

Jennifer Stock:

Hello everyone. Welcome to Ocean Currents on KWMR. This monthly show dives into the depths of the ocean and reveals the secrets of what covers 75 percent of our Earth's surface, the ocean. On this show we talk about ocean research, discoveries, and ocean policy and how we humans can get involved in protecting it. My name is Jennifer Stock and I bring this show to you once a month from NOAA's Cordell Bank National Marine Sanctuary and if you're interested in hearing past shows we have archives available on our website at cordellbank.noaa.gov. Today on our show we have an interesting topic of a large size.

If you ate and grew in a similar way as our subject on the show today, you would be eating and digesting 50-60 meals every day and you would be growing one foot in length every day. By your first birthday, you would be larger than a blue whale. The Humboldt Squid is the topic on Ocean Currents today. Stay tuned to hear about this elusive and fascinating invertebrate and what scientists are learning about their role in the ecosystem.

(pause)

Jennifer Stock:

The Humboldt squid is one of the larger squid species that we know of that can reach 120 pounds in weight and lengths of up to 9 feet long...that's with their tentacles. They predominately live in more tropical waters than around here, but in recently years they've been making a regular appearance in northern California waters. They've been seen offshore of Point Reyes at Cordell Bank and even further north into Oregon, Washington, and Alaska. I have Dr. William Gilly on the phone with us today and Dr. Gilly is a professor of marine and organismal biology at Stanford University's Hopkins Marine Lab in Monterey. His current work includes field studies on the Humboldt squid. Previous his work revolved around the complex nervous systems.

Most recently he has been working with the tagging of Pacific Pelegics Groups and had been attaching tags to squid to find out where they are spending their time. Welcome to the show Dr. Gilly. You're on the air.

William Gilly:

Oh, hello, Jennifer. Great to be on the air.

Jennifer Stock:

Excellent. Also, in the studio I have Ken Baltz from NOAA's National Marine Fisheries Service based out of Santa Cruz. Ken is an oceanographer in the fisheries ecology division for NOAA. He has an M.S. in physical oceanography and his interest is in

studying the physical oceanographic impacts to fisheries, primary productivity in the California current system, ground fish, Humboldt squid, and maritime oil spill response. So, welcome, Ken. Thanks for coming in the studio today.

Ken Baltz: Hi, Jenny. Thanks for having me.

Jennifer Stock: So, this is a really nice treat to have two people that are really studying an animal that has been so intriguing to me being with the Cordell Bank Sanctuary and this animal has been mysteriously appearing where we haven't seen them before. Unlike the Loch Ness monster and mermaids, this sea creature is not mythical. It really exists and in monstrous sizes.

When people first hear about sightings of big squid from Humboldt squid up to the elusive giant squid, *Architeuthis*, it inspires a gut reaction in most people. So, Dr. Gilly and Ken my first question to you is what was your gut reaction when you first became acquainted with this organism? Dr. Gilly, why don't you start?

William Gilly: I had known of the organism for a long time, but I went down to Baja for a number of years trying to find them in the Gulf of California and wasn't able to until the early 90's, actually, I guess it was and I sort of stumbled on them accidentally in a little fishing village late at night because we had to camp out there because of bad storms and what not and I was just amazed the first time I had seen this squid in the flesh and there were just thousands of them being unloaded from little boats into a waiting truck and it was just an amazing discovery that first time. It was really exciting.

That was the first time I ever saw...well, these weren't living, they were already caught and maybe the next day we went out in our little boat and caught some with the fisherman and that was really exciting to see the first one come up and it was really kind of eerie when you see them come up out of the water at dusk because they're definitely sort of monster-like looking, that's for sure.

Jennifer Stock: And is this what inspired your further studies and your career?

William Gilly: Well, I'd been going down to Mexico camping and fishing in this area for a number of years and then when I found these squid, I thought, "Oh wow! I've got to figure out some way to work on these because this would be a great place to do this," and so in a way that was the beginning of that research career, but as you said I'd been working on squid for many, many years before that, but mostly little nine-inch squid not the nine-foot squid.

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- Jennifer Stock:* Great. How about you, Ken? What was your gut reaction the first time you were acquainted with the Humboldt squid?
- Ken Baltz:* Well, I think it was the same that reaction that everybody had out there in the field and that was, "Woaaaaahh," because the first time I saw it was in a trawl net. We were out doing field work off of the coast of California and we caught them in our trawl nets, our midwater trawl nets where we trawl at night, and we're trying to catch these very small juvenile rock fish that are an inch or two in length and instead of catching them, these large squid showed up in the nets instead. So, it was quite striking and everyone on the vessel was like, "Woah! What is this? Jumbo squid! Humboldt Squid!"
- So, everybody came running down and wanted to touch them, wanted to take pictures of them, wanted to handle them. It was intriguing for everyone and was quite an exciting moment when we first started catching these in our nets.
- Jennifer Stock:* And what year was this that you first started catching them in these juvenile rockfish survey cruises?
- Ken Baltz:* It was last year in 2005. It would be May, June of 2005 when they first started showing up in our mid-water trawl nets.
- Jennifer Stock:* So, this has started a whole new project for you. Originally, this was a cruise to be monitoring the abundance of juvenile rockfish from year to year and all of a sudden there's this new feature into the study. Can you talk a little bit about what's come on from that?
- Ken Baltz:* Oh, sure. I'd love to. Yeah, we've been looking at the annual abundance and reproductive success of rockfish off the coast of California since 1983 and the first time we started seeing these squid was last year during our 2005 annual survey and we thought it was particularly interesting because 2005 was the first year that we saw almost total reproductive failure in absence of juvenile rockfish off the coast of California, especially in our core area in between Point Conception and Northern California.
- So, it was something very, very new to our survey and something quite intriguing and it led me and my collaborator, John Field, who's working with me on this project, to start to think about these squid and what impact, if any, they may be having on these juvenile fish that we normally catch and these rockfish, juvenile rockfish, are important both recreationally and commercially.

They're very specious along this coast and historically they've been very important set, family of fish. So, it got us thinking, "What are these squid up to while they're up here and why are we catching them," and all those associated questions.

Jennifer Stock: So, how have you gone about this beginning of this study to try to figure out why they're up here?

Ken Baltz: Well, with any sort of new critter that you start looking at, first you look at the literature and see what's known about the animal and subsequently found out that Yelle, Dr. Yelle knew a lot about them and he was right next door. So, I went and talked to him personally about them and then got some ideas from him. My collaborator, John Field, had some ideas of his own about looking at their diets because they're normally not up here in northern California, central California. So, we thought, "Well, what in the world are they going to be eating," and "How much are they going to be eating," and try to figure those things out and since we're catching some in our trawl nets and also through squid jigging through the recreational fishing activities of some of the party boats in the area, we were able to get our hands on a few specimens, quite a few specimens.

We've looked at over 500 stomachs now and been able to see exactly what is in their stomach.

Jennifer Stock: When I first....I used to work on Catalina Island teaching marine science to students, we used to dissect squid and one year there was a lack of loligo opalescents, the smaller squid species. So, we were forced to go to the Humboldt squid and boy when we opened those things up, they had a stinky stomach. Really smelly, red, and liquidy and what is that from or what are some of the other prey items you would find?

Ken Baltz: Good question. We're really quite surprised and excited about how much we've actually found in their stomachs. I think we've found, so far, over 1,200 different prey items that has counted for over 50 taxonomic groups. So, they're eating just about everything they can get their arms on: fish, and invertebrates, even birds. We've found sea urchin tests, euphausiids or krill, obviously they're eating those too and we're finding a lot.

They seem to have a preference for fish, mesopelagic fish and pelagic schooling species such as hake or whiting, rockfish, northern anchovy, and interestingly enough one of the top 5 species that they prefer is each other. They're cannibalistic.

Jennifer Stock: Amazing. Dr. Gilly, have you studied much about the diet that Humboldt squid have or...your work has mainly been involved in their amazing nervous systems. Can you talk a little bit about some of the incredible findings you've had with the nervous system of Humboldt squid?

William Gilly: Early on I realized that to...well, I knew this all along, that to do experiments on the nervous system, you have to have a squid in a laboratory situation where you can put electrodes to it and wires and recording instruments and it's not so easy to do that on a squid in the ocean and that entails catching a Humboldt squid and bringing him into the lab. Of course, they weren't in northern California at the time. They were only in the gulf of California, which doesn't have neurophysiology labs set up. So, I decided I needed to try to figure out how to bring the squids into the lab.

That, in turn, led me to realize we don't really know anything about where they are in the ocean as far as in the water column, what temperatures they prefer and so forth. So, in order to duplicate that in the lab to be successful at holding them, one has to learn about their environmental preferences in addition to their diet because you have to feed them in the lab. So, that sort of led to the field work and the tagging and all that phase. So, I'm still waiting, actually, to learn how to hold them in the laboratory to bring them back to do some fantastic neurological work, which is in my mind at this point only, but as far as the diet goes, I've collected many, many squid stomachs like Ken and have looked at them casually, but the main colleague that I work with in Mexico, Uni Mercaida, has analyzed probably, certainly as many or even more stomachs in his Ph.D studies and since then from squid in the gulf of California and he finds they overwhelmingly, as Ken says, prefer these small mesopelagic, midwater lantern fish as their favorite and then they also eat various kinds of crustaceans including krill.

In the Pacific Ocean off Baja they love little pelagic red crabs, which this far north we never see except for when they wash up on the beach after a strong El Nino, but as he says, they're very diverse. They eat pretty much anything they can find including each other. So, there's certain similarities in their diet in the Gulf of California and Monterey Bay system...or the California system, but then there's regional specialties that they seem to indulge in as well.

Jennifer Stock: So, based on the variety of the diet that Humboldt squid eat from what you've seen from the dissections and the fact that they're moving up north now, is there a concern about the type of impact they might have on populations of fishes and invertebrates up here

or are they such a generalist, they kind of eat whatever they can and they're going to eat whatever they can in abundance, but this could potentially have an impact on some of the local fisheries here. Is that something that you're looking into?

William Gilly:

I guess Ken would be more appropriate to ask about that because he's actually working up here. From my point of view, I think they do eat anything. They are generalists, but they certainly have preferences. They're highly intelligent animals that have choices and the things that they find tasty that are present in abundance that are easy for them to catch would be probably their algorithm that they use to decide what it is they're going to eat when and if that happens to be juvenile rockfish or hake or some other commercially or sport fishing important species then they'll latch on to those probably and decimate the population of the local area, I would think, and if that population can be replenished from outside, then you can generate some kind of stable system and I think that's going on now in the Gulf of California.

They're there year-round, but they migrate between two feeding grounds, six months on, six months off. So, it's like they come in and work over this ecosystem locally for six months and then move on somewhere else for six months and then come back again. So, they sort of let the ecosystem recover. So, that may be an unusual situation. We don't know really how they're remaining resident in certain areas and how much they're migrating away and how they're using these local ecosystems or even regional ecosystems like that.

Jennifer Stock:

Yeah, it seems a little early to tell, perhaps. Ken, what are your thoughts on that?

Ken Baltz:

Yeah, it's...I think it's a really important question to ask as far as their impact on an ecosystem. It's one of the things that we're trying to find out in our studies is to elucidate what effect they're having, if any, on the ecosystem of the northern California current system and preliminary findings through modeling and through these diet studies, we're seeing that there seems to be a huge difference in, sort of, their place in the ecosystem in the tropics versus the place they are at in the northern California current system known as trophic level and we're seeing that in the tropics they're a primary forage species. They're being eaten by large fish, such as tuna, commercially important fish such as tuna and other species that are caught down there, but in the northern California current system, they seem to be the ones doing the eating.

So, for the ecosystem up here off California, you know, payback might be hell. I really am starting to feel sorry for some of the species they're eating up here because you have this tropical species that's very short-lived, high turnover rate, high metabolism, very energetic, very voracious predator, doesn't sleep. All it does is hunt and sleep from the time it's born until it dies and it's amongst a bunch of species that are very slow-moving, slow metabolism, very low turnover rate. Some of these rockfish live to be over 100 years old and it just sticks out like a sore thumb when you compare it to its peers out there in the northern California current system. So, it could very well be having some detrimental impacts to a lot of these species that aren't used to these squid.

They're not around here historically. So, they don't know how to handle them and it appears they certainly don't know how to escape from them and they may very well decimate a lot of the species in the northern California current system. It's too early to tell that at this point, but it seems to be an indication that that may be happening. I know over the last 2 years, 2005-2006 from our annual juvenile rockfish survey, the last two years have been the worst two years that we've ever seen for juvenile rockfish abundances since we've been doing the survey over the last 25 years. So...

Jennifer Stock: There are other factors, though, that could be affecting the juvenile rockfish populations, aren't there?

Ken Baltz: Yes, absolutely.

Jennifer Stock: What are some of those other factors?

Ken Baltz: Well, there could be climatic effects, environmental effects, and also fishing pressure has been shown to effect the rockfish quite a bit. There's not as many older, healthy females in the system as there used to be and those older, healthier females are the ones that produce very robust young fish in great numbers. So, there are other mitigating factors for the population declines in rockfish, but it's been very striking that the last 2 years have been so, so bad for these juvenile rockfish and it mimics the time that we are seeing large numbers of squid.

Jennifer Stock: As well as reduced upwelling and reduced amounts of krill. So, it's a lot of different factors here that I'm sure are being considered. Now, one question...

William Gilly: I want to make a point...

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- Jennifer Stock:* Yeah, go for it.
- William Gilly:* ...as a sidebar on that last one. Yeah, in addition to the juvenile rockfish that Ken's been finding quite recently, even though they've been monitoring continuously for 20 years, after the '97, '98 El Nino, researchers at Embare doing the underwater R.O.V. Transect work began seeing lots of Humboldt squid and fewer hake. So, basically if you look at the population or the number of hakes sighted on their ROV transects versus squid, squid went up and hake went down kind of over the same time course during the time when the rockfish looked like they were holding their own, according to Ken's work, and then now that hake are not seen very much at all, I think with the Embare transects and now the rockfish seem to be disappearing. So, you know, one doesn't know whether the squid are kind of working their way down the food chain or what, but they may be or there may be something like that going on as well.
- Jennifer Stock:* Wow, that's amazing just to hear about that down in Monterey Bay as well. Now, this is a really big fishery in Mexico. Ken was saying earlier that this is the largest fishery in the world by weight. Is that correct?
- William Gilly:* It's the largest cephalopod fishery.
- Jennifer Stock:* Cephalopod fishery and that's down in Mexico. Now, if...
- William Gilly:* It's mostly in South America, but there's a good about a third of it, maybe a quarter of it comes from Mexico and three-quarters from South America right now.
- Jennifer Stock:* Okay. If we have more squid moving up the coast here of California, do you anticipate becoming more of a commercial and recreational fishery on the west coast?
- William Gilly:* It's certainly become a lot more of a recreational fishery. If you look on the web on squid fishing in California, you'll find all kind of charter boats, party boats going out. I've never been on them, personally, but Ken has and is doing work with those folks. So, that business, I think, has actually gotten pretty big in the winters in California. Commercial fishing, I guess there's still not an established market and a reliability factor people and fishermen worry about. So, I think the commercial fishing in California has been sort of local, small-scale, hit and miss type things.

I know Phil's in Moss Landing was handling them for a while. You'll occasionally see them in the Monterey Fish Market, but there's no serious commercial fishing effort right now that I'm aware of, but the numbers may justify such an effort, biologically, anyway. I don't know about economically and the factors that fishermen really have to worry about to make an intelligent decision like that. There's no good gear for them people are using now and so forth.

Jennifer Stock: Right, they catch them on a jig-line right? It's like, one at a time?

William Gilly: Well, in Mexico they're caught on jig-lines one at a time, but there labor is not the prohibitive factor. So, in order to do that up here, you'd have to be paying a fisherman relatively modest wages for pretty hard physical work of hauling up 50 pound squid one at a time on a hand-line for 10 hours a day.

Jennifer Stock: Interesting.

William Gilly: So, it could be done. There's automatic jigging machines that the Japanese have made and unfortunately, they're designed for a smaller squid so in Mexico they try to use these automatic jigging machines and they can't...they don't have enough horsepower, basically, to haul up six jumbo squid at once. So, they're trying to find smaller examples of the Humboldt squid down there, juveniles, to use those machines on, but otherwise it's one squid, one at a time, by hand lines.

Jennifer Stock: I see. Now, how do they treat them because I understand Humboldt squid have quite a bit of ammonia in their bodies, potentially to help them float and move up in the water column.

William Gilly: Yeah, I don't know if it's really rigorously established what the compound or compounds are that make them taste bad, but they certainly have something and that seems to vary with the climate and the seasons and what they're eating and it's very poorly understood, but most of the catch in Mexico gets sold, right now anyway, to Asian-owned squid processing, freezing plants. They boil it in some sort of red-spice liquid and that either overpowers the flavor that's bad or removes the flavor. It's some kind of proprietary, secret process, yu know, and then they freeze and ship that back to mostly Korea for final processing and distribution.

There's very little of the squid down there that's actually sold for fresh squid. Most of the fresh squid you buy in

California...calamari steaks either at a fish market or a restaurant, if they're square blocks almost a half-inch thick, it's almost certainly Humboldt squid and it probably comes from factory ships operating off of South America that flash-freeze the squid and things like that and how they treat the squid on board those ships, if at all, I have no idea.

Jennifer Stock:

Amazing.

William Gilly:

A squid that you buy in California is quite tasty, but as I say, it does vary with where you catch the squid, even in the gulf of California and what season and I suspect that has something to do with what the squid are eating.

Jennifer Stock:

Oh, what they're eating might determine how they taste, huh?

William Gilly:

My theory.

Jennifer Stock:

Oh, it...the theory...Ok. Well, we might have to do a little edible tasting up and down the coast, go down to South America.

William Gilly:

Yes!

Jennifer Stock:

Ken, you wanted to add something?

Ken Baltz:

Yeah, I've also heard recently from some people that know about the fisheries in Mexico that...seems like the fishermen tend to prefer the smaller, medium-sized squid. It seems like the larger ones may not, may taste a little more sour. I'm not sure about that, but I heard that and so I'm not sure what that's about.

Jennifer Stock:

I'm sure there's some local folks around here that have been doing some taste tests themselves and I'm sure I'll be hearing from them next week.

William Gilly:

I've only heard once from someone up here that, this was a few years ago, someone caught some squid and gave them to him and he gave him one squid one day and it tasted really good and then he gave him another squid the next day and it tasted bad and that's the day the squid were up on the surface off Cyprus Point or someplace around Monterey eating anchovies at the surface. So, I don't know and the day before that they were caught deep. So, whether they were regularly eating different things or say even this whole report is third-hand. So, but that's the only tale I've heard of squid caught in the same place at the same time that tasted both bitter and good.

Jennifer Stock: I could see where that could be a lucrative issue in establishing a fishery in the United States for the squid. Well, it's just about 1:30 and we need to just take a quick, short break. So, Dr. Gilly, please stay on the line...

William Gilly: Okay.

Jennifer Stock: ...and we'll be back in just a moment.

William Gilly: Sure will.

Jennifer Stock: Before we go into a little bit more about the current research that's being done, I just want to touch base on some of the amazing adaptations that Humboldt squid have, the chromatophores, and I noticed, you know, last year when they had them somebody brought me some tentacles and a pen and on the tentacles, there are these kitenous on them and I wanted to know if either of you could talk a little bit about how these kitenous rings are used in the hunting of their prey and describe those a little bit? Dr. Gilly, are you there?

William Gilly: Sure, yeah, I'm here.

Jennifer Stock: Are they called kitenous rings, those rings on the tentacles?

William Gilly: They are. I'm sure there's some very complicated latin-ish, morphological name for them, but I'm not aware of it. Ken might know.

Ken Baltz: I don't.

William Gilly: So, kitenous rings would do, basically, they would look like a little ring about anywhere from a centimeter to a few millimeters in diameter with little teeth pointing in towards the center of the circle and the teeth would be directed slightly outward when the ring is held in a sucker cup. That's an important fact to bear in mind. So, each ring is held in a little sucker cup on the arm. Each sucker cup, in turn, is on a little movable stalk and there's a little rim of muscle, sort of, that covers the teeth and it can be opened up expanded.

So, you have these little individual suction-cup machines with teeth that are used to grab on to prey and hold it and the thing that's remarkable is that these things are very sharp. They will pierce your own skin, human skin, if you let the squid grab on to your

arm or leg, but, and they have thousands of these things on their arms, but the amazing thing is that the squid, as we talked about before, mostly eating these little fish: 1, 2, 3 inches long. So, they're obviously evolved and designed to handle much bigger prey than they seem to be eating and no problem with doing stomach analysis, right now, is by looking inside the squid's stomach and seeing what's there, you can't really identify the soft parts of fish.

Like, a squid could eat a salmon and not eat any of the bones and you might not know it by looking for the hard parts of the salmon in its stomach. So, it's possible that these squid that are equipped with these 10,000 sucker cups or whatever that are capable of handling big prey actually are handling big prey and we don't know about it.

Jennifer Stock: I think I read that there was some documentation of a Humboldt squid taking out a thresher shark. Is that realistic?

William Gilly: I've never heard of that. A lot of these observations of squid eating big things are made in nets. So, if you catch a bunch of animals in a net and, like a purse thing and close them in in a restrictive space, it's not exactly normal behavior and squid have been known to start eating yellowfin tuna and other large fish under those circumstances. So, the thresher shark thing may be something similar to that. Now, whether that...So, that shows you the squid can, you know, attack and eat something like that. Now, whether it does it naturally is another question.

Jennifer Stock: Interesting.

Ken Baltz: You know, I just wanted to add as far as size of prey, they are known to exhibit fraternal cannibalism. That's where there will eat their brother, sister, or cousin, whatever, attack them and eat them. That's kind of rare in the ocean. Most cannibalism is usually the older adults eating smaller ones of the same species. So, as far as size, it's pretty well documented that they are able to eat animals at least the size of themselves.

William Gilly: Yeah, I think they prefer to try to pick on a smaller weakling, but doesn't much matter how big the squid is because you're just taking little bites out of it. So, if they find an old weak big squid, I'm sure they're just delighted to attack that as a feisty younger squid.

Ken Baltz: They seem to also like to take advantage of squid that are hooked on a jig and being reeled up. They tend to follow it up and beat on

it and attack it and take chunks out of it as it's coming up, at least the first couple that we catch on the squid jigs. They follow it up and munch on it.

Jennifer Stock:

I could see this animal being a great subject for our kids' games, some type of video, arcade game because they have these multiple personalities that kind of exhibit, you know, in their survival here. Well, I'm really curious now...So, we've talked a lot about some of their adaptations and their voraciousness as predators. So, the big question is, what are they doing up here outside of their normal range and moving north? Is this what we're trying to find out through some of the studies that you're doing?

William Gilly:

Well, they're doing what they're evolved to do and that is eat heavily in a certain place and either remain there as long as the food remains on the table or move on somewhere else and I think we're just seeing them passing through our area right now as part of their normal behavior as a species with their whole range, which goes from the tip of South America, now up as far as Sitka, Alaska we know. So, if you think of an individual squid, it probably spends its entire day searching around for the easiest place to find a lot of food up in the water column, up and down from the surface, maybe down to 2,000 feet deep, but also horizontally over an area of maybe 30 miles diameter. Now, every squid is doing that, but every squid isn't an independent organism. They probably swim around in small groups of 100 or so.

So, each group of 100 squid is probably engaged in that same searching behavior and probably, if you look over the whole region, you're going to have thousands or tens of thousands of groups of 100 squid just buzzing around like bees in a swarm searching all the time and if something good is found, if a good area is found, if there's some area where there's a local burst of productivity, so there's a lot of food all of a sudden, the squid are going to move in there very quickly. That's their specialty, I think, is detecting new areas of productivity and they're the first to rush in and they'll remain as long as the food remains and then they'll move on or they'll die and perhaps wash up on the beach. That's the way I see them operating and I think right now, off Monterey and these other areas to the north of us, we just happen to be in a productive place that has something it offers them.

It doesn't necessarily have to be a, you know, something that's simple and obvious to see. It could be quite subtle because a lot of things they eat are things we normally don't monitor or observe very much.

Jennifer Stock:

Do you think this is going to be a permanent movement up the coast here?

William Gilly:

I don't know. They've been here now for ten years off Monterey in the canyon system. I think as long as the productivity remains and there's things for them to eat and they don't deplete their environment, they probably will stay on a long-term basis. Now, what long-term is, whether it's another 10 years or 20 years, 50 years, I wouldn't guess. They were present in the Monterey canyon system in the 30's, so many that the state wanted...fishermen were plagued by these things and considered them a pestilent and petitioned the state to have a bounty on their eradication.

So, then they disappeared again. So, we don't understand really why they move and disappear and when they're in large number like this, the exact specifics of it. It's easy enough to say they just move around and search all the time, but they're obviously cueing on some environmental features or productivity that if we could monitor or understand more completely, maybe we understand something about the squid movement or, conversely, if we understood the squid movements more we can get insights into what environmental factors may be important to really consider and monitor.

Ken Baltz:

Yeah, I just wanted to echo what Gilly said. They were ephemeral visitors to this part of California in the 30's for about five years and then vanished to show up again, you know, 75 years later. So, it's hard to say if they're going to be here for the duration. They may be ephemeral visitors once again or they may set up shop once again for a little while longer. I don't know. Maybe changing conditions, a warmer ocean that we're seeing these days may have something to do with them sticking around longer. Maybe once they deplete their food supply, they may vanish like they did in the 30's.

No one knows that at this point. It's sort of a hope that the thing that makes them disappear is not the fact that they've denuded the whole California current system of these preferred species before they vanish.

William Gilly:

Yeah, I think it's really interesting to ask what they're going to do in Alaska because there it's even more recent than California. It's a very rich area. They have the environmental...they're...one adaptation we didn't talk about is their tolerance of temperatures. So, they seem to be essentially tolerant of, you know, most temperatures that one can find in the ocean.

So, that, per se, is not a limiting factor for them, but it's more of what they can find to eat. So, but, it would be great to have people monitoring presence of squid and what they're eating at all of these different places that we've been talking about from Alaska down to Chile, but right now, basically, Ken and I are the only people in the northern hemisphere trying to do very much with these squid as far as I'm aware. So, it's obviously two very small groups trying to look at a huge, global problem is difficult.

Jennifer Stock: Ken did you want to add something?

Ken Baltz: I just, I wanted to add that they're seeing off Chile, central Chile, a real problem with the decimation of hake and the secretary of their fisheries down there has actually closed down a major portion of that very, very important, economically important fishery, the hake fishery, down there and it's all due, from their point of view, to these Humboldt squid and what they're doing to the hake.

William Gilly: Yeah, now again Jennifer said, "Well, it could be climate change," and yeah, all of these things are probably factors. So, there's probably no one single factor that's the smoking gun, but when you have one big influence and another big influence simultaneously, maybe removing one or something can make a big difference.

Jennifer Stock: Yeah. Everything's connected....

William Gilly: Yeah. Right.

Jennifer Stock: ...out in the food web.

Ken Baltz: I just wanted to also...what you were talking about earlier and what Gilly mentioned was some of their adaptability. They're not constrained by temperature and they also seem to have the ability to exploit the oxygen minimum layer in the ocean and I know that's something that Gilly has seen and looked at closely. I'd like to hear from him about his tagging studies and specifically about the adaptability of these squid in relation to that oxygen minimum layer. I find it very intriguing.

Jennifer Stock: What...can we just back up for our listeners? What is the oxygen minimum zone in the ocean? Where is this depth and what is it?

Ken Baltz: I'm actually going to defer to Gilly on this since he's a really...a great expert on this.

William Gilly:

I would argue with Ken. I'm not a great expert on the oxygen minimum layer. I'm not an oceanographer. So, what I know has come from talking to oceanographers and the first-hand observations and monitoring it, but what it is, basically, in the eastern Pacific and in certain other parts of the world's oceans that are highly productive like the Arabian Sea, the Benguela System off Africa, you have a place where you have deep water close to continental shelves that are very steep like off of California and you have a lot of surface productivity from upwelling in the California current system or the Peru current system and that high surface productivity leads to lots of phytoplankton, lots of secondary productivity of zooplankton and a lot of fish and things eating that plankton, which gets put out as feces and dead animals of various sorts, dead organic matter.

That dead organic matter sinks down in the water column and gets metabolized by microorganisms and that leads, basically, to an extraction of the oxygen that decreases with depth and it reaches a minimum, kind of, well it's hard to really define the minimum, but typically, the oxygen minimum layer would be a layer in the midwater where the oxygen concentration is less than 10 percent of what it is at the surface and off California, that depth would be from about 600 meters deep to 800 meters deep. In the Gulf of California, it's much shallower. It's anywhere from 200 to 400 meters deep down to, again, about 800 meters deep.

As you go north, that oxygen minimum layer goes deeper. So, off Alaska, it starts at about 800 meters and it goes down to like, 1,000 meters. So, there's this geographical change in the oxygen minimum layer at different depths, but in that oxygen minimum layer, you're essentially in a world where things that we're familiar with can't live because there's no oxygen for them to breathe. Even though they have gills, they can't extract oxygen which isn't in the water. So, what you tend to find are a few species, but huge numbers of individuals of a few species that have evolved special adaptations to live in this hypoxic world and one of these is the favorite food of the Humboldt squid, these lantern fish that we talked about, the 1 to 2 inch long little fish.

These little fish and most things that live associated with the oxygen minimum zone, a lot of them will migrate towards the surface at night and then retreat to the oxygen minimum zone in the day. So, the idea is that by living in the oxygen minimum zone during the daytime, they can avoid predation from fish that are visual hunters and then at night they migrate to the surface, towards the surface, anyway, to eat the plankton that's rich up there

and there's a huge number of organisms that do this, that either live in the minimum zone or at the upper edge of it, especially. The upper edge of the oxygen minimum zone actually has so many organisms in it during the day that you can actually see it with echo sounders and it's called the deep acoustic scattering layer and then you can see that migrate to the surface at night.

It's the largest migration of organisms on the planet. It happens every day.

Jennifer Stock: And a lot of Krill species...

William Gilly: Yes.

Jennifer Stock: ...hang out in that as well.

William Gilly: Yeah, krill is another example of something that would hang out in this oxygen minimum zone during the day and then maybe migrate up towards dusk or the evening. So, there's a lot of crustaceans, a lot of other kind of cephalopods, a lot of fishes, and the numbers of these species could be astronomically large and very dense, especially when they're concentrated down in this layer in the daytime. So, the Humboldt squid have evolved the ability, it seems, to be able to use this resource.

They can...the electronic tagging work we've done shows that they seem to penetrate depths that are seriously hypoxic, meaning 5 percent oxygen or something like that, and they'll be down there for ten hours moving up and down in the water column just as rapidly as they seem to do when they come toward the surface at night and probably continue feeding. So, they seem to be eating day and night and adjusting their position either to be in this oxygen minimum zone or just at the surface, just at the boundary of it or in well-oxygenated water. So, they can tolerate this low-oxygen environment. They seem to make use of it, which gives them a huge advantage over fish like tuna because tuna cannot use this environment.

They'll die if they're under these conditions. So, basically this oxygen minimum zone is a huge midwater environment that basically is a predator-free zone for the squid and they can use it to their benefit and it's a penalty to their competitors. So, I think this environmental feature is key to the success and spread of the *Docidicus*. There is something going on with this environment that they're cueing on, either directly or indirectly that's involved with their spreading.

Jennifer Stock: Now, can you...we have just about eight minutes left. Can you talk a little bit about the tagging you're doing with top...the tagging of Pacific pelagics and what is the big question that you are trying to solve with the tagging? Is it the use of these oxygen minimum zones or what is the big question you're hoping to answer with your tagging work?

William Gilly: Well, the big questions are evolving as we go along because when we started out, we didn't really have any questions because we didn't know anything about the animal. So, the big question was then, was, "Can we tag it and can we learn anything," and the answer was, "Yes." Now, it's, well, yes, how long do they spend in the oxygen minimum zone? How fast are they swimming around there, actually? What are they doing there and how much do they migrate horizontally? What are their long-distance migrations in the ocean?

How are those coupled to oceanographic changes in the oxygen minimum zone or other things that can trigger migration. So, we're working mostly in the Gulf of California as our little model system. So, whether those things we find there are applicable to the whole eastern Pacific, you know, that remains to be seen. So, the big question is how these squid are operating over the whole basin of the eastern Pacific from Chile to Alaska, but I think just like any other scientific question, if you look at small pieces, you can learn something that can then be generalized for the bigger picture.

Jennifer Stock: Yeah, the more pieces of information we're able to learn about it seems like we can put the pieces of the puzzle together, but there are so many factors in everything that's going on here. It's going to be interesting to piece it together.

William Gilly: Well, yeah. That's why I say we need a lot more people in different place basically doing the same type of work Ken and I are doing in Monterey and in the Gulf of California because those are just two little specks on their range just in the northern hemisphere, let alone in the south. So, I think to have 20 different labs looking at different geographical regions in some kind of systematic research program to see what the squid are eating.

Who's eating them? When are the squid there? What are the oceanic conditions, both on the surface and deep in the ocean, and then see what kind of similarities emerge from different geographical areas would be a really useful thing to do and that just requires a lot of funding and organization, which at present, is

not in hand. So, we're actually talking about trying to do something like that, but whether we succeed will remain to be seen.

Jennifer Stock

Ken?

Ken Baltz:

Yeah. Along those lines, because there is a lot of interest and intrigue from scientists as well as fisherman we are starting to get more collaborators. We'd like to get more, but we've had some really great help from fishermen, who've collected stomachs for us. They've collected specimens for us, some of them hundreds of specimens, and we really appreciate that and there's more interest of people up along the northwest coast of the United States who are collecting specimens for us because, like Gilly said, not too many people are doing any concerted projects on these squids as of yet, but there is a lot of interest and we're looking to try to collaborate and do more as what Gilly talked about and then I think that will be important if these squid remain around here and start to have impacts or potential impacts on the ecosystem.

It is going to be important that people work together to try to see what's happening because it's, you know, it may have a real effect on the economic importance of fisheries of the United States.

William Gilly:

Yeah. I think one can argue that it's, you know, wherever it goes, it restructures that ecosystem. So, that's a really big deal and, you know, even it's as important a thing as a marine protected area restructuring an ecosystem of...it's a huge factor that one needs to understand and I think, as Ken said, if squid remain the researchers will come. I think we just happen to be doing it because we think it's important to do.

If these projects fell into our laps, whatever, and maybe a lot of people, you know, everyone has their own work going on and you think, "Well, I'm not going to shift gears and work on the *Dosidicus* because it could be gone in six months or a year," and that may be true.

Jennifer Stock:

Interesting. If there are people that are listeners that are interested in somehow getting involved, either through funding or collecting specimens is there an email address or phone number that either of you would want to offer for anyone to contact you at?

William Gilly:

Sure. I'm always happy to answer any questions about squid by email or, that's the easiest, or phone because I'm seldom answering the phone, but I'll give my email address or do you have it?

Jennifer Stock: Sure. Um, actually, why don't you announce it and I'll re-announce it.

William Gilly: Okay, because I have to pronounce it properly because it's Lignje, because if you speak Serbo-Croatian you understand, but if you don't it's L-I-G-N-J-E at Stanford dot edu.

Jennifer Stock: Excellent, so that's L-I-G-N-J-E at Stanford dot edu if anyone wants to contact you about other squid questions.

William Gilly: Sure and yeah, we have volunteers and things like that at Hopkins Marine Station if people are local and want to find out about those possibilities or just visit the lab if they're passing through in Monterey, that's fine too. Just feel free to contact us.

Jennifer Stock: Wonderful. So, this has been an interesting show. I have this vision of squid overtaking the world right now and they seem to have the capabilities to do that. We're just about...it's about time to wrap up, but one thing I'd like to ask both of you, since you've had a heavy role in researching this animal that can really have an impact on our ecosystem, what would you...what's the one thing you would like to tell listeners about their role in protecting the ocean as a whole. Squid definitely have quite an impact, but we all as humans are having impacts too and I just want to hear from both of you what you'd like to say to listeners.

Ken Baltz: Yeah, Jenny, thanks for the question. It's a good question and one thing these squid bring to my mind and it's sort of a way of answering your question is that there's so much connectivity out there in the ocean and globally, everything is connected, and things run down hill and everything we do in our daily lives is ultimately connected to it and I was just thinking the other day about growing up in Arkansas on the farm I grew up on, you know, back in the 70's when I was a real youngster and we're just now finding out that some of the pesticides and fertilizers that ran down the Mississippi River and into the Gulf of Mexico is now contributing to a large dead zone in the Gulf of Mexico and so even those people in the Midwest that are farmers have an impact on the ocean and we see that there's a lot of connectivity out there and we see it in the squid too.

They're not just in the tropics. They have connections. We're not sure what those connections are yet, but they have connectivity to this Pacific Ocean basin.

Jennifer Stock: How about you, Dr. Gilly? Your thoughts on...

William Gilly:

I was going to say the same sort of thing. I was...sort of try another things, you know, just are the way they are and something isn't necessarily good or bad. So, you know, these connectivities and the context in which you view something that gives us a value judgment about whether something is good or bad. So, if you're a hake, *Dosidicus* invasion is a bad thing, but if you're a sperm whale it's a great thing because you love to eat the, So, I think the thing that the squid really teaches me and I hope helps others to see is that when you look at a given problem in the ocean it shouldn't even be labelled as good or bad.

It's just the way things are and by trying to understand, you know, how things are operating maybe we can begin to approach why they're like that, but it's extremely complicated and I think that's just an important thing to bear in mind and that lends itself to simple explanations of what's going on like everything's due to...well, first it was El Nino, now it's global climate change, but now over-fishing is also a favorite thing. So, various groups just sort of latch on to one explanation and ignore the connections between all of them and I think that's really a danger to increasing our understanding of the world at large, not just the oceans, but relationship of man to each other and other countries and other political systems and...

Jennifer Stock:

Thank you.

William Gilly:

...everything.

Jennifer Stock:

Excellent. Thanks so much. We're just out of time right now. We could talk about squid for another hour, but I want to just thank both of you, Dr. William Gilly and Ken Baltz from NOAA fisheries for joining us today on Ocean Currents. It was great to hear from both of you about the natural history and what we have to keep our tuned open for as far as research goes and I just want to say thank you to all...for listening and I just wanted to let you know the next show is January 15th and we'll be talking to someone from the Sand Francisco Ocean Film Festival for part of the show. The San Francisco Ocean Film Festival is January 19th through the 21st in 2007 and it is an excellent event to see some independent films about the ocean. So, thanks for joining us today on Ocean Currents and keep your eyes open for squid.