Leila Nilipour: What are those?

Andrew Sellers: Tunicates... These are all solitary tunicates. This is a colonial tunicate. And up here it's all algae.

Leila Nilipour: We're on a boat in the Las Perlas archipelago, in the Bay of Panama, and they're showing me a square plate, like a bathroom tile, covered with these little rubbery-looking organisms. They are called "tunicates" precisely because they have a kind of cape or "tunic" covering them. But on the inside, they are like a pipe. From one end they absorb seawater, from which they extract nutrients, and from the other end they release it. They are also called sea squirts, because if you press on them, they release a squirt of seawater.

AS: Then the plates come out like this. So, the top plate is for algae to grow because it's exposed to the sun and the bottom plate is where invertebrates like barnacles and tunicates, things like that, usually settle.

LN: If you haven't heard of these organisms before, that's normal. They're not exactly the most glamorous thing in the ocean. They're small, immobile, and reef fish usually eat them before they can grow too much. Although you may have heard of the SpongeBob cartoon, a sea sponge, and of his pet snail, Gary. Both are organisms that could appear on these plates.

LN: And what are you doing Carmen?

Carmen Schloeder: I am cutting these cages that help keep out the fish so that they don't come in and eat our organisms during the four months that they are here at sea. And we are going to take this plate out so we can weigh it, take a picture of it and expose it to predators later.

LN: But, even if they go unnoticed, these organisms are super important to the health of the oceans and a group of scientists wants to understand how changes in the smallest creatures in the sea can alter the entire food chain of the animals that depend on them. And also, they are on the lookout for other tiny organisms that could be dangerous to the health of our oceans: marine invaders.

LN: Welcome to Biodiversa, the podcast of the Smithsonian Tropical Research Institute in Panama, also known as STRI. My name is Leila Nilipour and I am a science journalist. In this episode, we will travel to the Bay of Panama and the Gulf of Chiriqui in the Panamanian Pacific to understand what happens when there are changes in the environment that affect the availability of nutrients and their impact on the entire marine ecosystem.

LN: What I am about to tell you occurred between July and November of last year. During these months, considered part of the rainy season, the ocean in the Bay of Panama is warm. However, during the summer months, between mid-December and April, a combination of ocean currents and winds change the conditions, causing a phenomenon known as upwelling.

Natasha Hinojosa: When upwelling happens, it brings a lot of nutrients from the deep, cold waters to the surface. And that is like a fertilizer for everything that is growing in the sea right now.

LN: Not only are the waters much richer in nutrients than the rest of the year, but they are also very cold. If you've ever bathed in freezing water in the bay of Panama under the summer sun, upwelling is the reason. However, although it is part of the same ocean, in the Gulf of Chiriqui, some 300 kilometers to the west this does not happen.

AS: The nice thing about the Gulf of Chiriqui and the Gulf of Panama is that you are in the same region, you are in the same ocean, but you have two totally different environmental conditions.

LN: This is Andrew Sellers, a Panamanian scientist from STRI and one of the main researchers in this project that I am telling you about. For him and for many scientists, it is advantageous that the Panamanian Pacific has, so to speak, "two Pacific oceans in one": the Bay of Panama, which gets cold and has a boom in nutrients seasonally, and the Gulf of Chiriqui, which always has warm water. This makes it a natural laboratory to study what happens in the same sea under changing environmental variables.

AS: So, the idea is to observe how these environmental changes affect the interactions between algae and herbivores, because as there are more nutrients and more productivity, algae grow faster.

LN: Herbivores are generally small fish that feed on the algae, a necessary task to prevent them from expanding too much on the reefs and affecting the health of the corals. But during the upwelling season, when there is an excess of nutrients, the algae may grow faster than the herbivores can eat them, causing overgrowth on the reef. This is one of the dynamics that Andrew wants to study.

AS: So, what we want to see is whether the herbivores are able to keep the algal cover down even during these periods where there are more nutrients. On the other hand, they're also...

LN: On the other hand, there are the encrusting invertebrates, organisms without backbones that grow fixed in one place, like the tunicates we were talking about at the beginning. They also include mollusks, anemones, sponges or barnacles. These organisms travel through the sea as small larvae until they find a place to settle and grow. You may have seen them clinging to docks or on the underside of ships.

AS: So there may be differences in invertebrate growth and also the recruitment of invertebrates that is influenced by upwelling.

LN: These immobile organisms, which, like algae, receive many more nutrients during the upwelling season, could become larger and more abundant during the summer months. And predators, i.e., the fish that feed on them, could have difficulty keeping their populations in check. This is another dynamic that Andrew seeks to understand.

LN: That's kind of what you expected, I imagine.

AS: Yeah. What's interesting too is that this is all at the base of the ecosystem: the algae, all these filter feeders. So it's interesting to see how all that energy that's going into the base of the chain is dispersing to the herbivores, to the predators. So we are also trying to do that with the fish project.

LN: Algae and filter-feeding invertebrates are at the base of the food chain. They are the first to absorb nutrients floating in the seawater. Then there are the small fish that feed on them. In turn these small fish are the food for larger fish, and so on up to the top of the food chain, which are the large predatory fish, such as snappers, groupers and sharks. A third component of the experiment seeks to understand how upwelling might affect the survival of small fish, those that eat algae and invertebrates.

AS: The cold. I mean, the colder water may cause metabolic changes on the fish, where maybe they are eating less.

LN: That is, in addition to facing greater amounts of algae or invertebrates, during upwelling, their metabolism could be impacted by the lower temperatures, causing them to eat less. It's like being in front of an unlimited buffet and losing your appetite, which in the case of humans might not be serious, but if the balance of the ecosystem depended on your appetite, perhaps it would be. Although there are other variables at play.

AS: If you have more food, it may be that you're accumulating more lipids, you have more energy.... or it could be that because of the cold you are more stressed, so that's what we're seeing with cortisol levels in the blood.

LN: I mean, it could also be that the abundance of food during the upwelling season causes these fish to store more fat in the body. Or that the cold weather has them a little stressed. To find out if this is the case, they collect fish and test them to see if cortisol, the stress hormone, or their stored fats levels change between seasons.

LN: Is this the same experiment that was at Saboga?

AS: Yes, it is another replica site. So, we have that one, another one here and another one in Mogo Mogo over there. And in Coiba we have three sites and in August we are going to set up five more sites in Costa Rica.

LN: Before we continue, a summary of what we've heard so far. Andrew and his colleagues are looking to compare the effect of fish on algae and on invertebrates at upwelling and non-upwelling sites. And another question they want to solve at the same time is whether fish help control invasive invertebrate species on the reef.

AS: Mark has been doing a lot of studies offshore near the Canal looking at what species are being introduced via ships and a lot of those species are encrusting invertebrates like the ones we see on the plates.... So, we want to see how much those species that are on the coast are expanding in distribution towards the reefs.

LN: These invasive species are not from here, and for some reason or another they end up living in ecosystems where they don't belong. One of the best-known invasive species, for example, is the Lionfish, which is native to the Indo-Pacific and was introduced and is now abundant in the Panamanian Caribbean. And Mark, the person Andrew mentions, is Mark Torchin, a STRI scientist who focuses on studying the invasive species we've been talking about. This is Mark.

Mark Torchin: Yeah, so we've documented quite a few in the ports and the marinas on, near the shore where boats are accessing, so areas that you know, areas where there's a lot of marine traffic, you know particularly associated with the Canal, the ports, the marinas....

LN: In his decades-long studies in Panama, Mark has documented several invasive species in the ports or marinas near the coast, areas where there is a lot of marine traffic. Many of the fouling invertebrates travel the world thanks to maritime trade, either attached to the hulls of ships or as larvae in their ballast tanks. This can cause them to end up in places far from their native habitat. And in Panama we have the Canal, through which up to 14,000 ships pass each year, and although ballast water exchange within the Canal is prohibited, many introduced species enter the ecosystem through ballast water exchange outside the Canal, on the coast.

MT: Initial pilot studies that Andrew has done show that yeah, there are some of those same introduced species that we find on the mainland out on the reefs in the islands, but only when predators are absent.

LN: And as Mark explains, Andrew's preliminary studies have found that some of these invasive species that have been detected in coastal areas make it out to the reefs only when there are no predators. So, I wanted to know, how much damage could these small, immobile organisms cause? With the lionfish it's understandable, because it is a voracious predator that could cause an imbalance in the ecosystem, but a barnacle, which is a small marine crustacean, or a sponge?

MT: So, they generally can occupy space, cover areas and outcompete other species.

LN: What Mark is saying is that they can become a threat if they manage to occupy reefs to the point of leaving native species without space. In fact, an article by the United Nations Environment Program lists invasive species as a major cause of nature's crisis, as they have contributed to nearly 40 percent of all animal extinctions since the 17th century, causing environmental losses of up to $100 billion a year. In Pacific reefs, in particular, losing local species to invasive species could cause an imbalance in ecosystem dynamics with repercussions on everything that depends on them, such as the food chain we mentioned earlier.

MT: Important to think about that and you know, think about how what we do to our fish communities in terms of fishing them out as well as, you know, how the environment's changing and how that's going to influence those those interactions as well.

LN: So, we must think about how overfishing, in combination with environmental changes might impact the ability of the fish to prevent invaders from taking over the reef. But how would we know if invaders have arrived on the reef in the first place and if the fish are being able to control them? The answer lies in some plates and mesh cages. Those we heard about at the beginning of the episode.

CS: I mean, there are two types of experiments. There's the main experiment that has all the treatments: the open plates that are exposed to the fish for that whole period, the closed cages that don't allow the fish to enter and the partial cages, which also serve as a cage control, to see if anything changes in the water flow, or the shade, etcetera, right? Everything that can happen if you put a cage around it is controlled through that control.

LN: This is Carmen Schloeder, the one you heard at the beginning cutting some cages. Carmen works with Mark, and she's the research director of the lab. And the plates she's talking about are these little square structures, the ones that look like a bathroom tile, that we heard about earlier. These plates can be placed under the sea and function as a solid surface on which algae and invertebrate larvae can settle and develop. Something like an artificial reef. The experimental part consists of putting cages around some plates and not others.

MT: So, some are protected from predators for three months, exposed to predators for 3 months as they normally would be in a natural environment.

LN: This is how Mark sums it up: some plates have mesh cages around them, which allow algae and invertebrate larvae to enter, establish and grow protected from the fish for three months. Other plates have nothing around them and are exposed for the same three months. In other words, the fish could easily eat any algae or invertebrates that decide to settle there.

LN: And you check them every three months?

AS: Yes, exactly. You take the plates out...so the plates, so after 3 months it would come out something like this...that's the way it is when it's exposed.

LN: On one side, the side that was facing upwards and exposed to the sun for three months, it's covered with brown and greenish algae. The side facing down was more diverse, with different colored tunicates, white, brown and pink shades, the occasional crab and even a branching coral. The smell of the sea was very penetrating.

LN: What are those?

AS: Tunicates... These are all solitary tunicates. This is a colonial tunicate. And up here it's all algae.

LN: The idea of checking them after being three months underwater is to compare what would grow on a reef in a natural situation, which would be the exposed plates, versus what would grow in a situation without predators, which in this case would be the plates surrounded by mesh cages.

CS: Wow, I have never seen so much on a plate. These little ones, for example, these tunicates we're only going to see when there's a cage, we don't see them on the open plates, because the fish really like them. It looks delicious...

LN: This would allow scientists not only to detect if there are any invasive invertebrate species on the reefs, but also to predict what would happen to the reef in a potential overfishing situation. One in which there are not enough fish left to keep the ecosystem in balance. And just to better understand the issue of predation on the reef, after three months at sea, some plates are removed from their cages and left exposed for 24 hours.

CS: So, the cages are removed. Now we are going to weigh them and then they go back to the reef and there the fish can have their feast, the buffet.

LN: While she was explaining this to me, Carmen weighed the plates with all the organisms that had grown attached to them during the three months in the cage. And she was taking pictures of them to have a visual record of the species that had settled there.

CS: 152A is 214 grams. 152B, weighs 217 grams.

LN: We had gotten off the boat on a nearby island to do this, because to get accurate weights you need to place the scale on solid ground. It was a rainy day, so we took shelter under the ruins of an abandoned house facing the sea. After weighing the plates, they would be placed back on the reef and filmed to see what kind of fish came to eat the invertebrates that had grown on them.

CS: So this is just a separate experiment to see what type of fish can come to eat, how much they eat, in what period of time, more or less, if one hour is enough, because they are very attracted to what is there, or if in 24 hours there is more predation because sometimes the season also means a lot, right, the day, the night in the activity of the fish. So all that must be taken into account.

LN: 24 hours later, the plates would be removed from the sea and reweighed. This difference between the initial weight, with all the organisms attached to the plate, and the final weight, after being exposed to the fish for a day, allows us to calculate the predation rate. The rest of the plates, those that were kept caged with the organisms intact, would be taken directly to the laboratory for DNA analysis to determine with certainty the presence or absence of invasive species in the reef.

LN: With this one you would have an upwelling and a non-upwelling one...

CS: Yes... exactly... 195 grams.

LN: The analysis of these plates would culminate the first year of the experiment. A round had already been completed in the summer, during the upwelling season. And now this round from July to November, without upwelling. So I wanted to know... at first glance, did you notice any difference?

AS: Yes, a lot more things grow, more tunicates, more barnacles during upwelling. Super marked difference.

LN: That afternoon, after returning the plates to the reef, we took the plates from a second experimental site in Las Perlas. It was still raining heavily, and we needed to find another sheltered place on the mainland where we could weigh them and take photos. A resident of Saboga, the nearest island, knew Alexis, the captain of our boat, and offered us a space below his house.

A pleasure, Natasha...Victor, Victor.

LN: As we worked, he sat off to the side, quiet, but watching curiously.

CS: 194A. It's 218 grams and is an exposure. 182B

LN: Until he finally asked.

Victor: Is this to see how the site is improving or...?

Natasha Hinojosa: It's to see how strong the predator effect is here in the Gulf of Panama between two types of seasons... so you know about the upwelling season, right?

LN: Natasha Hinojosa, who is a PhD student in the lab of STRI scientist Matt Leray, and who is participating in the experiment, was the one who explained it to him.

NH: If we look at the cages that are completely exposed, they are almost flat, they don't have anything on them because the fish are eating everything, but the ones that are caged have a lot of tunicates, crabs, nudibranchs, a whole community, so you can see that the effect of the fish eating is a predatory effect.

LN: In the end, getting the answers from these experiments will take a lot of time and effort. Andrew and his team already have some preliminary data from the first year, such as the difference in species abundance that you can see with the naked eye between upwelling and non-upwelling seasons, but the 2023 results are still pending. And also those from several sites in the Costa Rican Pacific thanks to a new collaboration with the University of Costa Rica. Although not everything goes well all the time, as when we accompanied Andrew to the area around Coiba and the boat's motor wouldn't start...

AS: Coibita, Coibita, do you copy?

Captain: The engine starter cable is not connected, go ahead, give me a little space... the cable broke, that's why it will never start.

AS: We can be towed, I think there's no other way....

LN: But it always works out, and there are days of hope, like when the Saboga resident offered us shelter from the rain under his house so we could weigh the plates on solid ground.

Victor: Even if I am not here, feel free to stop by...

NH: Thank you very much, I am very grateful.

LN: Everyone is doing the best they can with what they have. And I'm not just talking about the scientists, but the organisms that help keep the reef healthy. Mark sums it up well.

MT: All these animals and algae are competing for space. They're looking for somewhere that they can hold on to and make a living. And in tropical areas the native biodiversity is important for providing biotic resistance, essentially kind of pushing some of those invaders out or at least not enabling them to take... occupy a lot of...you know, spread and expand.

LN: All these invertebrates and algae are competing for space, looking for a place to settle and establish themselves. And native biodiversity has proven to be important in keeping the invaders at bay...or at least in helping to prevent them from taking up too much space. And maintaining the health of reefs, well, is no small task. After all, they are home to ¼ of all marine species. In other words, they are the basis on which our oceans and coasts are sustained, making them one of the most valuable ecosystems on the planet.

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