Telemetry and the LHX Tag

What is telemetry? Telemetry means 'measuring at a distance'. It is a word composed of the Greek word 'tele', which means distant, and the Greek word 'metros', which means measurement. Telemetry allows us to collect information without being there in person. For example, a webcam is a kind of telemetry that allows us to remotely collect behavioral information, or allows us to remotely read flipper tags or brands, all without being there. The most common application of telemetry on marine mammals is through the use of small electronic devices that are attached to animals and either record information or transmit a signal. While the very first telemetry devices that were used were very simple, mechanical recording devices, modern units are typically very small computers and are in fact very similar to cell phones (smart phones). We call devices that record information without transmitting it 'archival tags' - that's because they create an archive or collection of information. Archival tags usually have a number of different sensors that provide the data these tags record. For example, temperature sensors can tell how cold the water is that animals are swimming through (or how cold the air is if they are 'hauled out'). Pressure sensors can detect how deep underwater an animal is diving. Movement sensors can tell if an animal is sleeping or active. GPS navigation sensors can tell where on the surface of the ocean an animal is located (GPS does not work underwater). Light sensors can tell how much light there is for an animal to see by. And so on... there are many ways to use archival tags to record where an animal is, what it is doing, and what the environment around the animal looks like. For example, if we place an archival tag with a pressure sensor and a movement sensor on a sea lion, once we look at the data such a tag may have recorded over let's say 1 week, we may be able to tell exactly how many dives the sea lion made during this week, how many hours it spent sleeping and how may hours diving at sea, and we can even tell how long and how deep every single dive was that the animal made. We can even tell when the animal was eating fish: we put a very small 'pill' into the stomach of the animal that can sense temperature. This pill transmits the temperature information to the archival tag the animal carries on it's back (more on how we attach tags below). Since a sea lion is a warm-blooded mammal, its stomach is warm, about 37 degrees Celsius (or 98 degrees Fahrenheit). However, the fish that the sea lion eats are cold-blooded, and are at the temperature of the ocean water, much colder, typically about 5 to 10 or at the most 15 degrees Celsius. Therefore, whenever a sea lion eats a fish, the little pill it is carrying in the stomach senses a drop in temperature, and transmits this data to the archival tag on the back of the sea lion.

<u>Getting telemetry data back:</u>

But, how do we get this really interesting and useful data back into our hands? Such archival tags have to be recovered to be able to read the stored information. Usually this means that the animal carrying the tag has to be recaptured again for a second time (the first time was to attach the tag), which may be very difficult. If the tags are not recovered, they are useless. That's why researchers also use transmitting tags (again, very similar to cell phones). The simplest kinds of transmitting tags only transmit one type of signal that is used to find or locate an animal, but they do not transmit any actual data. Fancier tags actually transmit data either in real time (just as it is collected), or data that was previously recorded. Who can receive these transmissions and who can read this data? That depends on the type of system used. For example, some transmitting tags do actually use cell phone systems. That means data transmissions from the tags are picked up by cell phone towers and then sent to the home lab of the scientist as an email or text message. This works well on land, for example when working with moose, elk, or other large land animals. It does not work at sea because there are no cell phone towers at sea (it does work somewhat in coastal areas). Signals from tags that only transmit a locating signal but no data can be picked up by small hand-held radios (almost like walkie-talkies). This only works over short distances usually less than a mile or two. These types of tags are often used for the purpose of finding an animal, for example for capturing it and recovering an archival tag also attached to the animal. The fanciest types of tags transmit their data to satellites. These tags are incredibly useful as they give us a lot of very valuable information on the animal carrying the tag, but without the need to run around with hand-held receivers, and without having to recapture the animal and recover the tag. Tags that transmit their data directly to satellites also work with animals that are at sea anywhere on the planet.

How do we attach archival or transmitting tags to animals?

There are several ways we can attach tags to animals, include using suction cups on smooth-skinned whales, or using a small collar or harness like those used on dogs. However, these methods don't work well on seals, sea lions or diving birds. They are so streamlined that any collar would fall off. Instead, we glue the tags directly to the fur (for seals and sea lions) or feather (for diving birds like penguins). We use 5-minute epoxy from the local hardware store for this. The glue firmly attaches the tags to the hair or feather, and the tags stay on for many weeks or months in a way that does not harm the animal. However, the tags do not stay on forever since all these animals molt once per year. When they molt they change their fur or feather coat: old hair or feathers fall out and are replaced by new ones. At this time, any tags glued on simply fall off with the old fur or feathers. This is good because it means we don't bother the animals for too long, but it is also bad because it means we can never follow an animal or record its behavior for more than 12 months at the most, often times for much less than that, depending on when during the year we can capture them. So, by using telemetry devices we can learn a lot about the behavior and activities of marine animals at sea, when we cannot directly observe them. But can we use telemetry to monitor animals for periods longer than 12 months?

Implanted telemetry devices:

To get around the problems with tags glued to fur or feathers falling off at the most after 6-12 months, researchers have started using surgically implanted tags. An implanted tag is a device that is inserted inside of the body of an animal. Most people have probably heard of microchips that are used for pet identification. These so-called PIT-tags (that stands for Passive Implantable Transponder) are very small - typically the size of a large grain of rice - and are inserted under the skin of a dog or cat using a syringe-needle applicator. PIT-tags can be so small because they don't have heir own battery. Instead, they get their energy from what is called an 'interrogator', a scanner/reader device that looks like a large wand similar to those used for hand-held airport security screening. Such a reader wand is waved over the body of an animal, and in doing so emits electromagnetic energy that a special device can pick up and use. The device can then respond by emitting a very low power signal in return. If the reader wand receives a response from a PIT tag it will display information such as serial number, and sometimes even temperature. PIT tags have the big disadvantage that the reader wand needs to pass within a few inches of the tag to pick up a signal, because the tags have to use very little energy as a result of not having their own battery. To transmit a signal over a greater distance, a battery is needed, and generally, the longer the distance once tries to cover the bigger the battery has to be. That's why externally attached tags that need to transmit up to a satellite (over great distances of hundreds of kilometers) often have very large batteries, the size of flashlight batteries. We can even implant such large devices into large animals, but they can no longer be simply inserted under the skin through a syringe needle. Instead, we have to surgically implant such larger tags in an operation on a fully anesthetized animal. Different types of implanted telemetry tags have been used for a long time, and on many different animals. The first few applications used very small, short-range temperature transmitters in laboratory rats, and also in wild rodents. For such small animals, the batteries had to be very small, and as a result the transmitting range and life span were both very short. These tags were only able to transmit a signal over a few tens of meters, for maybe up to four weeks. Now larger tags are used in larger animals that last longer and can transmit over greater distances. Archival tags that record data are also implanted, but these have the big disadvantage of once again requiring recapture and even a second surgery to remove the implanted device, to get to the stored data. Unfortunately, implanted transmitting tags are faced with the fact that the host body weakens the signal substantially. For example, while many external telemetry devices exist that can successfully communicate with satellites over a distance of hundreds of kilometers, currently no implanted devices are capable of sending a strong enough signal to reach a satellite.

The Life History Transmitter - a new idea:
This is where the Life History Transmitter (or in short the LHX tag) comes in. I specifically developed the concept of this highly specialized telemetry transmitter for the purpose of helping us address the many questions surrounding the past and present population trends in the Steller sea lion. I wanted a telemetry device that could give us very specific information on individual Steller sea lions over the course of many years, and no matter where the animals might be and what might happen to them. I specifically wanted information on how long individual animals live, where they die, and how they die. Most of all, I was interested in finding out how many of them die from predation by sharks or killer whales. In other words, I wanted data from the missing '*corpus delicti*'. Two of these requirements were seemingly in contradiction with one another: multi-year tagging, and unlimited coverage (that means we get data back reliably no matter where on the planet the animal is located). Pretty much the only way to get unlimited coverage is through satellite data links. The only way to get multi-year tag retention is through implanted tags. However, we cannot transmit data to satellites from implanted devices that have a reasonable size.

The solution: delayed transmission, archival satellite transmitters:
The solution to this problem lay in the idea of using a tag that first works as an implanted archival tag while the animal is alive, and then works as an external transmitting tag after the animal has died. How can that work? This implanted archival tag has a satellite transmitter that only begins to transmit to satellites after it has come out of the host animal's body, after the animal has died. LHX tags are designed to work for many, many years. They should work for 10 years and longer. They are implanted into the gut cavity of the host sea lion (the belly). There they monitor several sensors and record data from these sensors, but they don't even attempt to transmit. The LHX tags also try to determine the state of the host animal: is it alive, or has it died? Once a tag has determined that the animal has died, it switches into a different mode of operation. It now tries to determine whether it has come out of the body of the dead host animal. The idea is that this '*extrusion*' should happen through a number of natural processes. Most likely, the body of a dead animal will decompose. This process may also be accelerated through scavengers that consume portions of the carcass. For example, in the oceans there are many scavenging organisms, such as worms, crustaceans, but also some fish. Along the shore, other scavengers may contribute to the process, such as vultures, eagles, foxes, rodents, crabs, insects and others. Once the decomposition process is sufficiently advanced, the remains of the body fall apart

and the LHX tag falls out. If this happens underwater, the LHX tag will float to the surface of the ocean, since it is lighter than water (it floats or is 'positively buoyant'). At this point, the LHX tag will recognize that it has come out of the host animal's body, and that it is at the surface of the ocean or lying on a beach. That's when it starts to transmit all the data it has previously stored through the life of the animal. Now that the tag is outside of the body the signal is strong enough to reach an orbiting satellite. Once we receive this data back from the satellite (via email), we know that the animal carrying the tag has died, when it died, where it died, what it did throughout its whole life, and maybe even why it died. So, we may not hear from a tag for many years, but once we do, we get some amazing data we could not get by any other means, no matter where the animal may have moved and where or when it might have died - in other words, we will eventually get data no matter what might have happened to the '*corpus delicti*'.

How about if the host animal was killed by a shark and eaten (if the '*corpus delicti*' was consumed)? Three things could happen: most predators like sharks and killer whales do not swallow large prey such as sea lions whole. Instead, they tear them apart and eat the bits and pieces one at a time. There is a good chance the LHX tags will come flying out of the killed sea lions body as the predator tears it apart. The tags are designed to remain 'free-floating': they have a special coating that prevents connective tissue from sticking to the tag. This makes it more likely the tags will come flying out and won't get swallowed by the predator. However, it is also possible that a predator does swallow an LHX tag. In that case, it will likely pass through the digestive tract of the predator and be passed out with other excrements, or it may be thrown up. We know this is what happens to the stomach temperature pills. In this case the tag would eventually still end up outside floating on the water from where it would begin transmissions. There is of course a slight possibility that the predator just happens to bite down on a tag, and it may crush it. In that case, the tag is destroyed and we won't hear from it.

<u>Challenges in using LHX tags:</u>
That is the biggest problem with the use of LHX tags: if we don't hear from a tag, we cannot really tell whether the animal carrying the tag is still alive, or whether it maybe died and the tags were unable to uplink to a satellite. There are several reasons why a tag may be unable to uplink to a satellite: a predator may have crushed it or it may have suffered some internal failure. All electronic devices can fail; batteries can run down, software can malfunction. However, even a tag that works without a flaw just as planned may be unable to uplink to a satellite if it is stuck under a rock somewhere, or is covered by algae. How do we deal with this problem?

<u>Two is better than one:</u>
The best way to deal with this problem is to use two LHX tags for each animal. For starters, this dramatically increases the probability that we will hear from at least one of the two tags. However, what's even more important is that we can now actually estimate how likely it will be that a tag will be unable to uplink to a satellite. If all study animals are released with two LHX tags, then if all goes well we will hear from both tags if an animal dies - we call this a dual data return. In a number of cases - hopefully a small number - we will hear from only one of the two tags in what we call a single data return. In an unknown number of cases we will hear from neither tag (we might call this a dud). By comparing the number of single returns to the number of dual returns we can actually estimate how many duds may have happened. Obviously, we need to have a reasonably large number of returns to be able to come up with these estimates.

Carcass testing:
To get the required numbers, we actually do what we call '*carcass testing*'. Basically we are simulating mortalities, but for obvious reasons we don't do that with live animals. Instead, we use the bodies of animals that have already died (these are called *carcasses*). We get them from our regional stranded animal response network (like the Oregon Marine Mammal Stranding Network, check out their website at http://mmi.oregonstate.edu/ommsn). Then we insert two LHX tags into the carcass, just like we would in a live animal. Then we deposit the carcass on a beach, or take it out to sea in a boat and drop it overboard. In this case, we know that the animal has already died (it did so before we ever got to work with it), and also where (where we deposited the carcass). Then we have to wait and see how long it takes before we hear from one or both of the LHX tags. Most people are surprised by how quickly the decomposition process happens that 'releases' the tags from the decomposing carcasses. Of course this depends on many factors like location, temperature, weather, and what scavengers might be there. In our carcass testing, we have seen LHX tag releases in just over 2 weeks, and some have taken as long as ten weeks. On average, the tags were released within a little over one month. From our carcass testing and actual live animal returns, we now have a pretty good idea how many of the LHX tags may be unable to uplink, and how many events we may have missed:

How reliably do LHX tags work?
Currently we are estimating that about 1 in 10 LHX tags that were extruded from a dead body cannot uplink to a satellite. We do not know why about 10% of the tags don't uplink, since this value is a combination of possible technical failures of a tag (for example a dead battery), a tag being destroyed by a predator in an attack, or a tag getting stuck somewhere where it cannot reach any satellite. That is actually a pretty good result, given the many challenges in making tags that work reliably under such difficult conditions. Even with external tags we are very happy if we get a data return rate of 75%, so 90% is just peachy! This also means that for dual LHX tag deployments, we will very likely only miss 1 in 100 mortalities, or the other way around, we have a 99% likelihood of actually getting data back if an animal dies. This is a much higher success rate than for conventional telemetry projects, probably for two reasons: 1) I have spent a lot of time and effort together with the company making these tags (Wildlife Computers) to make sure these tags are as reliable as they can possibly be, and 2) the use of two tags in each animal does make a big difference (the difference between 90% and 99% success).

What can we learn from the data we receive from LHX tags after animals have died?
The most important bit of information we receive from the tags is simply the confirmation that the animal has died. But we get more data than that: we find out exactly when the animal has died, to within 30 minutes. That is because LHX tags have temperature sensors that tell them when the host animal is still alive (it is warm). Once a warm-blooded animal dies, it's body core temperature begins to drop, and this pretty much starts as soon as the animal is dead, unless the dead body is in a very warm environment (our sea lions are in a very cold environment). The LHX tags sense this drop in temperature and record the time and date when it happens. That way, even if the tags don't begin to transmit for weeks or even months, we know exactly when the animal died. This same technique is used in police *crime scene investigations*. That's how a medical examiner may estimate when a crime victim may have actually died, even if the body was only found several hours later. The examiner will take a number of measurements, including the ambient air temperature, the body mass (weight) of the body and the temperature inside of the dead body. Knowing that the body must have started at 37 degrees Celsius (or 98 degrees Fahrenheit), the examiner

can then calculate how long it must have taken for the body to drop to the current temperature inside of the body. This only works if death did not occur too long before the measurements were done.

This is a huge difference in terms of the data quality compared to a marked-animal observation study, if observations like counts are only conducted once per year, as is the case with sea lions in Alaska. If you only check on who is alive once per year, and you don't see a specific marked individual, it might have died, but you don't know when. You only know that it died sometime between two observations. If for example two observations were done on August 1st, but 12 months apart (once in 2009 and once in 2010), then you can only say the animal died sometime between these two dates, on any of the 364 days between them. Plus, you cannot even be sure if the animal did in fact die, it may have simply moved outside of the observation area. With LHX tags, we know exactly on which day and even in which hour of the day an animal died, no matter where it died.