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IN FOCUS

New insights: animal-borne cameras and accelerometers reveal the secret lives of cryptic species



Animal-borne cameras, accelerometers and depth loggers have revealed the secret life on the world's largest bony fish the ocean sunfish (*Mola mola*). Photograph credit: Mike Johnson

In Focus: Nakamura, I., Goto, Y. & Sato, K. (2015) Ocean sunfish rewarm at the surface after deep excursions to forage for siphonophores. *Journal of Animal Ecology*, **84**, 590–603.

Logging cameras and accelerometers have opened our eyes to the secret lives of many enigmatic species. Here some of the new opportunities provided by this technology are reviewed. Recent discoveries are highlighted including the observation of selective feeding on energy-rich parts of prey. As such, biologging cameras provide new opportunities for consideration of selective feeding within the same sort of theoretical framework (marginal value theory/optimal foraging) that exploitation of prey patches has been examined. A recent study with the world's largest bony fish, the ocean sunfish (*Mola mola*), is highlighted where animal-borne cameras allowed the ground-truthing of data sets collected with depth recorders and accelerometers. This synergistic use of a range of biologging approaches will help drive an holistic understanding of the free-living behaviour of a range of species.

For over 30 years, a range of logging and transmitting packages ('biologgers') have been attached to animals to record their free-living behaviour, and the range of data sets that have been routinely collected include extended tracking in both horizontal and vertical dimensions [for an early review, see Priede (1992); for a more recent review, see Rutz & Hays (2009)]. These data have allowed, for example, insights into patterns of space use to inform conservation planning, the physiological ecology of diving and flying, drivers of ceilings to migration distance and the navigational mechanisms employed during migration (Hochscheid, Bentivegna & Hays 2005; Chapman *et al.* 2011; Hays & Scott 2013; Bishop *et al.* 2015; Fossette

et al. 2015). Over the last few years, the wide availability of small logging cameras and accelerometers has opened up a new chapter in the information that can be collected from free-living animals. Animal-borne cameras came to the fore with the work of National Geographic and their Crittercam package, which has been deployed on a wide range of taxa including marine mammals, sharks and turtles (Marshall 1998). The utility of this approach soon led to a range of other animal-borne camera systems being developed (Hooker et al. 2002; Rutz et al. 2007), and nowadays, relatively small, cheap, commercially available high-resolution cameras (both stills and video) can be deployed on animals (e.g. Thomson & Heithaus 2014). Similarly, accelerometers have moved from rather specialized logging devices built and deployed by only a few users to commercially available units that are readily

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available and widely used. Yet despite their current wide use and the rich data sets they provide, animal-borne cameras and accelerometers are generally used for short deployments because of the constraints on the memory size of loggers and/or the bandwidth available through data relay platforms such as the Argos service (Fig. 1a). Hence, the synergistic use of loggers that can provide information over different temporal scales offers lots of



Fig. 1. (a) Conceptual diagram of the performance envelope that reflects the interplay between logging interval and logging duration for various common data types used in biologging. The approximate position of data types on the logging interval vs. logging duration continuum is displayed. In general, instruments that sample at high frequency (commonly accelerometers and video) and/or where the data volume per record is high (commonly video and still images) can only log for relatively short durations and are problematic to relay remotely where bandwidth is restricted (e.g. via Argos). These information rich, short records can inform on the behaviours exhibited in other longer term records that are possible, for example, for depth and location. Over time increased logging capacity shifts this performance envelope to the right. (b) Conceptual representation for how the quality of a foraging patch (indicated by the size of the patch shape) or the nature of a prey item remaining (e.g. energy density of uneaten part) may decline over time and hence precipitate a decision on when that patch or item should be abandoned.

promise, with the value of such synergistic deployments being elegantly shown in a recent study of the foraging ecology of the world largest species of bony fish, the ocean sunfish (*Mola mola*), by Nakamura, Goto & Sato (2015) in the this issue of Journal of Animal Ecology.

Ocean sunfish are huge, reaching over 2000 kg (Pope et al. 2010). They are thought to be gentle giants, travelling slowly through the open ocean, propelled not by their tail but rather by their dorsal and ventral fins, to feed on gelatinous plankton (Pope et al. 2010). Direct observations of these unusual fish are generally limited to sightings of individuals at the surface, where sunfish sometimes bask. However, over the last few years, various animal-borne instruments have started to shed light on their behaviour over extended periods of time. A number of years ago the first deployments of pop-off archival tags (PATs) started to reveal the extended migrations of sunfish and their deep diving ability (Sims et al. 2009; Dewar et al. 2010), general patterns of movement seen in many diverse taxa including some sea turtles, marine mammals and birds. Across this range of diving taxa, the interplay between the energetic costs of diving vs. rewards of prey capture has been variously explored for many years (e.g. Wilson et al. 1993). Also in some cases, cooling at depth and the need to rewarm at the surface play a role in driving diving behaviour (Cartamil & Lowe 2004). Endothermic divers typically consume relatively high energy density prey such as krill and fish and often cease feeding at times when prey are too deep or light levels too low to allow efficient prey capture (e.g. Hays 2003). Set against this backdrop, at first glance, the sunfish's diet of jellyfish seems unusual because of its generally very low energy density (Doyle et al. 2007). To uncover the details of the foraging behaviour of diving ocean sunfish, Nakamura, Goto & Sato (2015) deployed forward pointing cameras, accelerometers and depth recorders on ocean sunfish in the seas off Japan. After a pre-set interval, the instrument package detached from the animals and floated to the surface where it was retrieved, sometimes many 10 s of km from the deployment location, using a VHF homing beacon. The data provided by the loggers were astonishing. The logger data revealed how sunfish cool in the ocean depths and so need to come to the surface to rewarm prior to the next foraging excursion, a pattern that seems common across various diving fish (Cartamil & Lowe 2004). Clearly visible in the camera footage were a number of gelatinous plankton species, including scyphozoan jellyfish, siphonophores and ctenophores. As sunfish approached these items, they sometimes accelerated quickly before grabbing and consuming the prey, while in other instances, they slowed down and made a more guarded approach prior to prey capture. Importantly, in almost all cases, prey capture events had a signal evident in acceleration data sets, that is the cameras allowed ground-truthing of the data collected by accelerometers. This study sets the scene for extended use of accelerometers and depth tags to assess foraging success

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over extended spatial and temporal scales. This methodological advance is important, as ocean sunfish, in common with other marine species, face huge seasonal and spatial variations in their prey abundance, and hence, their movement strategies and foraging success in such a heterogeneous environment are key questions (Sutherland *et al.* 2013).

As well as identifying foraging success and prey species, the camera footage also revealed that ocean sunfish may selectively feed on certain parts of their jellyfish prey: in particular, consuming energy-rich components such as the gonads and oral arms and leaving behind more energypoor parts such as the swimming bell. This selective feeding parallels that seen in a range of carnivores and herbivores, across both marine and terrestrial systems, that selectively consume energy-rich parts of their prey, particularly in situations where prey are relatively abundant (e.g. Gende, Quinn & Willson 2001). Similar selective feeding behaviour on jellyfish has also recently been observed for the small Mediterranean fish the bogue (Boops boops) (Milisenda et al. 2014), while, in contrast, animal-borne cameras on leatherback turtles have revealed that entire jellyfish could be consumed (Heaslip et al. 2012). In a sense, the decision on when to leave a prey item and move on parallels the marginal value theorem that is generally used as a framework to examine the use of prey patches, that is we can consider a single prey item as a 'patch' in this sense and hence calculate when prey items should be discarded based on how the rate of energy acquisition varies with time spent on a single item (Fig. 1b). In short, when other prey items are available nearby, we would increasingly expect only the energy-rich portions of prey to be consumed and vice versa. The use biologgers now offers the potential for quantitative assessment of the occurrence and value of selective feeding for species that are hard to directly observe and hence will allow selective feeding to be more fully incorporated into analyses of the drivers of the fine-scale patterns of animal movement.

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