30 years of WILDLIFE TRACKING WITH ARGOS

ENVIRONMENTAL MONITORING
# CONTENTS

30 years of **WILDLIFE TRACKING WITH ARGOS**

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The Argos system revolutionized our vision of the ecology of marine predators. Today, this successful satellite system celebrates its 30th anniversary.

This year, it is exactly 20 years ago that we equipped 6 large albatrosses on the Crozet Islands with Argos transmitters that were actually meant for dolphins. One year later, our findings on the movements of these great travelers of the Southern Ocean appeared in Nature. The spectacular results of this study have popularized the use of Argos for animal tracking purposes. Ever since, the number of studies using Argos has increased exponentially.

Interest in the Argos system increased even further thanks to the continuous miniaturization of the “on board” electronics, which made it possible to study a growing number of increasingly small bird species. Starting with a 180g transmitter in 1989, engineers have nowadays succeeded in reducing the transmitters’ weight to a mere 9g by equipping it with solar panels.

Simultaneously, the transition from Argos-1 to Argos-2 and the possibility of transmitting information measured by special sensors (e.g. depth, light, temperature, GPS location, salinity, and fluorometry – both in real time and recorded by Pop-Up systems) have transformed animal tags into real oceanographic platforms. Nowadays, sea elephants and sharks equipped with Argos transmitters travel the oceans while relaying oceanographic profiles measured during their abyssal dives.

Faced with growing concern over the impact of climate change, environmental and behavioral data give us invaluable insight in how ecosystems and species respond to such threats. Thanks to the Argos system scientists are provided with the tools needed to observe endangered species and help protect our planet. Happy birthday, Argos!
Until the late 1980s, detailed study of bird migration was difficult. In the early 1990s, however, the new technology of ‘satellite tracking’ became available for the study of birds. This meant that the migration of individual birds could be tracked almost in real time. Since, we have studied the movements of about 20 bird species in Asia using satellite tracking. Studied species have included cranes, storks, swans, geese, ducks and hawks (see figures 2 and 3 below).

The Argos system is used to investigate migration routes, migration patterns through time and habitat use of these threatened birds in East Asia, with the aim of contributing to the conservation of the focal species and their habitats. Satellite tracking is a powerful research technique to study bird movements at middle (within a country) to large (global) scales, because it allows tracking of individual birds anywhere in the world nearly real time.

Satellite tracking of cranes and storks

Our studies were mainly concentrated on investigating the migrations of cranes and storks, utilizing Argos satellite tracking.

Worldwide, the crane family (Gruidae) is one of the most endangered families of birds. Ten species of the 15 in the family are considered to be threatened with extinction and one additional species is recommended for threatened status. Another family, that of the stork (Ciconiidae), includes 5 threatened species, and another two are classified as near threatened. Coincident with their conservation status, the populations of threatened species of storks and all but one threatened species of cranes are in decline.

Migration patterns and behavior

To relay bird locations, platform transmitter terminals (PTTs) have been employed in combination with Argos satellites. Location data were then utilized in a variety of applications, from determining migration routes, stopover patterns and wintering sites, through more advanced analyses including using various data overlays to examine habitat use, occupation of nature reserves, differential migration patterns between adults and juvenile birds, and the connectivity and network structure of migration pathways.

From the locations obtained, we have been able to precise migration routes, the temporal schedule of migration, and the relative importance of stopover sites based on the number of birds visited and their length of stay. Different migration strategies in juvenile and adult birds were also discovered.

Migration strategies

The results were spectacular: tracking data showed that cranes and storks covered highly

Migratory birds encounter habitat destruction, hunting, and collisions with aircraft during their migration. They may also carry the viruses of some infectious diseases such as West Nile fever and Avian influenza. It is therefore important to know the details of their migration routes and migration behavior.
variable distances on migration, both within and between species. Red-crowned cranes (Grus japonensis), for example, migrated from 671-2,509 km between their breeding and wintering sites, whereas Siberian cranes (Grus leucogeranus) migrated the furthest of all crane species we have tracked, covering 4,903-5,586 km between their breeding and wintering areas.

In accordance with distances covered, the detected number of rest stops taken by migrating cranes ranged from 0-17. Siberian cranes took the most rest stops of any species tracked (Kanai et al. 2002), while White-naped cranes (Grus vipio) were able to complete their migration with as few as one detected rest stop (Higuchi et al. 1996). Red-crowned cranes may have been able to migrate without resting at all (Tamura et al. 2000).

In short, cranes appeared to make the longest flights possible between rest stops. For Demi-selle cranes (Anthropoides virgo), this may be necessary due to the fairly inhospitable nature of habitats along their migration pathways (Kanai et al. 2000). However, migration routes of other species cover less extreme habitats, which suggests that traveling as far as possible as quickly as possible is strategic, rather than necessary.

Importance of stopover sites and reserve design

Because it allows birds to be followed more or less continuously through time, the Argos system can be used to identify important stopover areas for birds along migration routes. Areas identified as important (e.g. due to prolonged use by birds, or use by a substantive number of birds) are likely to be of significance for conservation of the focal species, and can be allocated conservation priority accordingly.

In China, for example, satellite tracking data have been used to identify important stopover and wintering sites for cranes and stork such as Bohai and Liaodong Bays, Poyang Lake, Three Rivers Plain, Tianjin, Qiqihar Baicheng area and the Yellow River delta. These sites are currently subjected to varying levels of protection, from none to some form of nature reserve. Argos tracking data has identified insufficiently protected areas that are important for cranes and storks, and facilitated these areas becoming focal for conservation.

A promising future for the Argos system

Due to limitations pertaining to the weight of satellite transmitters, satellite tracking can currently only be conducted on large and medium-sized birds like cranes, swans, ducks and hawks. However, as transmitters become smaller and smaller, the number of bird species that can be fitted with them is sure to increase. With additional improvements made to battery life and location accuracy, it will become possible to obtain even more detailed tracking information for even longer periods of time.

Next to that, migration strategies appeared to differ between cranes and oriental white storks (Ciconia boyciana). Cranes took fewer lengthy rest stops than oriental white storks. Most cranes rested for more than 6 days only 1-5 times during migration, whereas storks spent an average of 20 days at each of their 3-6 detected rest stops. Further, storks made much shorter daily flights than cranes (Higuchi et al. 2000; Tamura et al. 2000; Shimazaki et al. 2004).

Following these findings, recommendations have been developed for spatial improvements to nature reserves.

My personal experiences with Argos

It is nearly 20 years ago that I started satellite-tracking the migration of birds. I have always really enjoyed doing research and found it exciting to view the satellite locations and migration routes on my computer. I particularly enjoyed following the migration of Oriental Honey-buzzards (as shown in figures 2 and 3) as these buzzards visited all of the East Asian countries one by one. While watching their migration, I realized that the Argos system is a really wonderful and important research tool. I would like to acknowledge all of the relevant people involved in the development and management of this system, Happy 30th birthday, Argos!

Dr. Hiroyoshi Higuchi

Dr. Hiroyoshi Higuchi is Professor of Biodiversity Science in the Department of Ecosystem Studies, The University of Tokyo, Japan. His research focuses on the evolution, ecology and conservation of biodiversity. Birds are his main research target. He is also interested in the conflicts between wildlife and humans and the effects of climate change on the life of animals and plants. He has published many books including "What’s Wrong with Crows?" (Shogakukan, Tokyo) and “Bird Migration - Satellite Tracking of Migratory Birds” (NHK Books, Tokyo).
In Argos’s first operational year, some of the very first animals to be tracked with the Argos system were polar bears off the coast of Alaska. Although polar bears are classified as marine mammals, they differ from most other marine mammals by possessing a neck that is suitable for a collar attachment. Tag attachment for other marine mammals such as seals and whales is more of a challenge and successful tracking of some of these species did not occur until the mid-1980’s. As a late-comer to the field of satellite telemetry, I missed out on some of these early developments, but over the last 17 years I have been fortunate to observe a steady improvement in the system and its application to studies of the behavior of marine mammals. Key advances have occurred in at least 3 areas: methods for analyzing the movement data collected by the Argos system, proliferation in the type of sensors and therefore the variety of data types capable of being sent by an animal-borne transmitter, and miniaturization of transmitters.

New sensors and analysis methods

Once researchers discovered that epoxy could be used to glue telemetry tags to the fur of pinnipeds such as seals and sea lions (Fedak et al., 1983), Argos satellite tags gained widespread use in marine mammalogy. To progress beyond simply describing the movement path of marine mammals, we have relied on innovations in the sensors that satellite transmitters include as well as advances in the ways that we analyze the movement data. Recently there has been much progress in developing and applying new movement analysis methods such as fractal analysis, Lévy flights, first passage time, and state-space models (reviewed in Schick et al., 2008). A novel method that was recently applied to some of our northern fur seal tracking data offers promise for picking out behavioral change points from the Argos data, even when it suffers from the common problem of irregular sampling intervals and uncertain location error (Gurarie et al., 2009).

Until recently, the behavioral data that we could collect from marine mammals using Argos tags have been limited to water immersion and dive depth. For many years we have used archival (non-transmitting) tags equipped with additional sensors for direct measurement of variables such as prey ingestion, flipper stroking, and even physiological parameters like heart rate. Although bandwidth limitations had previously discouraged us from attempting to telemeter this data via satellite, we’ve recently begun using Argos satellite tags with sensors for stomach temperature because this is a signal that is relatively easy to compress into an Argos message with enough resolution to identify drops in stomach temperature that indicate prey ingestion of colder ectothermic prey by warmer endothermic marine mammals.

These new tags have facilitated a recent study of Steller sea lions in far eastern Russia. Adult Steller sea lions can be captured by darting them with a tranquilizer during the breeding season, but their wariness makes it very difficult to do this a second time to retrieve archival data loggers,
necessitating telemetry. In past studies, however, we obtained poor temporal and spatial resolution from Argos tracking during the short, over-night foraging trips of Steller sea lions. Traditional GPS receivers didn’t work due to the very short surfacings of sea lions, but with the new “Fastloc” technology from Wild Track Telemetry Systems that requires less than 100 ms to take a “snapshot” of the GPS constellation, GPS locations can now be obtained for marine mammals using Argos satellite transmitters to relay data.

We worked with Wildlife Computers to obtain a tag (Fig. 1) that included Fastloc GPS as well as stomach temperature telemetry and dive depth so that we could pin-point the location and timing of feeding by sea lions in an area (Fig. 3) where their populations had undergone a marked decline over the last few decades. Although many of us bemoan the low bandwidth of the Argos system, the inclusion of novel behavioral and environmental sensors in Argos satellite transmitters will expand research opportunities and the data is bound to be coming in faster than we can keep up with it.

More species tracked thanks to very small tag design

Another important advancement has been the dramatic reduction in the size of the transmitters. Marine mammals are relatively large animals, so the energetic consequences of carrying a satellite tag are not likely to be significant, but when attempting to attach a tag to marine mammals that lack fur, miniaturization is critical for being able to keep the tag attached. We were interested in tracking some of the medium-sized cetaceans that were too large to be captured for surgical attachment of a tag but too small for the larger tags being remotely implanted into large whales like blue and humpback whales. The solution was to design a very small tag (Fig. 2, 4) that flies through the air nearly as well as it flies through the water. These tags are launched onto the fin with a crossbow or air-gun and held to the fin with 2 small barbed titanium darts. The tags typically transmit for 1-3 months, but up to 6 months depending upon species, before the darts pull back out the same holes they created upon attachment.

These new miniature tags have rapidly expanded the number of cetacean species that can now be tracked via Argos. Some of these are whales whose movement patterns were poorly known, if at all, such as false killer, pygmy killer, melon-headed, and Blainville’s and Cuvier’s beaked whales. Thanks to Argos, it is finally possible to closely monitor their behavior and to develop recommendations for the protection of their habitat.

To learn more
ABOUT THE ALASKA SEALIFE CENTER:
http://www.alaskasealife.org

Dr. Russel D. Andrews

Dr. Andrews is an Alaska SeaLife Center scientist and a Research Professor for the School of Fisheries and Ocean Sciences at the University of Alaska, Fairbanks. Using remote-monitoring instruments, many of which he has designed and built himself, he has studied the physiology, behavior and conservation biology of marine mammals, sea birds and sea turtles from the Arctic to the Antarctic.
After the glaciers receded from the north, caribou expanded to occupy the vastness of the Canadian Arctic and within this realm, adapted their life histories to match their environments. Perhaps two and half million caribou wander across North America but even with such abundance, there are serious concerns for the species. Historically caribou have gone through periods of high to low abundance – in recent years many barren-ground caribou herds have undergone severe declines.

Massive spring migration
Most people are familiar with the massive herds of caribou that migrate over huge distances from their wintering grounds along the tree-line to give birth on the barrens. The migration rivals that of the African Serengeti. As a strategy to reduce predation by wolves and grizzly bears, the spring migration heads northward to traditional high density calving areas with births synchronized to a 10-day period. With tens of thousand of calves born in such a narrow window of time, predators are swamped and can kill relatively few young. Soon after birth, the caribou are again on the move and eventually return south to winter near or below the tree line.

Much less known are the mysterious woodland caribou of the boreal forest. Choosing to live a solitary lifestyle during spring and summer to give birth and rear their calves, boreal caribou form groups of 8-12 animals the rest of the year. Rather than congregate to calve, the females disperse throughout the boreal forests to avoid predators. The key to boreal caribou survival is stealth – the strategy is one of hide-and-seek.

Understanding the caribou’s ecology
While scientists have understood the basics of caribou ecology for decades, northern hunters have understood the ways of caribou for thousands of years. Unfortunately for caribou, the world is changing and the Arctic is a place changing faster than many other parts of our planet. Exploration and development of oil, gas, diamonds, and minerals is changing what was until recently, a pristine habitat ruled largely by the harshness of the climate. Even the boreal forest is at risk with logging, seismic lines, and other developments carving up the hiding places of boreal caribou and making them more vulnerable to predators.

The key to wise management of a species is a thorough understanding of their ecology. Caribou being the supermarket of the Canadian Arctic communities meant that we needed solid data on their distribution and abundance. In the early days, tracking of caribou by aircraft provided some insights but it was easy to lose animals in the vast wilderness. As satellite telemetry became available, it was obvious that this was the technology to explore the ways of the “snow deer”.

No other species plays such a central role in the dynamics of northern Canada as the caribou (Rangifer tarandus): an animal superbly adapted to snow and a diet of lichen. Spanning a huge range of habitats from dense boreal forests in the south to mountain plateaus to the barrens and the high Arctic Islands, caribou are the lifeblood of northern communities and a key component of healthy ecosystems.
Satellite tracking with Argos

Starting in 1996, the first barren-ground caribou in the Northwest Territories of Canada were equipped with Argos satellite collars. Using local hunter observations and reconnaissance surveys to locate study animals, net-gunning from a helicopter has been the only practical means of capturing the animals. Once safely controlled, the collars are quickly attached and the animals are set free.

Effective caribou protection

One of the key goals of the research is to understand the distribution of caribou so that photographic surveys can be made to monitor their abundance. Many of the barren-ground caribou herds are in decline and it is crucial to understand the spatial structure of the herds and how they interact. We know that herds exist but without detailed information on movements, fidelity, and habitat use, we can only guess at the appropriate management responses to harvest and development. Defining critical ranges is an essential part of the research.

This may sound simple but for animals with home ranges from 200 to 310,000 km², this is no simple undertaking. The traditional calving areas of barren-ground caribou are obvious areas for conservation but how do we manage the dispersed calving areas of boreal caribou? Since that first year of research, 352 barren-ground, 176 boreal, 11 mountain, 10 Peary, and 39 island caribou have been tracked by Argos satellites with funding from the Governments of the Northwest Territories and Nunavut and the wildlife management boards established under land claims. Some animals were followed for up to 6 years while others taken by subsistence hunters or wolves have provided less data – both the short and longer data series provide valuable insights on caribou populations.

The Arctic is warming and the once remote habitat of caribou is no longer as wild as it used to be. Effective protection and wise management of caribou and their habitat is absolutely reliant on technology. The Argos system, more than any other, has given scientist and managers the tools and data that they need.

To learn more

ABOUT THIS CARIBOU TRACKING PROGRAM:
http://www.biology.ualberta.ca/faculty/andrew_derocher/?
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When Microwave Telemetry, Inc. was started in 1991, we had already missed Argos’ childhood. That year we introduced our first PTT, the 95g PTT-100, which transmitted near the center of the Argos 1 band. We established that the Argos system could be routinely used to track migratory birds with low power satellite transmitters.

As they say, the rest is history. Lighter low powered transmitters truly opened up bird tracking through the Argos system. Since then, biologists have marveled at long range migratory paths, have done small scale habitat studies, tracked vectors of diseases and ultimately helped to save several endangered species. Much of this was made possible by improvements in the Argos system and us taking advantage of them in our new products.

The long road to smaller transmitters

The introduction of Argos 2 in 1998 and its wider bandwidth, allowed us to move away from the crowded center frequency and improve reception of messages at the satellite. By then, we had used hybrid COB (Chip on Board) circuit technology to miniaturize our PTTs’ electronics which enabled us to introduce a 30g PTT, and a 38g implantable version. We also had extended the operational life of our PTTs by equipping some with solar recharged batteries. This led to the 35g, 18g, 12g and 9.5g solar PTTs available today. Our long awaited, newest solar PTT only weighs 5 grams; though we tested prototypes almost two years ago, putting it into production was easier said than done!

Argos 2 arrived in time for us to deploy our first Archival popup tag in 1999, this following the deployment of our first single point popup tag in 1997. Marine biologists had long wished for devices that would archive data, detach and transmit the data to satellites, eliminating the need to recover the tag. Since then we have increased the capabilities of the popup tags, with the introduction of high rate archival popup tags, our tiny X-Tag and our even smaller E-Tag which is under development.

Although the Argos 2 receiver is more sensitive, resulting in the reception of weaker transmissions, around 2000 we noticed degradation of reception near the Mediterranean. Radio interference was affecting the satellites when they were over Europe and the Mediterranean. The introduction of GPS technology to our PTTs in 2001 partially solved this, allowing several locations, accurate to within 15m, to be collected and then transmitted through the Argos system within a few single messages. We now have GPS PTTs ranging in size from 70g down to 22g.

Argos-3: the next generation

Argos 3 was launched in 2006. Its increased receiver sensitivity further improved reception of low level signals at the satellite. We are now developing a new PTT to take advantage of the added capability of receiving QPSK modulated PTT transmissions. This may be especially valuable to our fish tags which can transmit as many as 10,000 messages in about 3 weeks. Unfortunately, we have not yet been able to take advantage of the two-way capability of Argos 3 as the added complexity would add weight to our PTTs which we are continually trying to reduce in weight and size.

As we look ahead to Argos 4, we hope to work closely with CLS to move forward and to be part of this unique journey. So, Happy 30th Birthday Argos, may you live long and prosper!
Since 2007, CLS offers a dedicated archival tag data processing service to fisheries scientists and marine biologists who prefer to focus on the ecological interpretation of their tag results rather than on the technicalities of tag data processing. This service, called Track & Loc, is the result of CLS’ unique experience in Argos, tag data processing and satellite oceanography. Hundreds of pop-up and internal tags have already been successfully processed by CLS’ scientific team and large programs such as the European Tuna Tagging Program have already trusted upon CLS.

How does it work?

Pop-up and internal archival tags record water temperature, depth and light which will then be used to perform underwater positioning. However, light-based positioning has very limited accuracy, yielding errors of several degrees (several hundreds of kilometers). Over the last few years CLS experts actively contributed to the development of improved underwater geopositioning techniques using optimal estimation techniques to significantly reduce the positioning error. This is made possible by combining the information from light-level measurements with additional positioning constraints provided by water temperature measurements, bathymetry and animal movement models. The Track & Loc service is operated by CLS scientists from the Marine Ecosystem Modeling and Monitoring team (MEMMS) of CLS’ Satellite Oceanography division. Currently, the Track & Loc service is used by over 30 programs in 20 countries, that track 17 species with approximately 350 tags.

Tagging project with the Malpelo Foundation

In 2006, 2007 and 2008, the Malpelo Foundation – a nonprofit Colombian organization whose objective is to promote the protection and conservation of the Colombian marine ecosystem – led a tagging campaign for the studies of two shark species S. lewini (hammerheads) and O. ferox (Small-tooth sandtiger shark), in the Tropical East Pacific Corridor (TEPC), a large marine protected area including the Galapagos (Ecuador), Isla de Cocos (Costa Rica) and Malpelo Fauna and Flora Sanctuary (Colombia). These areas are managed by different government conservation entities, such as the Colombian National Natural Park System, a key partner for the conservation efforts of the Malpelo Foundation. Seventeen pop-up satellite transmitting archival tags were deployed. The retrieved data were successfully processed by CLS scientists and delivered highly valuable information about the behavior and habitat of these shark species. It was found for instance that the diving depth for these two species strongly differed from each other: S. lewini appeared more constrained to the surface (0-50 m) with deep dives up to 900 m against 20 to 200 m for O. ferox (with deep dives up to 1800 m). This finding has important implications for their vulnerability to longliners. Additionally, it was shown that both species were confined to the Tropical East Pacific Corridor with very little movements from the tagging sites, thus proving once again the importance of protecting this area.

Figure 1. Kalman filtered trajectories for two tags (O.ferox above and S.lewini below), using a combination of sea surface temperature and bathymetry to constrain the estimates.