Has Animal-Borne Imaging Evolved for Use in Terrestrial Systems? An Analysis Based on Pilot Work with Black Bears

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In marine systems, animal-borne imaging systems (ABIS) have allowed researchers to explore questions nearly impossible to address otherwise because of the difficulty of observing animals underwater. This important tool has been deployed hundreds of times on a wide array of marine species, and with recent advances in technology it is likely that greater discovery will ensue with more species becoming candidates for deployment. Research on a variety of marine species has resulted in the advancement of knowledge of animals' foraging behavior including identification of food items, prey detection, and prey capturing techniques, on predator avoidance behavior, and interspecific socialization. This knowledge is often received as major scientific discoveries and often provides important insight relevant for conservation and management of particular species.

Given the significance of ABIS in aquatic research, I ask why the use of ABIS in terrestrial systems is in such a nascent state. I frame this discussion in the context of ABIS providing a useful tool for investigating conflict between humans and wildlife and providing greater knowledge of the behavior and ecology of large carnivores. I will discuss issues associated with black bears, reasons for why how ABIS can help resolve conflict, and discuss pilot work using the Crittercam on black bears in Yosemite National Park, an area notorious for conflict. I work for the National Wildlife Research Center and our mission is to reduce conflict between human and wildlife species. My area of expertise focuses on large carnivores. I work with Mexican wolves, timber wolves, black bears, coyotes, and brown bears.

So the big question is, can we have our cake and eat it too? I am referring to whether large carnivores can exist in this world where the human population is estimated to reach 9 billion people. From a conservation perspective it is one of the biggest issues facing large carnivores. I like to think of it as: can we have our sheep and predators too? My job is to try and create a situation where we live in harmony.

I need to acknowledge the two projects I'm going to discuss. The first is in Yosemite National Park and the second in Aspen, Colorado. I aim to touch on conflict issues associated with black bears in urban environments, and then focus on foraging decisions that bring animals into conflict.

I will be using Yosemite and Aspen as two different systems to give you an idea of what I'm talking about, and then focus at the end of how animal borne imaging can help. LaVern's talk really set up things nicely, as he showed you footage of what Crittercam can do for us *(First Deployment of a Terrestrial* Crittercam *on a Coastal Brown Bear*). I'm not going to show any video from Crittercam, but there is some footage at the exhibit from Yosemite if you're interested.

We know bears are hungry, intelligent and very adaptable (Figure 1). These intelligent animals in combination with social tolerance from people leads to what I refer to as niche expansion.

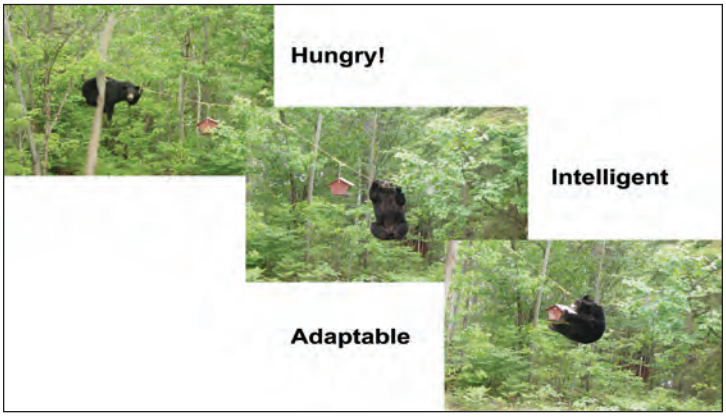

Figure 1: Niche expansion

Figure 2 demonstrates a result of niche expansion — bears coming into garages. They are breaking into kitchens, breaking into cars and getting into garbage bins. How big is this problem?

Figure 2: Results of niche expansion

Figure 3 displays some data from Colorado showing a general increase in conflict. We categorized conflict as agriculture, human and road kill. But the take home message is that it is a growing trend. And this is true across the country, wherever you have black bears and people.

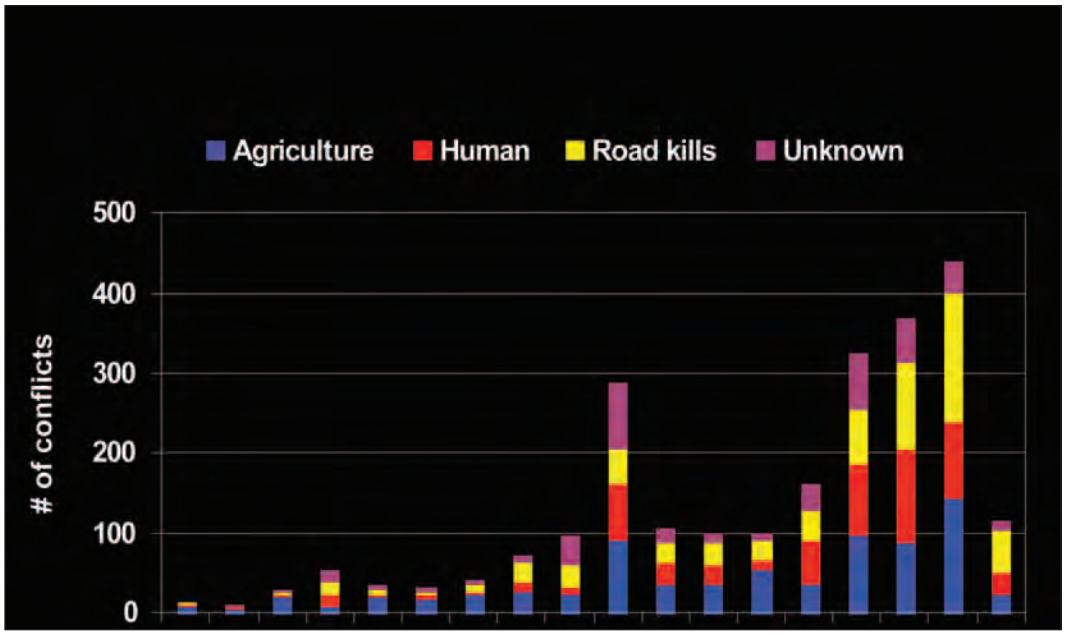

Figure 3: Increase in conflict due to niche expansion

There are two to three million visitors to Yosemite Valley alone each year, primarily in the summer. This creates a very interesting place for bears. They utilize a natural environment, but they also take advantage of food that humans bring with them. Bears steal food from cars, campgrounds and garbage cans, etc. So it is a great system for trying to figure out what bears are doing in these systems, but also how can we stop these problems.

I am going to go through a variety of studies that we've done to give you a better idea of the issues and how we study them. One of the big things that you will always hear is that mothers teach their cubs bad habits of stealing food from people. We've looked at this using genetics and behavioral data and found that how bears pick up bad habits is more complex then just learning it from mothers. Bears are generalists and very capable of learning these problem behaviors independent of their mothers.

We studied bear foraging, looking at use versus availability. One of the things that we found in Yosemite is that bears really preferred to break into minivans. You may ask why. Being a father of a three-year old child who sits in a car seat and scatters food, it seems fairly obvious why: minivans likely have more food odors.

We can look at black bear foraging based on fecal analysis. Fecal analysis can provide details of foraging habits that are helpful; however, it's probably not going to be as much detail as we want. And this is the take home message: we are in search of more detail regarding foraging decisions of large carnivores.

You can set up hair snares that collect hair from bears and look at genetics as well as stable isotope to get a general idea of bear diets. This is helpful; it gives you a general idea of what bears are foraging on, but again it lacks detail.

We can also do fatty acid analysis. We have done a pilot study testing for Trans fats in black bears. Trans fats are created by humans and commonly found in a variety of foods like chips, nuts, fried foods. By sampling this, we get an idea of whether a bear has been foraging on human foods. But again, these are not the details of foraging behavior that will help us stop bears from getting human food and ultimately getting into trouble with people.

Figure 4: GPS collars are used to collect fine scale movements

So how do we get detailed behavioral data on bear foraging? I am going to describe our efforts in a study centered on Aspen, Colorado. Aspen is situated in great bear habitat and is a very desirable place for people to live. That combination creates a tremendous potential for conflict between people and bears, especially if people are careless about how they handle trash and garbage. So we have set out to understand in more detail how bears incorporate the town of Aspen into their ecology and what we can do to reduce the conflict between bears and people.

A major part of the study involves using GPS collars on bears to collect fine scale movements (Figure 4). What I mean is that we are collecting a location of all our collared bears every 30 minutes. Attaining accurate spatial data on wildlife species through the use of GPS technology has been an important technological step, opening many avenues of inquiry within animal ecology. Accurate spatial data provides information on detailed movements of animals, resource selection, and habitat use. I will demonstrate some of the results. Figure 5 is an image displaying the locations of one bear over a couple months. The pink on the screen is the city of Aspen and each dot represents the location of the bear. You can see that this bear is going into Aspen and we can start asking questions about nightly movements and seasonal movements of this individual. For example, when the berries in and around Aspen became ripe, we saw a seasonal shift of this bear out of Aspen, into more natural environments surrounding the city, giving us insight into the importance of berry production on the behavior of bears.

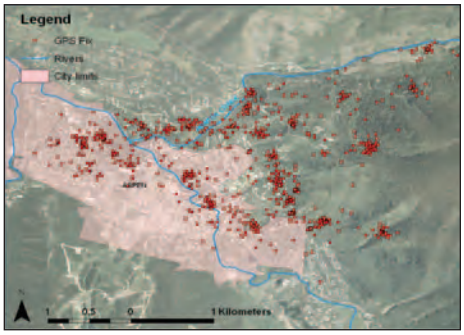

Figure 5: Black bear foraging decisions: seasonal patterns

Figure 6 outlines a single individual going through the city of Aspen at a finer scale then the last slide. These are fixed locations every 15 minutes for this particular individual and you can see that we are getting some fine scale movements. However we still do not know what the bear was doing at each location, which would be extremely valuable information. You can imagine if this bear had a Crittercam attached and was collecting footage at each location that we could then link spatial data to behavioral data which would be extremely helpful.

Because we don't have Crittercams, we have to instead backtrack to locations and try to piece together (i.e., guess) what the bear was doing. Backtracking is commonly employed and entails personnel collecting spatial data from the GPS units and then hiking to these points to attain data on feeding patterns, fine scale habitat classification, etc. As part of this study we download data from an individual's collar from the night before and then backtracked to these locations to determine what the bear was doing at that point. We are using this information to determine how many times bears are breaking into garbage cans to identify hot spots or areas that are really problematic. There are serious limitations to backtracking, including the need to locate the animal or attain the GPS collar in order to retrieve the GPS data; the substantial efforts expended in order to return to points

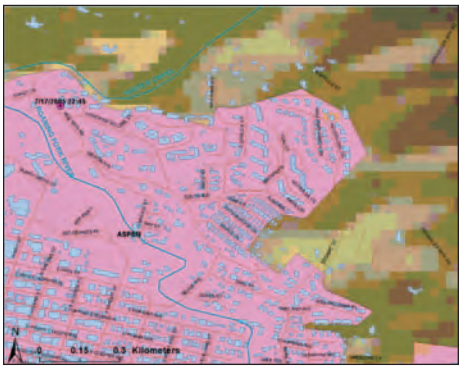

Figure 6: A single individual black bear moving through the city of Aspen.

especially in remote areas; and the difficulty of determining animal behavior post-hoc, especially with the long time delays between the time the data are retrieved and the time personnel get to the recorded GPS location. In the case of this study, personnel must backtrack to points to determine feeding activity, which is a labor intensive process and often restricted to visiting a small subset of points (5%) for any individual bear and identifying even a smaller set of those as confirmed feeding events. The ability to link GPS data to information from ABIS would likely reduce or eliminate the need to backtrack.

What we are finding, as you can see up in Figure 7, is that bears are targeting some specific places like garbage dumpsters at apartment complexes and construction dumpsters at constructions sites. This information has really helped us identify important sources of food that promote conflict. The other half of my job is figuring out what to do with these conflicts. I am not going to talk about that at all, though the important point here is that this data is very valuable for coming up with solutions.

Figure 7: Identifying problem sectors: bears are targeting garbage dumpsters

Do we need more detail? That question applies to using Crittercams or other animal-borne imaging systems to get more detail. I would definitely say yes. There is a perception, especially after listening to all these aquatic talks today, that we know a lot more about the terrestrial world because we can observe them more easily. But in the reality, as LaVern's talk showed, we really don't know that much about the foraging behavior of most terrestrial species. This is primarily because we are not able to follow most large terrestrial animals and study their foraging behavior without disrupting them. If we can link GPS data with an ABIS system, I think that will enhance our abilities to identify problem areas but also enhance our understanding of foraging ecology. There is also a lot of basic biology that we can learn as well. Then of course, the educational benefits I think are tremendous. There is a lot of wealth in Aspen, and I think creating an environment where people embrace the idea of having a clean city. Having an animal with a Crittercam on it walking through town and seeing, yes it's going to Hickory House BBQ or it's visiting Joe Smith's house, or whatever would be a really interesting educational treatment that may promote more cooperative relationships between bears and people.

Figure 8 is a shot of a bear that we captured. This was one or two black bears that we put a Crittercam on in Yosemite National Park. It was a learning experience in that we had issues with batteries and downloading the data real time. But I think we learned a lot about technological improvements that would enhance the system. Several important modifications could occur to increase the utility of ABIS for ecological inquiry in terrestrial systems, including an increase in deployment time and linkage of video footage to data from GPS units. To increase deployment times, we suggest several possible modifications. The first is elimination of real-time video transmission by replacing it with a store-on-board system that saves video data which can be downloaded when the camera is retrieved. Only in very rare cases is real-time data required to address research objectives; thus a store-on-board system could potentially save battery life that would otherwise be used for real-time data transmission. Because a store-on-board system is being used on aquatic Crittercam, the engineering has been worked out and can be applied to terrestrial systems. A second issue relates to the quality of video images recorded and ABIS battery life. The current terrestrial Crittercam utilizes high-quality video footage to capture TV quality images, but this quality is likely unnecessary for most research questions, and could be reduced to improve battery life and relax data storage requirements. Finally, the length of deployment could be greatly extended by having a camera system that is programmed to turn on and off at predefined intervals so that behavior and activity is recorded based on a sampling scheme. Ideally, the intervals when camera systems are turned on could be linked to systems recording GPS data.

To date, no deployments of CRITTERCAM or other ABIS in terrestrial environments have linked spatial data to video images. Solutions to this problem could be as simple as synchronizing a video camera to record at the same interval as a GPS system and could involve bracketing each spatial location with video imaging to ensure imaging was synchronized with the spatial data. But perhaps a more elegant solution would be an integrated GPS/ABIS that functioned as a single unit to record both animal position and video. In addition to a camera and a GPS module, this type of system would require a robust data storage medium such as solid-state EEPROM to withstand temperature variations as well as reduction in shock and vibration necessary for animal-borne imaging. An integrated system would also require a state logic controller to drive devices, take sensor measurements and log data as required. A high energy density battery system based on the lithium primary chemistry could be employed to supply power to the GPS/ABIS integrated system allowing long term deployments.

Finally, why animal-borne imaging systems? Because when we try to film bears, this is what we get. They love cameras. They are very curious creatures and they do like these camera systems.

I'd like to thank Nathan Lance, Sharon Baruch, and Tori Seher as my collaborators.

Figure 8: Energy-intensive process of capturing a black bear

Breck, Stewart. 2008. Has animal-borne imaging evolved for use in terrestrial systems? An analysis based on pilot work with black bears. Pages 63-68 in G. Marshall, editor. Proceedings of the 2007 Animal-Borne Imaging Symposium (Oct 10-13, 2007), Washington, D.C., National Geographic Society.