CAREERS

EYE OPENER A marine biologist invents a device to gauge human eyesight **p.255**

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ARIANA STRANDBURG-PESHKIN

A hyena wearing a specially customized wildlife collar (left) can feed valuable data to scientists.

FIELD INSTRUMENTS

Build it yourself

From custom wildlife collars to underwater recorders, a tailor-made field device is within a biologist's grasp.

BY ROBERTA KWOK

When Lisa O'Bryan was planning her postdoc project in 2014–15, she knew that she couldn't buy field instruments off the shelf. O'Bryan, a behavioural ecologist now at the New Jersey Institute of Technology (NJIT) in Newark, wanted to tag social mammals with audio recorders to investigate how their communication patterns affect the group's activities. But she couldn't find a wildlife collar with an audio feature, or the right stand-alone recorder to add to an existing collar.

So O'Bryan partnered with researchers at Swansea University, UK, who had already developed collars equipped with global positioning system (GPS) receivers and accelerometers — instruments that measure acceleration and enable scientists to identify resting, foraging and other behaviours. During a visit to Swansea, she learnt how to connect an Arduino microcontroller — a small, programmable device — to a microphone and recorder. Abid Haque, an engineering undergraduate student from India who was visiting the NJIT, customized open-source software from Arduino libraries to fit her needs. The team 3D-printed plastic casing for the components, and a specialist in equestrian equipment attached the casing to leather collars.

After testing them on domesticated goats, O'Bryan put the collars on baboons in Namibia last year. The field season went smoothly, and her team is analysing the data. The project made her feel more confident about fixing technical issues. "It's made me more versatile," she says.

O'Bryan is one of many biologists who have developed niche field instruments for their research (see 'A beginner's guide'). By going beyond commercially available options, researchers can gather new data, gain technical skills and sometimes even sell their products. But such projects are time-consuming and involve tricky engineering issues. Although some biologists develop their own lab instruments (see *Nature* **544,** 125–126; 2017), field devices bring different challenges because often, they must last a long time in the wild. In the worst-case scenario, an instrument failure can compromise an entire season of fieldwork.

To succeed, biologists can partner with engineers, use open-source electronics tools such as the Arduino platform, or work with companies to customize products. And the payoff can be satisfying. "The scientific rewards have been tremendous," says Randall Davis, a marine biologist at Texas A&M University in Galveston, who co-developed oceanographic data recorders with an engineer.

MEETING OF THE MINDS

Biologists can recruit engineers from their own universities or they can contact groups that specialize in field-research devices. In 2016, Frants Jensen, an ecologist now at the Aarhus Institute of Advanced Studies at Aarhus University in Denmark, and his colleagues wanted to develop custom wildlife collars to track communication and coordination in groups of hyenas. Jensen had previously studied marine animals using devices co-developed by Mark Johnson, an electronics engineer at the Sea Mammal Research Unit at the University of St Andrews, UK; Johnson agreed to help Jensen again.

Johnson's expertise was crucial. He noted, for instance, that when the radio transmitter came on, its power usage might reduce the battery voltage, which could potentially cause the device to lose track of time and fail to record data on schedule. So he programmed a microcontroller to save a timestamp every few seconds and note whether the recorder was on or off. He also minimized battery weight and positioned components to avoid chafing the hyenas.

Other biologists forge ahead without the expertise of an engineer. In 2014, Anna Prinz, a wildlife biologist who was then conducting research for a master's degree at Old Dominion University in Norfolk, Virginia, worked ▶

with Vikas Taank, a fellow biology graduate student with programming experience, to create a woodpecker-nest monitoring system[1]. The team used a mini-computer called a Raspberry Pi, and found that other users had written software to perform functions such as streaming video. That was ideal, because she "didn't want to build it from the ground up", says Prinz, now at the non-profit Sandhills Ecological Institute in Southern Pines, North Carolina. She watched online tutorials to learn how to build a circuit that could power infrared light-emitting diodes to illuminate the nest. They used the devices to record the breeding behaviour of acorn woodpeckers (*Melanerpes formicivorus*) for three months in California.

Researchers can scavenge for components and customization advice online. Jolyon Troscianko, a behavioural ecologist at the University of Exeter, UK, advises checking eBay.com and Amazon.com for parts. When his team was developing miniature videologgers to attach to New Caledonian crows (*Corvus moneduloides*), the researchers found small cameras online. If parts need to be modified, websites such as RCGroups.com offer tips from hobbyists.

Biologists can also ask a company to tailor an existing product — but the firm must be willing to help even if the customer is not placing a large order. "You're never going to be a huge profit centre for them," says Kelly Benoit-Bird, an ocean ecologist at the Monterey Bay Aquarium Research Institute in Moss Landing, California. She worked with a company to add sonar devices called echo sounders to an autonomous underwater vehicle (AUV). Depending on project scope and component prices, some changes might not incur an extra charge, whereas others could cost hundreds of thousands of dollars.

Working out how much data a device should collect can be tricky. Although it's tempting to amass as much as possible, recording at higher resolution and for longer durations may require a bigger instrument. But Jensen's team is deliberately collecting more data from some sensors than it might need. This will enable the group to determine the optimal resolution needed to obtain valuable information, he says.

DEVICE ADVICE
A beginner's guide

- Search the literature for similar instruments. Amateurs might be able to replicate another team's device or collaborate to create a modified version.
- Consider partnering with an engineer, especially if a device must be lightweight.
- Use popular programmable devices, such as the Raspberry Pi and Arduino. Open-source software may already be available to perform necessary functions.
- Choose materials that are strong (to withstand stress) and light (to maximize weight available for the battery).
- Test devices under realistic conditions, such as in low temperatures or salt water. Try out wildlife tags on captive animals.
- Do a pilot study. Schedule ample time to fix technical glitches or buy parts. **R.K.**

This customized autonomous underwater vehicle has sonar devices to detect marine animals.

KELLY BENOIT-BIRD

Typically, researchers need light, strong materials. Troscianko's team encased the crow cameras in thin films of a plastic called Polymorph; light packaging allowed the scientists to use a heavy, long-lasting battery. And an instrument must be rugged enough to withstand animals swimming, fighting or bashing against it. Prinz installed a Plexiglass sheet in front of her nest camera to protect it from the woodpeckers, and Jensen's team waterproofed the hyena collars' microphone and instrument casing.

Before launch, the devices must pass several tests. Researchers can expose instruments to harsh conditions, such as extreme temperatures, in the lab. Developers often try out devices on captive animals; Johnson's team tests marine-animal tags on dolphins and porpoises at aquariums. Trainers observe whether the instrument seems bothersome, and scientists ensure that the tag does not leave an abrasion.

Biologists should expect mishaps in the field. "There's 100 different ways that an instrument can malfunction when it's out at sea," says Davis. His team once deployed data recorders on southern elephant seals (*Mirounga leonina*) in Argentina and a battery connector short-circuited after about six weeks. Another year, a manufacturer — unbeknown to the team — had changed a video chip and the devices did not record any video.

To reduce risk, researchers can perform a pilot study and pair new instruments with established methods. When Benoit-Bird's team deployed its echo-sounder-equipped AUV to study marine animals, the researchers also gathered data from echo sounders installed on their ship. Although the onboard devices could not detect animals as deep down as the AUV could, they guaranteed at least some data.

Persuading funders to support development can be tough. Johnson recommends that scientists describe intermediate steps that could provide useful information, even if the device doesn't work perfectly. Before applying for competitive grants, teams might need to build a prototype to gather preliminary data. Davis's team, for instance, used a US$25,000 in-house university grant to create an early version of its recorder before getting funding from the US National Science Foundation (NSF).

Project expenses vary widely. Prinz's nest-monitoring system ranged in cost from about \$180 to \$500, depending on the power source. O'Bryan's baboon collar costs about \$1,100 to make, and her team is working on a cheaper version. But in harsh environments, costs increase dramatically. If a device must operate in the ocean, "your budget automatically has to have another zero, minimum", says Benoit-Bird, whose AUV project cost hundreds of thousands of dollars. Davis says that his team's prototypes originally cost \$18,000–20,000 to make, including research and development, and now can be produced for \$5,000–10,000; over about three decades, expenses have totalled less than \$1 million, he estimates.

> *"There's 100 different ways that an instrument can malfunction when it's out at sea."*

BUSINESS BOON

If the devices succeed, scientists can explore commercialization. The first step is usually to contact their university's technology-transfer office to verify correct procedures for patenting and licensing. Government programmes can help: as part of the NSF Innovation Corps Sites Program at the NJIT, O'Bryan gauged potential customers' interest in her team's audio-recording collars. But often, the market is small. Davis says that he has had trouble persuading a firm to mass-produce his team's oceanographic recorders, because they would probably sell, at most, 500 per year initially.

Still, some researchers have achieved

commercial success even with a modest number of customers. In the early 2000s, David Mann, a marine biologist then at the University of South Florida in Tampa, began selling underwater acoustic recorders, which his team had devised, to colleagues, and he started Loggerhead Instruments in Sarasota, Florida. He left academia in 2013, and his company currently sells about 100 devices per year for about $3,000–10,000 each.

When pricing products, scientists should consider the instrument's uniqueness. They should also assess the relative value provided by the device. For instance, Loggerhead's recorders can be deployed underwater for up to a year. Gathering the same data manually by sending a researcher on a boat could cost much more than the recorder, Mann says.

If scientists enjoy field-device work but do not want to run a business, they can join an existing company; there, engineers do most of the development, and biologists can work with customers and advise the firm. Kenady Wilson, a wildlife biologist, took a job at Wildlife Computers in Redmond, Washington, which designs and manufactures instruments for marine-animal research. She is analysing data from the devices and will help to determine which algorithms the company's software should include.

Biologists can also find positions in groups such as Xylem Analytics in Charlotte, North Carolina, a division of the water-technology company Xylem. The jobs are well suited to people who have experience with similar instruments and want to address global water challenges, says Rob Ellison, the group's vice-president of strategy and technology in Boston, Massachusetts.

But even a solely academic project can offer big rewards. Troscianko's crow cams caught the birds making hook-shaped tools[2], and Davis's recorders have revealed seal behaviour ranging from fish-hunting tactics to energy-saving gliding[3]. Measuring something new, says Johnson, brings "phenomenal satisfaction". ■

Roberta Kwok *is a freelance science writer in Kirkland, Washington.*

1. Prinz, A. C. B., Taank, V. K., Voegeli, V. & Walters, E. L. *J. Field. Ornithol.* http://dx.doi.org/10.1111/jofo.12182 (2016).
2. Troscianko, J. & Rutz, C. *Biol. Lett.* **11**, 20150777 (2015).
3. Davis, R. W., Fuiman, L. A., Williams, T. M. & Le Boeuf, B. J. *Comp. Biochem. Phys. Part A Mol. Integr. Physiol.* **129**, 759–770 (2001).

CORRECTION

The Careers Feature 'Candidate science' (*Nature* **544**, 259–261; 2017) erroneously referred to Bob Foster (Republican, Illinois). In fact it should have referred to Bill Foster (Democrat, Illinois).

TURNING POINT
An eye to success

As a postdoc studying marine biology at the University of Bristol, UK, Shelby Temple invented a device that assesses the health of human eyes. He describes his move out of research to commercialize the device.

NICOLA TEMPLE

How did you create this tool?
I was characterizing the ability of animals to see polarized light, and was curious about the human perception of polarization. So, using LCD screens, some customized components and the contents of my recycling bin, I invented a device to examine it. When I used the device to measure the threshold of human perception of polarized light, those measurements corresponded with the density of macular pigment in the eye. A low level correlates with poor vision and is a risk factor for age-related macular degeneration.

What did you do next?
With the support of the business incubator at the University of Bristol and programmes including Innovation to Commercialisation of University Research, I conducted market research and developed the device. I believed that my invention had potential for commercialization, so I left the incubator to launch a start-up company. The university owns the intellectual property and they gave me an exclusive global licence in exchange for equity and royalties.

How did you transition out of your postdoc?
I was able to ease away from lab commitments with funding that allowed me to take a four-month break while doing market research. I passed on a lot of my projects to colleagues, and although I am trying to finish off a few papers, it's really more of a hobby now.

Are you pleased with your present career path?
Yes. I felt like I was stagnating and was frustrated by the lack of opportunities in my home nation of Canada. Commercializing the device seemed like a great opportunity and could allow me to return to Canada in the future.

How does your company run with no revenue?
I won a Biotechnology and Biological Sciences Research Council Enterprise Fellowship, which has paid my salary for the past year. We have a start-up grant from Innovate UK and just completed our first round of investments.

What did your market research find?
Most people, including optometrists, don't know what macular pigments are, so we'll need to educate them. I also learnt how the device would fit into optometrists' business models.

Has it been difficult to move from research?
The learning curve was sharp: I took numerous courses to learn about business planning and modelling, accounting, sales and marketing. It has taken me a long time to shift my thinking to making money — there is a lot of pressure to get the device to the point of sale as soon as possible. It's a fantastic amount of work, but I have also been having a great deal of fun.

What are you doing now?
We are conducting a more focused, large-scale study to compare our tool's results with results from the existing method for measuring macular-pigment density, so there is a big push to get the next prototype ready for trial. As technical officer, I am working on the manufacturing process and am currently operating out of my house. We hope that by late 2017, a more developed version of the device will be ready before we invest in large-scale manufacturing. My dream is for the device to be used in every optometrist's office, and maybe in the future by primary-care doctors. I envision it as a standard part of eye-health checks, a bit like a blood-pressure monitor.

What is the best aspect of starting a business?
Building a great team with key skills to complement my own. For instance, the chief operating officer has taken over some of the business planning, which allows me to focus on the science. And it's my company, so I run it with my own ethos. Why not have board meetings that start off with nipping to Devon to surf? ■

INTERVIEW BY LOUISA COCKBILL

This interview has been edited for length and clarity.