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Current Science and Policy of Bycatch Reduction: An Interview with Professor Larry Crowder

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Professor Larry Crowder is the science director at the Center for Ocean Solutions (COS). He is also Ed Ricketts professor of biology at Hopkins Marine Station and a senior fellow at the Stanford Woods Institute for the Environment, both part of Stanford University. Previously, he was the Stephen Toth Professor of Marine Biology at Duke University.

Dr. Crowder's research centers on predation and food web interactions, mechanisms underlying recruitment variation in fishes, population and food web modeling in conservation biology, and interdisciplinary approaches to marine conservation. He has studied food web processes in both freshwater and marine ecosystems, and has used observational, experimental, and modeling approaches to understand these interactions in an effort to improve management. He was principal investigator for a number of large interdisciplinary research projects including the South Atlantic Bight Recruitment Experiment (SABRE), OBIS SEAMAP (Spatial Ecological Analysis of Megavertebrate Animal Populations), and Project GloBAL (Global Bycatch Assessment of Long-Lived Species). He has also directed and participated in a number of research, analysis, and synthesis groups at the National Center for Ecological Analysis and Synthesis (NCEAS) and for the National Research Council's Ocean Studies Board.

His recent research has focused on marine conservation, including research on bycatch, spatial ecological analysis, nutrients and low oxygen, sustainable seafood, ecosystem-based management, marine spatial planning, and governance. He is a AAAS Fellow and was awarded Duke University's Scholar/Teacher of the year award in 2008-2009.

ADZ: Thank you very much for agreeing to speak with me on *Intersect*'s behalf. Let's just start out with an overview of your research. What are you currently working on and/or most excited about?

LBC: There are a couple of projects that I'd thumbnail for you that I'm really excited about: all are related to my work at the Center for Ocean Solutions, and involve people working in my lab at Hopkins. The first one

is exploring the potential for using environmental DNA as a way to monitor relative abundance for vertebrate animals in the ocean. Basically, what this technique requires is collecting water samples and extracting free environmental DNA. All animals release DNA which decays in 2-3 days, so if you amplify the DNA that's in a sample of water, you get the DNA signature of everything that's been in the water for the last 2-3 days. We tested this approach in the open ocean tank at the Monterey Bay Aquarium. We're using something called next generation sequencing, in which the number of DNA strands that you get is proportional to the number in the sample. This technique could reflect relative abundance of species as well as presence-absence. We published a paper in PLoS One that showed that this technique was pretty reliable. If we treat the Outer Bay tank as a black box, we could detect all of the bony fishes in their relative abundance in the tank. In the first round of tests, we didn't get the sharks, the turtles, or the ocean sunfish to represent very well, but the more abundant bony fishes did. There's also potential to use this technique for surveying or censusing animals in the open ocean. In general whales aren't a problem because they're easily observable, but sharks can be hard to observe. So if you can extract their DNA, that's enormously helpful. This project was started by post-docs at COS, and since then we've gotten funding from Packard and the Seaver Institute through the Woods Institute Environmental Ventures Projects. One of the postdocs who originated this has taken a job at University of Washington, so we're continuing to collaborate with him there.

Another project that I've been working on is about sustainability in small-scale fisheries. We've made a lot of progress with new management innovations for big industrial fisheries, using better quantitative stock assessment approaches and management techniques to provide incentives for fishermen to fish more sustainably. But those technologies and those approaches haven't yet been extended to small-scale fisheries. Globally, 95% of the people who are supported by fisheries work in small-scale fisheries. Small-scale fisheries might harvest as many fish as industrial fisheries in terms of biomass, so it's a whole sector that really hasn't been carefully examined by science or effectively managed. Small-scale fisheries differ a little from industrial fisheries, in the sense that the communities that depend on the resources are tightly coupled to the resources. This means that you have to think about solutions that promote sustainability of biophysical ecosystems, and also the sustainability of the communities that depend on those ecosystems. It's inherently much more interdisciplinary work. There's a whole field of study about social-ecological systems— under the umbrella of sustainability science—that we're trying to apply to small-scale fisheries globally to create interventions with communities to make their fisheries more sustainable. The funding community around the world has gotten really interested in this, so in the future this may be an important topic of focus. What we're

trying to do at COS is to get out front with those initiatives and make sure that going in, we use all the information that we have about how those coupled systems work. The goal is to design interventions in a way that is most likely to be successful, both for the fish and for the people that depend on the fish. Usually in environmental issues things are cast as it's for the environment *or* it's for people. What we need is an *and* in that sentence: good for the environment *and* good for people, not *or*. That makes it particularly challenging, but it's fun, because the work we're doing is with an international working group that we pulled together at the Center, with natural and social scientists working together, trying to come up with clever ways to take on this problem. We know that probably there's going to be a lot of research and implementation that happens in various places around the world in the next 10 years, so we're also trying to get out in front so that we learn as much as we can from those experiments. We want to learn along the way and adapt to doing this better and better, because people haven't thought to manage small-scale fisheries for sustainability for long enough to know clearly what to do; we need to learn rapidly in this setting.

The last project builds off the bycatch paper that was published in the Proceedings of the National Academy of Sciences. It's been a challenge, thinking about all of the bycatch information that is out there. What you do with that information, if you know that there are fisheries that go after a target fishery, like a swordfish, and they catch albatrosses or sea turtles in the process? Do you just close the swordfish fishery? Not likely to happen. Or do you try and figure out how to fish the swordfish while minimizing the impact on the turtles and the albatrosses? Some people have proposed that you get that done by using different fishing gears, or setting the gears in different ways that reduce the impact on the non-target species.

The new concept is something that we're calling dynamic ocean management. It builds off of the idea that if you have satellite tagged all these animals, and you can model their movement and their habitat distributions based on remotely-sensed oceanography, you can model where the bycatch species are likely to be relative to those oceanographic features. The thing is, they don't sit in one place, so you can't close a rectangle in the ocean to fishing and protect them, because they move. You could have protected areas that move seasonally. What happens now, in bycatch management, if there's a spatial closure, it's a big box, just because at some time during the year there's a sea turtle someplace in that box that a fisherman might catch. But if you think of the sea turtles as moving seasonally, they're in a much smaller box in May, and a much smaller box in June [than the original big spatial closure], but the box is in a different place [in May and in June].

So the fundamental argument is: fishermen move, the ocean moves, the target species move, the bycatch species move. So why is the management static? This idea was suggested in the literature almost 15

years ago. But we're now at the cusp of having the technology and the modeling skill to be able to project, based on remotely sensed oceanography, where the sea turtles are likely to be. If you can move fishermen away from where the sea turtles are likely to be, they may be able to fish in much larger pieces of the ocean by agreeing not to fish where sea turtles are likely to be. Once a month, or once a week, you could update where that closed area is.

We have a research project [on this topic] that started as a working group through the Center for Ocean Solutions, with a broadly interdisciplinary team. A couple of people in that working group are postdocs in my lab at Hopkins. We have a grant from NASA to build out this technique, and have other grants in place. What's unique about this project is that, from the get-go, we're working with the agencies, we're working with the fishermen, we're working with the environmental groups that are concerned about these issues, to try and come up with what might be (no guarantees!) kind of a win-win: that provides protection for the protected species, at the level we're currently achieving or better, but also keeps more fishing opportunities open, so that the restrictions on the fisheries aren't a blunt-force tool. In this research project, we're not advocating any solutions yet: we're saying, let's do the research to see if we can design something that would be workable and would achieve multiple objectives, like protected species goals and keeping as many fishermen in business as we can.

ADZ: That actually gets at a bunch of my other questions. I was going to ask you about that study that was just published. So my question is, do you mind summarizing this paper briefly for our readership so that they can get a sense of what the main findings were, and what the ramifications or the next steps are now that the article is out there?

LBC: Most previous bycatch studies looked at the impact of a particular fishing gear, in a particular place, on a particular taxon group. So there were seabird and longline studies in the southern ocean, or there were sea turtle and trawl studies in the Gulf of Mexico. What we were able to do with funding from the Gordon and Betty Moore Foundation, over a 4-year period, was take on seabirds, sea turtles, and marine mammals in three major fishing gears. We did trawls, gill nets, and longlines including, literally, all the data in the world that we could put our hands on. So the idea was, for each of those taxon groups, to figure out, if there were bycatch issues, where were they? What gear was most problematic? What species were most problematic? Were there species disadvantaged by their life history (they live a long time and reproduce late)? Did they have behaviors that made them particularly susceptable to the fisheries, like seabirds that follow longline boats to eat the waste that they throw away? The other thing that the study allowed us to do was to look at, not just one taxon or one species at a time, but to look for hotspots where there are

interactions with fisheries in multiple species and multiple taxon groups. There's an unfortunate history of advocates for a particular species or a particular taxon group suggesting a change in management that creates a disadvantage for some other species and groups. For example, seabird advocates may be frustrated by bycatch in longline fisheries, and push agencies to get rid of longline fisheries, forcing fishermen to switch to bottom-set gillnets, which kill marine mammals and sea turtles at really high rates. We have a history of solving one problem and creating another.

So this comprehensive study actually tries to point out where the hotspots in the world are where there seems to be a lot of bycatch, and where the parts in the world are where (after thorough scouring) we just have too little data to say much of anything at all, like the Indian Ocean. So basically it's an overview, and I think it provides a good historical marker (i.e. what did we know, circa 2014, about bycatch in all of those taxon groups and fisheries?). People will be able to go back later and compare: have we improved? Have we filled in some of the data gaps?

That same project also produced, in addition to this paper, something like 40 other papers, including the first global assessment of marine mammal bycatch and the first global assessment of sea turtle bycatch. There's a whole armload of work that came out of that project that really has pushed ahead, in a much more complete and synthetic way, the view of bycatch in these taxon groups in modern fisheries. One of the crossover findings was frankly really scary to me: I worked on bycatch in industrial fisheries like the global longline fleet. We came across recent examples—the first studies were published around 2007—which showed that bycatch can be extremely high in small-scale coastal fisheries. Almost nobody was paying any attention to small-scale coastal fisheries regarding bycatch of turtles and marine mammals. Seabirds are distributed far enough north and south that there aren't so many small-scale fisheries in their geographic range, but turtles and mammals are in the tropics, and there are tons of small-scale fisheries in the tropics. There are just a handful of recent papers that suggest that the bycatch rates [in those fisheries] can be extraordinarily high. These fisheries are often fishing with small gillnets from open boats. Another alert from this paper is, don't just assume that bycatch is just an industrial issue. It can also occur in these small-scale fisheries. Of course, it's much more difficult to figure out how to reduce bycatch in a small-scale fishery when people in that fishery are so extremely resource-dependent, compared to an industrial fleet that's a big business, and can make changes somewhat more readily.

ADZ: One of the things that was brought up in that paper as well was the implementation problem, and all of the barriers to implementation. Do you see any ways that that might be made more effective, for implementing bycatch reduction technologies and policies and such?

LBC: One of the things that's really problematic is that these species are so wide-ranging. Protection within the exclusive economic zone of one country may not make a huge difference. But it also *can* make a huge difference. One of the postdocs on the project working on dynamic ocean management, Sarah Maxwell, recently published a paper in *Nature Communications* where she looked at satellite tracking data for 7 different species of marine mammals, turtles, and birds that spend part of their life history in the California current. She just looked at, where are they relative to the US exclusive economic zone? If they have protection in the EEZ, or even within the footprint of the current national marine sanctuaries, what difference does that make to the population? It turns out that even though they migrate across whole oceans, they spend a substantial amount of time *here*.

We could do better within the exclusive economic zones of countries. Eliot Hazen is also with the dynamic ocean management project. He published a paper in *Nature Climate Change* where he did these kinds of habitat models relative to oceanographic features for 15 species that were tagged in the Tagging of Pacific Pelagics Program (TOPP) that Barbara Block and Dan Costa work on. So he produced the ocean habitat models for 15 species, and he ran ocean climate models at 50 years and 100 years. He asked, we know where these species are on the map now—where will they be 100 years from now? If you're thinking about protecting them with some kind of spatial protection, if you think of that as static, you can close a block to protect them and they won't be in that block 20-30 years from now because of climate change. Thinking of this whole thing dynamically just makes a lot of sense. Ultimately, the restriction that is most daunting is governance in the open ocean, outside of the exclusive economic zone. Right now, there is very little strong governance in that part of the ocean. But people are starting to think about that. We do have the International Seabed Authority that is making decisions about how to allocate space on the sea floor for mining in the open ocean. So you could imagine something parallel to the open ocean seabed authority, called the International Pelagic Resource Authority, that actually does some spatial management with countries to reduce the impact on protected species, or to enhance fisheries. That's just been in area that hasn't been, in the past, strongly governed. We're gradually beginning to manage what used to be (broadly) open-access resources with stronger guidance, initially cooperative, and then maybe eventually with some kind of stronger management structure.

ADZ: So as the Science Director for Center for Ocean Solutions, where do you see it headed in the future, and are there projects that you would like to work on, moving forward, that you haven't gotten to yet?

LBC: There are lots of really daunting problems, and in the Center, we do a portfolio of different kinds of work. For some of our projects, the

science is pretty well understood, but what's not well understood is how to operationalize that science into a form that can be put to work by coastal managers. So part of what we do is not new science, but trying to operationalize and translate the science into forms that can allow managers to do a better job. Then the second part of the portfolio, which is smaller, looks at problems that are emerging problems. We know what they are, there are some approaches out there that may work, but those approaches need to be refined before they're applied. Things like marine spatial planning or ocean planning would fall under that rubric. Then we spend a small amount of our time--10-20%--thinking, what's the big new issue in the oceans? There are lots of them. There are old issues, like overfishing, that aren't new, but we still haven't completely solved them. Then there are emergent issues, like ocean-climate related issues or dynamic ocean management. This is exploratory stuff, where we don't know if it will be useful to managers. But in talking to managers, they can certainly imagine that this would be useful if we can do the proof of concept, refine the approaches, and make them defensible for use in a practical setting. The faculty at Stanford, the scientists at the Monterey Bay Aquarium Research Institute (MBARI), the educators at the Monterey Bay Aquarium—they're thinking about, what are the new issues that people haven't thought about yet? Let's get those into place, so that we're thinking about the most advanced ways, the most reliable ways, and the most cost-efficient ways to make decisions about the ocean, while also operationalizing and translating things that we understand pretty well, and making sure we do the best we can with that. It's sort of like knowing that you have a bycatch reduction technology for seabirds that works—demonstrably works, no question about it, but the fleet isn't using it. How do you get that to be something that sticks? That gets people engaged and is operationalized? At the Center, we do a whole variety of things, from operationalizing and translating pretty well-known science, law, and legal analysis, all the way up to things that people hear about, and then say, "That's cool, can we make it work?"

ADZ: Very neat! So my last question is, what can students and consumers do to be more conscientious about our impacts on the ocean, particularly related to fishing?

LBC: There's lots of guidance out there in terms of selecting what you choose to eat and what you choose to buy. So on the fishing side, there's trying to make sure that you're making good choices and sustainable choices. On the climate side, it seems like such a big problem, but everybody's choices have an impact on the problem. Some of it is, kind of, relieving guilt, and some of it can be really impactful. People need to think about the choices that they make when they buy food, the choices that they make when they buy cars, how you choose to live your life in terms of energy intensity and product intensity. Those are important things for

people to think about. More and more, we're finding that good environmental decisions are also good economic decisions: things that are good for the environment are also things that are good for the economy. People have put those in contrast, saying that [environmental action] is a job-killer, but the recent IPCC report which just came out suggests that we can't afford to overlook this problem. It's going to have potentially devastating impacts on everybody's plans for the future. So I think it's time to get serious about it and to get past quibbling and denying. You don't have to worry about what's actually causing it: the fact is that it's measurably happening. The question is, how do you cope, as a society and as an individual, with those changes?

ADZ: Thank you so much for speaking with me, Professor Crowder.