill. PROCEEDINGS OF THE EXXON VALDEZ OIL SPILL SYMPOSIUM. pp. 684-711. American Fisheries Society Symposium. Vol. 18 An estimate of total mortality of seabirds from the Exxon Valdez oil spill was derived from numbers of carcasses collected on shore.

Appendix Table B-2. Radio and satellite telemetry studies of marine mammals in Alaska specifically the Gulf of Alaska including Prince William Sound: see next page for additional details on researchers, publications, and websites.

Telemetry Type Vendor	Organism	Research Objectives or Issue	Region	Location	Organization, Program or Project
Radio	Harbor Seals	Assess factors for decline, develop quantitative models of foraging behavior in PWS	Gulf of Alaska	Prince William Sound	ADFG, PWSSC, Un AL, NMFS
Radio and Archival	Harbor Seal	Gulf Apex Predator-prey Project	Gulf of Alaska		University of Alaska Fairbanks Fishery Ind Technology Center
Radio	Sea Otters	Estimated survival of sea otters following Exxon Valdez spill	Gulf of Alaska	Prince William Sound	US Fish and Wildlife Service - Alaska Science Center
Radio	Sea Otters	California Coast Otter Relocation	California		Natl. Zool. Park, Smithsonian
Satellite	Beluga Whale	Management and Recovery of Cook Inlet Beluga Whales - Proposed Research	Gulf of Alaska	Cook Inlet	NMFS Alaska Fisheries Science Center
Satellite	Beluga Whale	Wintering grounds of beluga whales - migratory behavior info for sustainable management	Bering Sea		North Pacific Research Board - NMFS, ADFG,
Satellite	Seals - Elephant. Ringed, Harbor	Satellite telemetry for research and rehabilitation, provides info for outreach and education	Gulf of Alaska		Alaska Sealife Center
Satellite	Harbor Seals	Diving behavior of harbor seals in SE Alaska and Kodiak Archipelago	Kodiak Island, Gulf of Alaska		ADFG and NMFS
Satellite	Harbor Seals	Movements of satellite-tagged subadult and adult harbor seals in Prince William Sound	Gulf of Alaska	PWS	University of Alaska Fairbanks Fishery Industrial Tech Center
Satellite	Humpback Whale	Local and migratory movements of Hawaiian humpback whales tracked by satellite telemetry	Hawaii to Alaska	Gulf of Alaska	Oregon State Univ, Naval Research Center, Univ of Hawaii
Satellite	Marine Mammals - Stellar Sea Lion	Development of a life-history transmitter for Steller sea lions - determine survival rates	Alaska	Gulf of Alaska and other areas	Texas A&M University Laboratory for Applied Biotelemetry and Biotechnology
Satellite	Stellar Sea Lion	Program: Stellar Sea Lion Satellite Tracking	Alaska	Gulf of Alaska and other areas	NMFS
Satellite	Stellar Sea Lion	Project: Use of telemetry to study foraging ecology and behavior of Steller sea lions	Alaska	Gulf of Alaska, SE Alaska, Bering Sea	NMFS
Satellite	Beluga Whale	Project: Bristol Bay Beluga Whale	Alaska	Bristol Bay	NMFS and ADFG
Satellite	Harbor Seal	Habitat use and tropic interactions in Prince William Sound	SE Alaska, Gulf of Alaska	Kodiak Island, Prince William Sound	Exxon Valdez Oil Spill Restoration Program, ADFG
Satellite	Bowhead Whale	One of original works in developing satellite tags	Canada and Alaska	Beaufort Sea	MMS and the Canadian Department of Indian Affairs and Northern Development for
Satellite/Acoustic	Marine Mammals	Program: NMFS Marine Mammal Lab - Various studies on whales, sea-lions, seals	Alaska	Gulf of Alaska and other areas	National Marine Fisheries Service - Marine Mammal Lab
Satellite/Radio	Harbor Seals	Dive behavior, foraging, haul out site use	Gulf of Alaska	Prince William Sound	U.S. Fish and Wildlife Service
Archival - TDR	Killer Whale, Stellar Sea Lion, Various	Research into diving and foraging behavior using archival time-depth recorders (TDR)	Alaska, BC, Washington		NMFS and other researchers

Additional Information on Marine Mammal Biotelemetry References from Gulf of Alaska.

Telemetry Category	Organism	Information Source	Lead Investigator	Email	Phone	Publication and/or Research Interest
Radio	Harbor Seals	Web				Harbor seals numbers in the Kodiak area have been increasing since the early 1990s, yet harbor seals continue to decline in Prince William SoundTesting of methods to best track harbor seals in PWS, study of foraging and prey. Data will be incorporated into dynamic foraging models. Quantitative predictions of lifetime reproductive success will be derived from the model along with population-level consequences under different foraging strategies for seals. GIS database is being compiled. http://www.wildlife.alaska.gov/index.cfm?adfg=marinemammals.research
Radio and Archival Time Depth Recorder (TDR) - Advanced Temetry Systems (ATS); Wildlife Computers	Harbor Seal Phoca vitulina richardii	Web and Annual Report	S. Harper and K. Wynne	kate.wynee@uaf.edu		Harper, S. and K. Wynne. 2005. Dive behavior of harbor seals (Phoca vitulina richards) within Steller Sea Lion critical habitat on the east side of Kodiak Island, Alaska. Pages 93-112 in Gulf Apex Predator-prey Study (GAP) Final Report FY2001-2003 NOAA Grant NA16FX1270 University of Fairbanks, School of Fisheries and Ocean Science. http://www.sfos.uaf.edu/gap/publications/annual_reports.htm
Radio - Advanced Telemetry Systems (ATS)	Sea Otters Enhydra lutris	Scientific Article	B.E. Ballachey	brenda_ballachey@usgs.gov		Estimated survival of sea otters (Enhydra lutris) for 1 year post weaning during 1992–1993 in Prince William Sound (PWS) after 1989 oil spill. Sampled oiled areas - West PWS and unoiled areas E PWS. Survival was 25% lower in W PWS and condition was better in E PWS.Foraging success was greater in EPWS than in WPWS, consistent with either an effect of length of occupation or the effects of oil on the prey base or a combination of these effects. Length of occupation and oiling history likely influenced juvenile survival.
Radio	Sea Otters Enhydra lutris	Scientific Arcticle				Ralls, K; Siniff, DB; Doroff, A; Mercure, A. 1992. Movements of sea otters relocated along the California Coast. Marine Mammal Science. Vol. 8, no. 2, pp. 178-184. 1992.
Satellite	Beluga Whale	Conservation Plan	Program			Cook Inlet Beluga Whale Conservation Plan. Other research includes satellite tagging to investigate seasonal movements, dive and migration patterns; biopsies of individual whales to obtain tissue samples for research into genetics; a population age and growth model; forage fish analysis; fatty acid analysis; and behavioral-telemetry studies associated with disturbance and avoidance of human activities.
Satellite	Beluga Whale	Article and Report	R Suydam PR Richard	rsuydam@co.north-slope.ak.us		Suydam, R.S., LF Lowry, KJ Frost, GM O'Ocorry, D Pikok. 2001. Satellite Tracking of Eastern Chukchi Sea Beluga Whales into the Arctic Ocean ARCTIC VOL. 54, NO. 3 P. 237–243 Richard, PR; Martin, AR; Orr, JR. 1998. Study of Late Summer and Fall Movements and Dive Behaviour of Beaufort Sea Belugas Using Satellite Telemetry.Report: OCS /MMS98-0016. Available from: NTIS, 5285 Port Royal Rd, Springfield, VA 22161, USA; Satellite Tracking Point Lay Beluga Whales - 1998-2002 http://www.fakr.noaa.gov/protectedresources/whales/beluga/ptlay.htm
Satellite	Beluga Whale	Web and Reports	Roderick Hobbs	Rod.Hobbs@noaa.gov		Beluga whale stocks that summer in the Beaufort Sea, Chukchi Sea, Arctic Ocean and the Bering Sea are all thought to winter in the Bering Sea. Beluga whales are harvested in Alaska, northern Canada and eastern Russia. Identification of genetic stocks, their migration behavior and the degree to which they are shared among regions are necessary for effective management of sustainable harvest levelshttp://project.nprb.org/view.jsp?id=5e60c813-182d-4cc7-bce4-5bd783e9045f; Suydam, R.S., LF Lowry, KJ Frost, GM O'Ocorry, D Pikok. 2001. Satellite Tracking of Eastern Chukchi Sea Beluga Whales into the Arctic Ocean ARCTIC VOL. 54, NO. 3 P. 237–243
Satellite	Elephant Seal	Web			907) 224-6300	Alaska SeaLife Center (ASLC) opened in May 1998, providing a modern research and wildlife rehabilitation facility. They also use the facility for teaching about rehabilitation process. They have a major outreach and education program that includes telemetry Rehabilitated mammals tracked in GOA include - Elephant Seal, Harbor Seal, Ringed Seal. http://www.alaskasealife.org/master/about/index.html
Satellite	Harbor Seals	Article - Report	K.K. Hastings MJ Rehberg			Hastings, K.K., R.J. Small, M.A. Simpkins, U.G. Swain. 2001. Dive behavior of adult and subadult harbor seals from Kodiak Island and SE Alaska. Pages 184-209 Harbor Seal Investigation in SE Alaska Annual Report to NOAA Fisheries. Alaska Dept of Fish and Game. Rehberg, M.J., R.J. Small. 2001. Dive behavior, haulout patterns, and movements of harbor seal pups in the Kodiak Archipelago. Pages 209-238 Harbor Seal Investigation in SE Alaska Annual Report to NOAA Fisheries. Alaska Dept of Fish and Game. http://www.wc.adfg.state.ak.us/index.cfm?adfg=marinemammals.seal
Satellite	Harbor Seals	Scientific Article	LF Lowry			Lowry, LF; Frost, KJ; Ver Hoef, JM; DeLong, RA. 2001. Movements of satellite-tagged subadult and adult harbor seals in Prince William Sound, Alaska. Marine Mammal Science [Mar. Mamm. Sci.]. Vol. 17, no. 4, pp. 835-861. Satellite-linked tags were attached to 49 subadult and adult harbor seals captured in Prince William Sound (PWS), Alaska, and their movements were monitored during 1992-1997. Seals were tracked for a total of 5,517 seal-days and were located on about 80% of the days that tags transmitted. Most locations were in or near PWS, but some juvenile seals moved 300-500 km east and west into the Gulf of Alaska. While several seals travelled to 50-100 km offshore, virtually all locations were in water <200 m deep. Overall, juvenile seals moved more than adults and had larger home ranges. Movements were significantly affected by month, and age by month and sex by month interactions. In all months, mean distances between successively used haulouts were <10 km for adults and <20 km for juveniles. Mean monthly home ranges varied from <100 km super(2) to >1,500 km super(2), and were smallest during June-July. Mean haul-out to at-sea distance was 5-10 km for adults and generally 10-25 km for juveniles. Satellite-linked tags provided an effective means of r
Satellite	Humpback Whale	Scientific Article	Bruce Mate	mateb@ccmail.orst.edu		Bruce R. Mate, Robert Gisiner, and Joseph Mobley. 1998. Local and migratory movements of Hawaiian humpback whales tracked by satellite telemetry. Can. J. Zool. 76: 863–868 These data represent the first route and travel speeds for humpbacks migrating from Hawaii toward Alaska.
Satellite	Marine Mammals - Cetaceans, Pinniped, Turtle - over 15 species	Web	Program			Wide range of species - Whale - Blue, Right, Humpback, Sperm, Fin; Turtles - Loggerhead, Green, Kemp's Ridley, Seals - Gray, Hooded, Harbor, Dolphin - Rough-toothed, White-sided, Risso's; Harbor Porpoise Research includes determining movements and behavior of rehabilitated seals and turtles, part of NE Stranding Network. http://whale.wheelock.edu/Welcome.html
Satellite	Marine Mammals - Stellar Sea Lion	Web	Project - M.Horning			Life History Transmitters (LHX) in Steller sea lions: assessing the effects of health status, foraging ability, and environmental variability on juvenile survival and population trends. As a central part of the Steller LHX project, we will determine survival rates of juvenile Steller sea lions, using long-term, implanted satellite-linked life history transmitters. For the first time, this project will also deliver longitudinal, multi-year dive effort data from individual, free-ranging marine mammals http://www.tamug.edu/labb/
Satellite	Stellar Sea Lion	Web	Tom Laughlin	tom.loughlin@noaa.gov		Satellite telemetry - Steller sea lion foraging ecology - transmitters collect information on animal dive characteristics, time on land and at sea, and other data, which are then transmitted to the Argos satellite. ttp://access.afsc.noaa.gov/sslprojects/SSLProjects_Detail.cfm?ID=102
Satellite	Beluga Whale	Web				ADFG working with Bristol Bay Native Association to track beluga whales using satellite telemetry to investigate beluga whale and salmon interactions in the Kvichak River system. This cooperative project also includes NMFS, Alaska Beluga Whale Committee, USFWS, and NPS.
Satellite - SDR-T6, 0.5 W, Wildlife Computers	Harbor Seal Phoca vitulina richardii	Scientific Article and Reports	K.K. Hastings	kelly_hastings@fishgame.state.ak.us		K.K. Hastings, K.J. Frost, M.A. Simpkins, G.W. Pendleton, U.G. Swain, and R.J. Small. 2004. Regional differences in diving behavior of harbor seals in the Gulf of Alaska. Can. J. Zool. 82: 1755–1773; Gotthardt, T. 2001. The foraging ecology of harbor seals in southcentral Prince William Sound, Alaska: 1994–1997. M.Sc. thesis, University of Alaska, Anchorage, Alaska; Frost, K.J., Lowry, L.F., Ver Hoef, J.M., and Iverson, S.J. 1997. Monitoring, habitat use, and trophic interactions of harbor seals in Prince William Sound, Alaska. Annual report to the Exxon Valdez Oil Spill Trustee Council. Restoration Project 96064. Alaska Department of Fish and Game, Division of Wildlife, Fairbanks.
Satellite - Telonics and Wildlife Computers	Bowhead Whale	Scientific Article	Bruce Ward	bruce.mate@hmsc.orst.edu		Bruce R. Mate, Gregory K. Krutzikowsky, and Martha H. Winsor. 2000. Satellite-monitored movements of radio-tagged bowhead whales in the Beaufort and Chukchi seas during the late-summer feeding season and fall migration. Can. J. Zool. 78: 1168–1181 Satellite info two principal advantages compared with other surveys: (1) it gives the simultaneous dynamic movements of individual animals and (2) its coverage is not limited by logistic and political constraints. Its principal advantage over conventional telemetry is that collecting data does not require on-site personnel and costly ships or aircraft.
Satellite/Acoustic	Marine Mammals	Web	Program			http://nmml.afsc.noaa.gov/CetaceanAssessment/cetacean.htm - Cetacean Assessment http://www.afsc.noaa.gov/NMML/AlaskaEcosystems/akprog.htm Alaska Ecosystems Research Program; http://nmml.afsc.noaa.gov/AlaskaEcosystems/sslhome/Satellite/Default.htm Telemetry Research Page
Satellite/Radio	Harbor Seals	Scientific Articles and Technical	Robert M. Suryan	robert_suryan@fws.gov	(907) 786-3444	Suryan, R.M. and J.T. Harvey. 1998. Tracking harbor seals (Phoca vitulina richardsi) to determine dive behavior, foraging activity, and haul-out site use. Mar. Mamm. Sci. 14(2):361-372.
Archival - Time/Depth/Recorder (TDR)	Killer Whale, Stellar Sea Lion, Various	Web Articles	Various			Example Article - Robin W. Baird, M. Bradley Hanson, and Lawrence M. Dill. 2005. Factors influencing the diving behaviour of fisheating killer whales: sex differences and diel and interannual variation in diving rates. Can. J. Zool. 83: 257–267

Appendix Table B-3. Radio, acoustic and satellite telemetry studies of anadromous and marine fishes in Alaska specifically the Gulf of Alaska including Prince William Sound: see next page for more details on researchers, publications, and websites.

Telemetry Category	Organism	Research Objectives or Issue	Region	Locale	Organization
Acoustic	Fish Heads (Seafood Waste)	Impacts of seafood waste discharge in Orca Inlet, Prince William Sound	Gulf of Alaska	Orca Inlet PWS	Prince William Sound Science Center
Acoustic	Ling Cod	Tracking ling cod use of marine reserves	SE Alaska	Sitka Sound	Univ of California Sea Grant
Acoustic	Yellowtail Rockfish	Techniques for tracking deepwater rockfishes	SE Alaska	Lynn Canal	NMFS - Auke Bay Lab
Acoustic/Archival	Steelhead	Pilot effort of the POST project tracking steelhead adult migration	Kenai Peninsula, Ninilchuk River		USGS - Alaska Science Center, Biological Science Of
Acoustic	Copper Rockfish and Lingcod	Describe the home range of rockfish inside voluntary "no-take" zones.	Puget Sound		San Juan County Bottomfish Recovery Program
Acoustic - "acoustic curtains"	Salmon, Trout, Sturgeon, Shark	Pacific Ocean Shelf Tracking Project - Demonstration of acoustic curtains along continental shelf	NE Pacific Continental Shelf	Gulf of Alaska - Graves Harbor	Census for Marine Life (CoML)-POST project, Kintama Res
Acoustic - curtains and nodes	Same as Above	Puget Sound Biotelemetry Project - 20 separate organizations developing a regional biotelemetry network studying 13 distinct species	Puget Sound		Four Tribes, 4 Federal Agencies, Un of Wash/ID, WDFW, sportfishing groups
Acoustic/Radio/PIT	Pacific Salmon, Lamprey, Sturgeon	Columbia River Basin Federal Hydropower System-studies of dam and reservoir fish passage	Columbia River		Federal and State Agencies, Public Utility Districts
Archival	Salmon and Steelhead	One of first applications of archival data storage tags - daily behavior and thermal habitat	N. Pacific, Bering Sea, Gulf of Alaska		University of Washington
Archival	Salmon	NPAFC Salmon Tagging - NPRB priority to study factors affecting w. Al salmon stock dynamics/mortality/migr	Bering Sea, Gulf of Alaska, Pacific Ocean		Basis Working Group, North Pacific Anad Fisheries Comm
Archival Tags	Pacific Cod	Evaluating archival tagging of Pacific cod	Kupreanof Strait		NMFS - Alaska Fisheries Cntr
Archival/PIT	Coho Salmon smolts	Testing electronic archival tags in Alaska salmon Exxon Valdez Oil Spill (EVOS) Project	Kenai Peninsula, Ninilchuk River		USGS - Alaska Science
Radio	Coho Salmon Smolts	Investigate coho smolt migration and identify important Copper River delta habitats.	Gulf of Alaska	Copper River Delta, PWS	
Radio	Cutthroat Trout	Seasonal Movements of Radio-tagged Coastal Cutthroat Trout on the Copper River Delta, Alaska	Gulf of Alaska	Copper River Delta, PWS	US Forest Service
Radio	Cutthroat Trout	Evaluate cutthroat trout spawning habitat areas near or above potential road corridors	Gulf of Alaska	Copper River Delta, PWS	Alaska Dept of Fish and Game; Sport Fish Division
Radio	Rainbow Trout	The seasonal distribution, migratory behavior, and habitat use by Alagnak River rainbow trout	SE Alaska, Bristol Bay	Alagnak River	USGS - Alaska Science Center, Biological Science Office
Radio	Chinook Salmon	Development of a Long-term Monitoring Project to Estimate Abundance of Chinook Salmon in the Copper River, Alaska, 2001-2004	Gulf of Alaska	Copper River Delta, Prince William Sound	Forest Service, Dept of Interior, Alaska Dept of Fish and Game
Radio	Blue-back Herring	Anadromous herring passage at locks and dams	SW Atlantic	S. Carolina	Normandeau Assoc
Radio	Sockeye Salmon	Migration/spawning of Lake Clark Sockeye Salmon	SE Alaska	Lake Clark	USGS - Alaska Science Center,
Satellite - Smart Position-Only Tag (SPOT), Pop-Up Sat Archival Tag (PAT)	Salmon Shark	Study of warm water shark (Salmon Shark) in cold waters	NE Pacific including Alaska	Gulf of Alaska and Prince William Sound	Tracking of Ocean Pelagics (TOPPS), NMFS, ADFG http://www.toppcensus.org.
Satellite Pop-up Archival Transmitting (PAT) Tags	Pacific Halibut	Use of archival pop up tags to monitor habitat use and behavior of Pacific Halibut	Gulf of Alaska		USGS
Satellite Pop-up Tags	Nearshore and Pelagic Species - Pacific Halibut tested	Testing satellite pop-up tags as a tool for identifying critical habitat of halibut and other species, Chinook, Cutthroat Trout, Lingcod	Gulf of Alaska		USGS Satellite Telemetry - Exxon Valdez Oil Spill (EVOS) Project

Additional Information on Anadromous and Marine Fish Biotelemetry References

Telemetry Category	Organism	Information Source	Lead Investigator	Email:	Phone:	Publication and/or Research Interest
Acoustic Telemetry	Fish Heads (Seafood Waste)	Web - Report	Bishop, Mary Anne Richard Thorne	mbishop@pwssc.gen.ak.us thorne@pwssc.gen.ak.us		Tracking fishheads (waste) from seafood processing plants. A number of measures are used including video camera, visual surveys, halibut sampling. Acoustic tracking will be part a tagging program to track the rate and direction of fish head dispersal. 2006 - purchased 16 tags and used tracking hydrophone system from PWSCC. Research Projects Catalog at: http://www.pwsrcac.org/resources/2006cat/2006ProjCat.pdf
Acoustic - VEMCO	Ling Cod Ophiodon elongatus	Article and abstract	Richard M. Starr	Starr@mlml.calstate.edu		We used array of recording receivers to estimate natural mortality, residence times, and rates of movements of lingcod in a marine reserve in southeast Alaska. Starr, RM; O'Connell, V; Ralston, S; Breaker, L. 2005. Use of Acoustic Tags to Estimate Natural Mortality, Spillover, and Movements of Lingcod (Ophiodon elongatus) in a Marine Reserve. Marine Technology Society Journal [Mar. Technol. Soc. J.]. Vol. 39, no. 1, pp. 19-30. Richard M. Starr, Victoria O'Connell, and Stephen Ralston. 2004. Movements of lingcod (Ophiodon elongatus) in southeast Alaska: potential for increased conservation and yield from marine reserves Can. J. Fish. Aquat. Sci. 61: 1083–1094 (2004)
Acoustic - Smith and Root	Yellowtail Rockfish	Article	H.R. Carlson	-		H.R. Carlson, RE Haight, J.H. Helle. 1995. Initial displacement of yellow tail rockfish. Alaska Fishery Research Bulletin [Alaska Fish. Res. Bull.]. Vol.2, no. 1, pp. 76-83. 1995
Acoustic and Archival Tags - VEMCO and LOTEK	Steelhead (Oncorhynchus mykiss)	Web	Jennifer Nielsen	jennifer_nielsen@usgs.gov	907.786.3670	The USGS Alaska Science Center is initiating one of three pilot studies within the POST project. Archival and sonic tags will be used to describe the distribution of salmon as they leave the freshwater environment and range into the open North Pacific Ocean. This project focuses on tagging steelhead kelts from the Ninilchik River. Steelhead kelts were tagged with either an acoustic or archival tag along with a PIT tag to assess migrations from the freshwater environment as the fish return to saltwater. An array of recording buoys was deployed around the mouth of the Ninilchik River to describe direction and timing of movements as the fish return to the ocean. Archival tags will then be collected as the fish return to streams in subsequent spawning migrations. Environmental variables measured by the archival tags include temperature, pressure, and ambient light. The ambient light data will allow for geolocation estimates based on time of sunrise, sunset, and local noon and reconstruction of the environment encountered by individual steelhead migrating at sea. The data from the acoustic tags will provide detailed information concerning movements of fish at a loc
Acoustic	Copper Rockfish and Lingcod	Report	Eric Eisenhardt			Eisenhardt, E. 2003. Acoustic telemetry of rocky reef fish home range to evaluate marine protected area size. Georgia Basin/ Puget Sound Research Conference, 18 pgs. The 2002 Acoustic Telemetry Project for the San Juan County Marine Resource Committee's Bottomfish Recovery Program answers the question "How small is too small?" for the County's voluntary "no-take" marine reserves. Use of Radio-acoustic positioning telemetry RAPT system.
Acoustic - VEMCO	Greenspotted Rockfish Sebastes chlorostictus; Bocaccio S. paucispinis	Article	Richard M. Starr	Starr@mlml.calstate.edu		Starr, R.M., J.N. Heine, and KA. Johnson. 2000. Techniques for tagging and tracking deepwater rockfishes. North American Journal of Fisheries Management 20:597-609
Acoustic - VEMCO "acoustic curtains"	Salmon- Chinook, Coho, Sockeye; Trout - Cutthroat, Steelhead; Charr - Bull T., Dolly V.; G. Sturgeon, Shark - Six and Seven gill	Web and Scientific Article	Heather Holden and David Welch	Heather.Holden@vanaqua.org	604-659-3587	One of seven initial CoML projects. A program to develop and promote the application of new electronic tagging technology to study usage of marine environments and migration routes of Pacific Salmon and other migratory species. Website includes a list of acoustic curtains, current researchers, and publications.
Acoustic - VEMCO curtains and nodes	Salmon- Chinook, Coho, Sockeye; Trout - Cutthroat, Steelhead; Charr - Bull T., Dolly V.; G. Sturgeon, Shark - Six and Seven gill	Personal Comm.	POC - Fred Goetz	fred.goetz@usace.army.mil	206.764.3515	A series of agencies, tribes and sport fishing groups have creatged a regional collaborative network of acoustic receivers, appx 220, as both "curtains" and individual receivers (nodes) covering most of the Puget Sound. Studies include local habitat use, regional migration, and continental shelf salmon migration. Equipment is the same as POST so migratory animals tagged in Puget Sound can be followed along the cont. shelf.
Acoustic/ Radio/PIT - HTI, VEMCO, Lotek, Biomark	Pacific Salmon, Pacific Lamprey, White Sturgeon	Articles, Web	Program			The longest timeperiod and largest number and type of telemetry studies in one area in the world. Studies are to assess impacts of the Columbia River hydropower system on juvenile and adult salmon. A number of telemetry types and vendors are used.
Archival	Salmon and Steelhead	Article	Robert Walker	rwalker@fish.washington.edu		Walker, VR; Myers, WK; Davis, DN; Aydin, YK; Friedland, DK; Carlson, RH; Boehlert, WG; Urawa, S; Ueno, Y; Anma, G. 2000. Diurnal variation in thermal environment experienced by salmonids in the North Pacific as indicated by data storage tags. Fisheries Oceanography [Fish. Oceanogr.]. Vol. 9, no. 2, pp. 171-186.
Archival - Lotek - geolocation, temp, depth; Staroddi - depth, AlphaMach - temp	Salmon	Report	Robert V. Walker	rvwalker@u.washington.edu		Walker, R.V. 2005. Semiannual progress reports to North Pacific Anadromous Fish Commission. Walker, R.V., N.D. Davis, K.W. Meyers, and J.H. Helle. 2005. New information from Archival Tags from Bering Sea Tagging, 1998-2004. Pdf files. http://doc.nprb.org/web/02_prjs/r0204pr_jan-jun05.pdf#search=%22lotek%20and%20Alaska%22
Archival Tags	Pacific Cod	Web	Somerton Nichol	dan.nichol@noaa.gov , david.somerton@noaa.gov		Objective to determine vertical movement patterns of Pacific cod - relating vertical behavior might affect catchability during resource assessment surveys: tag cod with data storage tags (temp and depth) in . http://access.afsc.noaa.gov/sslprojects/SSLProjects_Detail.cfm?ID=128; www.afsc.noaa.gov/Quarterly/jfm02/divrptsRACE.htm , Hollowed-NMFS-Fish_files/frame.htm
Archival Tags (LOTEK), PIT tags and VI-alpha tags (Visible Implant Alphanumeric	Coho (Oncorhynchus kisutch)	Web	Derek R. Wilson, Phil Richards and Dr. Jennifer L. Nielsen	derek_wilson@usgs.gov jennifer_nielsen@usgs.gov	907.786.3576 907.786.3670	With the aid of archival tags, we can document critical marine habitats and their relationship to the health and survival of salmonids in their first year at sea. Newly designed archival tags are small enough to be surgically implanted into the body cavity of young salmon. These tags record temperature, pressure, and light data from the surrounding habitat. These data can be used to define critical habitat and plot movement patterns of Pacific salmon in the marine environment. Coho salmon have been chosen as the pilot species to test this new technology because of high rearing success in hatcheries and the tendency of males to return as jacks after only 6 months at sea. A minimum size of 180 mm is recommended to effectively tag juvenile salmon with internal archival tags and 150 mm for soft VI-alpha tags (Visible Implant Alphanumeric). Coho between 150 mm to 300 mm will be tagged, observed for 2-4 weeks, and released into their natal stream during normal coho smolt out-migration. Recovery of the archival tags is dependant on a strong sports fishery, commercial fishery, and a fish weir below spawning grounds at the release stream. However, many questions still

Radio	Coho Salmon smolts (Oncorhynchus kisutch)	American Fisheries Society Conference Web	Kirsti Jurica	kjurica@fs.fed.us		Jurica, K., D. Lang, S, Meade. 2005. Spring and Fall Migration Patterns of Juvenile Coho Salmon on the Copper River Delta, Alaska. 2005. Radio telemetry was used to investigate the spring and fall migration pattern of coho salmon smolts in a 10 km2 basin on the Copper River Delta.Radio transmitters (0.75 g) were implanted in the abdomen of fish and tracked until battery life ended (ave = 22 days) or fish entered the ocean environment. is information is being used to determine smolt run timing and to identify habitats of the lower Copper River Delta that are important during migration.
Radio	Cutthroat Trout (Oncorhynchus clarki clarki)	Web Abstract	David Saiget	dsaiget@fs.fed.us	503-622-3191 x637	Saiget, D. 2005. Seasonal Movements of Radio-tagged Coastal Cutthroat Trout on the Copper River Delta, Alaska. Abstract in the The 2005 Coastal Cutthroat Trout Symposium Status, Management, Biology, and Conservation, Port Townsend, Washington, American Fisheries Society. radio telemetry to track movements of 27 adult Coastal Cutthroat trout on the North Gulf Coast/Copper River Delta, Alaska
Radio	Cutthroat Trout (Oncorhynchus clarki clarki)	Web	Brian Marston	brian_marston@fishgame.state.ak.us	907 424-3213	Potential resource developments east of Copper River Delta makes concern for trout sport fisheries of the area. Potential road constructions would require crossing over 250 streams and rivers, 48 of which have been identified as anadromous streams. study sought to track spawning movements of cutthroat trout in a key tributary of the Glacial Martin River. Radio telemetry techniques were used to track spawning trout in the Green River in order to map spawning habitats, and determine if trout utilized areas above potential road corridors.
Radio	Rainbow Trout (Oncorhynchus mykiss)	Web and Scientific Article	Julia Meka	julie_meka@usgs.gov	907.786.3917	Meka, J. M., E. E. Knudsen, D. C. Douglas, and R. B. Benter. 2003. Variable migratory patterns of different adult rainbow trout life history types in a southwest Alaska Watershed. Transactions of the American Fisheries Society 132:717-732. Meka, J. M., E. E. Knudsen, and D. C. Douglas. 2000. Alagnak watershed rainbow trout seasonal movement. Pages 35-42 in J. H. Eiler, D. J. Alcorn, and M. R. Neuman (editors). Biotelemetry 15: Proceedings of the 15th International Symposium on Biotelemetry. Juneau, Alaska, USA. International Society on Biotelemetry. Wageningen, The Netherlands. [PDF file - 52 kb] http://www.absc.usgs.gov/research/Fisheries/Alagnak/population.htm
Radio - Advanced Telemetry Systems (ATS)	Chinook Salmon (Oncorhynchus tshawytscha)	Article	Jason Smith	jsmith@lgl.com		Smith, JJ; Link, MR; Cain, BD. 2005. Development of a Long-term Monitoring Project to Estimate Abundance of Chinook Salmon in the Copper River, Alaska, 2001-2004. Alaska Fishery Research Bulletin [Alaska Fish. Res. Bull.]. Vol. 11, no. 2, pp. 118-134. 2005
Radio - Lotek	Blue-back Herring	Reports Article	Normandeau Associates			Assessed fish passage of blueback herring through a lock and dam using radio telemetry. Normandaue and Associates. 2003. Effectiveness of the Pilopolis Lock at attracting adult blueback herring and American shad, Spring 2003. Prepared for Santee Cooper, S. Carolina Public Service Authority, Project No. 19409.
Radio - Lotek	Sockeye Salmon (Oncorhynchus nerka)	Web and Scientific Article	Carol Ann Woody	carol_woody@usgs.gov	907.786.7124	Dynamic in-lake migration patterns observed for homing sockeye salmon (pdf 762k) - poster given at the American Fisheries Society Annual Meeting in Anchorage, Alaska on September 12-15, 2005 Alaska National Interest Lands Conservation Act (ANILCA). http://www.absc.usgs.gov/research/Fisheries/Lake_Clark/radio_telemetry.htm
Sateillite - Combined Tags - Smart Position-Only Tag (SPOT), Pop-Up Satellite Archival Tag (PAT)	Salmon Shark Lamna ditropis	Scientific Articles	Barbara Block	Stanford University		Issue: Increased sport fishery - need more information on movements. Tagging of Pacific Pelagics (TOPP), a satellite tracking system has documented of the range of salmon shark. Some sharks rapidly migrate SE to Canada/US while some remain in PWS and Gulf of Alaska during winter months (Hulbert et al. 2005). While salmon are predominant prey from mid-July to mid-December, they are opportunistic feeders and euryphagous, feeding on a wide variety of prey. These foraging habits may explain varying migration routes (Hubert et al. 2005, Weng et al. 2005). Movement is dependent partially on the quality and density of prey as well as preference of mating and pupping locations. Although majority of stomach contents collected in the 1999-2001 Exxon Valdez Restoration Project were salmon, other organisms included squid, sablefish, Pacific herring, rockfish, eulachon, capelin, spiny dogfish, arrowtooth flounder, and codfishes. http://seagrant.uaf.edu/nosb/papers/2006/soldotna-shark.html .
Satellite - Combined Tags - Smart Position-Only Tag (SPOT), Pop-Up Satellite Archival Tag (PAT)	Salmon Shark Lamna ditropis	Scientific Articles				SALMON SHARK REFS Hulbert, L.B., A.M. Aires-Da-Silva, V.F. Gallucci and J.S. Rice. 2005. Seasonal foraging movements and migratory patterns of female Lamna ditropis tagged in Prince William Sound, Alaska. Journal of Fish Biology 67, 490-509. Weng, K.C., A. Landiera, P.C. Castilho, D.B. Holts, R.J. Schallert, J.M. Morrissette, K.J. Goldman, and B.A. Block. 2005. Warm sharks in polar seas: satellite tracking from the dorsal fins of salmon sharks. Science 310:104-106. Pennisi, E. October 7, 2005. Satellite Tracking Catches Sharks on the Move. Science 310: 32-33. www.sciencemag.org
Satellite Pop-up Archival Transmitting (PAT) Tags	Pacific Halibut	Article	Andrew Seitz	aseitz@ims.uaf.edu		An independent method to collect environmental preference data (and ambient water temperature) and migration distance of demersal fish, a method adapted from large pelagic fish. Seitz, A.C., D. Wilson, B.L. Norcross, J.L. Nielsen. 2003. Pop-up archival transmitting (PAT) tags: a method to investigate the migration and behavior of Pacific Halibut Hoppoglussus stenolepis in the Gulf of Alaska. Reprinted from the Alaska Fishery Research Bulletin Vol 10 No. 2 Winter 2003 - http//www.adfg.state.ak.us/pubs/afrb/afrbhome.php
Satellite Pop-up Tags	Nearshore and Pelagic Species - Pacific Halibut Hippoglossus stenolepis tested	Web	Dr. Jennifer L. Nielsen	-		Seitz, A., D. Wilson, and J.L. Nielsen. 2002. Exxon Valdez Oil Spill Restoration Project Final Report Testing Pop-up Satellite Tags as a Tool for Identifying Critical Habitat for Pacific Halibut (Hippoglossus stenolepis) in the Gulf of Alaska. Restoration Project 01478 Final Report. U.S. Geological Survey. Alaska Biological Science Center, Anchorage, Alaska. Seitz, A. C., B. L. Norcross, D. Wilson and J. L. Nielsen. 2005. Identifying spawning behavior in Pacific halibut, Hippoglossus stenolepis, using electronic tags. Environmental Biology of Fishes.
Satellite/Acoustic	Marine Fish and Mammals	Web	Program			http://www.absc.usgs.gov/research/Banding/banding_program.htm; http://www.absc.usgs.gov/research/seabird_foragefish/index.html

Appendix Table B-4. Acoustic and Satellite telemetry studies of marine invertebrates in Alaska and examples from other areas outside Alaska: see next page for more details on researchers, publications, and websites.

Telemetry Type Vendor	Organism	Research Objectives or Issue	Region	Location	Organization, Program or Project
Acoustic	Giant Octopus	Native villager interest in Exxon spill and potential impact on Octopus, part of subsistence lifestyle. Octopus appear to decline after spill, study was in intertidal areas.	Gulf of Alaska	Prince William Sound and Cook Inlet	Alaska Pacific University
Acoustic	Dungeness Crab	Defining essential habitat - seasonal distribution and migration in Glacier Bay	SE Alaska	Fritz Cove, SE Alaska	Auke Bay Lab, NMFS
Acoustic	Red King Crab	Aggregating behavior of king crab, seasonal shifts in habitat use and bottom distribution.	SE Alaska	Auke Bay	Auke Bay Lab, NMFS
Acoustic	Tanner Crab and Red King Crab	Glacier Bay National Park - Testing the Effectiveness of a High Latitude Marine Reserve Network: A Multi-Species Movement Study in Glacier Bay National Park, Alaska	SE Alaska	Glacier Bay National Park	USGS - Glacier Bay Field Station
Acoustic	Pacific Squid	Testing acoustic telemetry to track Pacific squid movements in Puget Sound	Puget Sound	Central Sound	Puget Sound Biotelemetry Project - NMFS, University of Washington, POST
Acoustic	Arrow Squid	Tracking squid movements using sixty-four automated acoustic receivers aligned as underwater 'curtains' across the entrances to bays and inlets.	SW Pacific	Storm Bay, SE Tasmania	University of Tasmania, Census for Marine Life
Satellite - Pop-up; Radio	Cephalopods	Tracking squid using Pop-up satellite tags and radio tags.	Various		R. Odor, lead for Census of Marine Life

Additional Information on Marine Invertebrate Biotelemetry References

Telemetry Category	Organism	Information Source	Lead Investigator	Email	Phone	Publication and/or Research Interest
Acoustic	Dungenness Crab	Web	Kirstin Kari Holsman	kkari@u.washington.edu		Daumbald, B. 2003. The ecological role and potential impacts of molluscan shellfish culture in the estuarine environment. WRAC Project Termination Report. Holsman, K. 2003 In situ observations of Dungeness crab (Cancer magister) movement using underwater video and acoustic telemetry. Pacific Ecology Conference 2003, Bamfield Marine Station, BC.
Acoustic	Red King Crab	Article	RP Stone	bob.stone@noaa.gov		Stone, RP; O'Clair, CE; Shirley, TC. 1993. Aggregating behavior of ovigerous female red king crab, Paralithodes camtschaticus , in Auke Bay, Alaska. Canadian Journal of Fisheries and Aquatic Sciences [CAN. J. FISH. AQUAT. SCI.]. Vol. 50, no. 4, pp. 750-758.
Acoustic - Sonotronics	Dungenness Crab	Scientific Article	Robert P Stone	bob.stone@noaa.gov		Stone, R.P. and C.E. O'Clair. 2001. Seasonal movements and distribution of Dungeness crabs Cancer magister in a glacial southeastern Alaska estuary. MARINE ECOLOGY PROGRESS SERIES Mar Ecol Prog Ser Vol 214: 167-176
Acoustic Tags - VEMCO and Lotek	Crustaceans - Tanner Crab Red King Crab; and Pacific Halibut	Web and Study Plan	Philip N. Hooge Spencer J. Taggart	philip_hooge@usgs.gov jim_taggart@usgs.gov	907.364.1577 907.697.2637	Taggart, S.J, P.N. Hooge, J. Mondragon, and A. Andrews. 2002. STUDY PLAN - Testing the Effectiveness of a High Latitude Marine Reserve Network: A Multi-Species Movement Study in Glacier Bay National Park, Alaska. USGS Alaska:PDF. Evaulation of information hypothesizes that “no-take marine reserves” may promote marine biodiversity, increase scientific understanding and enhance the long-term sustainability of many fisheries. Studied halibut and crustaceans using acoustic telemetry. Studied movement between reserve and non-reserve areas using "acoustic gate". Sets stage for future studies, which will address the effect of the reserves on larval supply and the role of reserves as ecological sources vs. sinks. http://www.absc.usgs.gov/glba/marine_reserves.htm
Acoustic, Acoustic "Curtains" VEMCO; Acoustic Release - Sub Sea Sonics	Arrow Squid Nototodarus gouldi (Cephalopoda: Ommastrephidae)	Scientific Article	Kate E. Stark			K.E. Stark, G.D. Jackson, J.M. Lyle. 2005. Tracking arrow squid movements with an automated acoustic telemetry system. Marine Ecology Progress Series Vol. 299: 167–177. Sixty-four automated acoustic receivers were aligned as underwater ‘curtains’ across the entrances to bays and inlets.
Acoustic, Mobile Tracking (Active Tracking) - Vemco	Giant Octopus Octopus dofleini	Web	David Scheel, Tania Vincent	dscheel@alaskapacific.edu		Study began from native villages interests in the Exxon Valdez oil spill impacted area. Octopuses are part of subsistence lifestyle and numbers of octopuses appeared to be declining after the spill. The study occurred in shallow intertidal areas of PWS, 5 animals were tagged and mobile tracked (receiver provided by PWS Institute. This project was supported by the Exxon Valdez Oil Spill Trustee Council and Project Aware. A complete report has been provided to the EVOS Restoration Office. http://marine.alaskapacific.edu/Marine/MAR%20Facilities.php
Satellite - Pop-up; Radio	Cephalapods	Scientific Articles				O’Dor R (2002) Telemetered cephalopod energetics: swimming, soaring, and blimping. Integr Comp Biol 42:1065–1070; O’Dor RK, Hoar JA, Webber DM, Carey FG, Tanaka S, Martins HR, Porteiro FM (1994) Squid (Loligo forbesi) performance and metabolic rates in nature. Mar Freshw Behav Physiol 25:163–177

APPENDIX C

Regional to International Scale Acoustic Telemetry Programs with Reference to Alaska

Ocean Tracking Network (OTN) – is a large-scale global initiative that aims to comprehensively monitor ocean conditions and marine life response to these conditions. The network includes acoustic curtains, in selected continental shelf and open ocean telemetry regions that utilize acoustic equipment manufactured by VEMCO and ocean observing systems technology to measure physical properties by Satlantic. The ocean tracking network is affiliated with a number of ocean observing programs.

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Census for Marine Life (CoML) – is a ten-year international project. It has a number of international and regional marine study projects including Alaska. The Pacific Ocean Shelf Tracking (POST) project and Tagging of Pacific Pelagics (TOPP) study are demonstration biotelemetry projects for the planned global Ocean Tracking Network (OTN).

Chief Scientist Ron O'Dor
http://www.coml.org/

CoML Research Coordination – Alaska
http://www.coml.us/dev2go.web?anchor=coml_us_leadership

US National Committee for the Census of Marine Life. There is a Scientific Steering Committee (SSC) for the CoML for US, **Vera Alexander is the SSL Liason.** She serves as Assistant to the Provost for Fisheries and Oceans Policy. She also serves as Director of the MMS/UAF Coastal Marine Institute and the UAF Pollock Conservation Cooperative Research Center, supported by the Pollock Conservation Cooperative. She is also a professor of Marine Science at UAF.

CoML Nearshore Geography in Shore Areas Program – Regional Area – Eastern Pacific, Prince William Sound Research http://www.nagisa.coml.org/EasternPacificPage.htm
Funding provided by Gulf Ecosystem Monitoring Program – Sampling in Prince William Sound, Kachemak Bay, Kodiak Island

Pacific Ocean Shelf Tracking (POST) Project. One of seven initial CoML projects. A program to develop and promote the application of new electronic tagging technology to study usage of marine environments and migration routes of Pacific Salmon and other migratory species: it includes development and placement of acoustic lines along coastal areas in Alaska.

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250-714-0044; Fax: 250-714-0045
david.welch@kintamaresearch.org

Tagging of Pacific Pelagics (TOPPs) – One of seven initial CoML funded projects. A program using electronic tagging technologies, Satellite Argos and Pop-up Archival Tags, to study migration patterns of large open-ocean animals and the oceanographic factors controlling these patterns.

Project Leaders: Dr. Barbara Block
Prothro Professor of Marine Sciences
Stanford University.
http://www.toppcensus.org/Default.aspx?bhcp=1

Department of Biological Sciences
Hopkins Marine Station
Pacific Grove, CA 93950, USA
Phone: (831) 655-6236
block@leland.stanford.edu
http://www.tunaresearch.org/

TOPPs Salmon Shark Research. Tracking of salmon sharks in PWS Alaska.
http://www.toppcensus.org/web/FeatureDetails.aspx?id=58&WG=10

Hawaiian Undersea Listening Array (HULA) and Bioacoustic Ocean Observatory – is planned to be the first large-scale Bioacoustic Ocean Observatory. The Bioacoustic Ocean Observatory concept involves the deployment of undersea listening arrays to acoustically track, using Hydroacoustic Technology Inc (HTI) equipment, many types of pelagic animals continuously, in real time, and in relatively large volumes of ocean. The eventual goal is to build a cabled undersea listening array that will be constructed to track acoustically tagged or vocalizing pelagic animals continuously, in three dimensions, and in real time. While the technology for doing this on a small scale is already available, nobody has attempted to do this on a large scale. HULA is a proposal to develop a new generation of acoustic tags, modified receiver and processing hardware, and a multiple-mooring prototype observatory. When completed, this prototype observatory will be able to operate as a stand-alone system or can become the basic building block to be added to nodes along the cable backbone of either our proposed undersea listening array or other cabled observing systems (e.g., MARS, NEPTUNE, VENUS).

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http://www.orionprogram.org/RFA/Proposals/Greene.pdf

APPENDIX D

Biotelemetry Firms

Telemetry Category	Vendor	Web-site	Address	Email	Phone
Satellite	Telonics	www.telonics.com/	932 E. Impala Avenue Mesa, AZ 85204-6699	info@telonics.com	480.892.4444
Satellite and Pop-up Archival (PSAT)	Wildlife Computers	www.wildlifecomputers.com	8345 154th Avenue NE Redmond WA 98052	tags@wildlifecomputers.com,	425.881.3048
Satellite and PSAT	Microwave Telemetry	http://microwavetelemetry.com	8835 Columbia 100 Pky Suites K and L Columbia, MD 21045 USA	inquiries@microwavetelemetry.com	410.715.5292
Archival Data Storage Tags (DST)	Star-oddi	http://www.star-oddi.com/	Vatnagardar 14 104 Reykjavik Iceland	north.america@star-oddi.com	354.533.6060
Archival DST	Lotek	www.lotek.com/	115 Pony Drive Newmarket, ON Canada L3Y 7B5	telemetry@lotek.com	905.836.6680
Archival DST	Alphamach	www.alphamach.com	349, de Ramsay Mont St-Hilaire Qc, J3H 2W4 Canada	rtur@alphamach.com	450.446.3153
Radio	Advanced Telemetry Systems (ATS)	www.atstrack.com	5438 Betty Circle Livermore, CA 94550	sales@atstrack.com	763.444.9267
Radio	Grant Systems Eng	www.grant.ca/	111 Manitou Drive King City, ON Canada L7B 1E7	radiotelem@grant.ca	905.833.0061
Radio and Combined Acoustic/Radio (CART)	Lotek	www.lotek.com/	115 Pony Drive Newmarket, ON Canada L3Y 7B5	telemetry@lotek.com	905.836.6680
Acoustic	Grant Systems Eng	www.grant.ca/	111 Manitou Drive King City, ON Canada L7B 1E7	radiotelem@grant.ca	905.833.0061
Acoustic	Hydroacoustic Technology Inc (HTI)	htisonar.com	715 NE Northlake Way Seattle, WA 98105-6429	support@HTIsonar.com	206.633.3383
Acoustic	Lotek	www.lotek.com/	115 Pony Drive Newmarket, ON Canada L3Y 7B5	telemetry@lotek.com	905.836.6680
Acoustic	Sonotronics	www.media-masters.com/sonotronics	1130 E. Pennsylvania St. Suite 505 Tucson, AZ 85714	mgregor@azstarnet.com	602.746.3322
Acoustic	Thelma AS	www.thelma.no/static/telemetry.html	Post box 6170 Sluppen N-7435 Trondheim, Norway	telemetry@thelma.no	47 73 87 78 04
Acoustic	Vemco	www.vemco.com	100 Osprey Drive Shad Bay, Nova Scotia Canada B3L 2C1	dmwebber@vemco.com	902.852.3047
PIT Tag	Biomark	www.biomark.com	7615 West Riverside Dr Boise, Idaho 83714	biomark@micro.net	208.275.0011