David Levin: 00:01:36 You're listening to the loop, a podcast about the mud microbes and mammals and the Gulf of Mexico. I'm David Levin. For the past seven years, we've covered the work of scientists studying the aftermath of the 2011 deep water horizon oil spill, and today we've reached the end of the road. The research is winding down and this is our last podcast, which is pretty hard to believe. So in this episode we're going to try something a little bit different. We're going to sit down with four of the key scientists from C-IMAGE, which is the center for integrative modeling and analysis of the Gulf ecosystem.

David Levin: 00:02:10 And we're going to look back at the last several years of research where they've started, what they've learned and where this work could take us in the future. So joining me in the studio today are Steve Murawski, a fisheries biologist at the university of South Florida and co-principal investigator of image. We have Isabel Romero, a geochemist who is also at the university of South Florida and joining us remotely, Dana Wetzel, a biochemist at the Mote Marine laboratory and // Michael Schluter who is a fluid dynamics researcher from the Hamburg Institute of technology. Welcome to everybody.

ALL: 00:02:48 Thank you. Thank you. Thank you for having me. Thank you. Welcome.

David Levin: 00:02:51 So first off, I want to look back at kind of how C-IMAGE started. Let's go back to just after the deep water horizon. And Steve, maybe you could tell me a little bit about why C-IMAGE was necessary in the first place and how it really came to be.

Steve Murawski: 00:03:07 Well, how it really came to be was the, the funding that enabled all of this to happen. Typically in oil spills, you have the interplay between the responsible party, in this case, BP and trans-ocean and others. The government.// And also the scientists that work for them.

Steve Murawski: 00:03:32 But in the case of Deepwater Horizon, there was a large academic contingent that wanted to work in this field and be helpful. And so early on, BP negotiated with the white house under the Obama administration to put together a $500 million research fund, whichhas been the basis for a 10 year $50 million a year program administered by something called the Gulf of Mexico research initiative or GoMRI. And CIMAGE is one of a number of funded centers that was successful in their proposal to continue on with research.

David Levin: 00:04:10 So can you tell me a little bit about some of the urgency right after Deepwater horizon? What were some of the questions that first came up? And you know, funding obviously is an important part of research, but so are these burning questions that you need to answer.

Steve Murawski: 00:04:25 Certainly. And and you know, sort of when Deepwater was happening there was a significant amount of mistrust of the oil companies, of the government, et cetera. So there was a real niche for independent academic scientists because like it or not, the public generally trusts independent people who are perceived as not having a financial interest in the outcome. And so early on there were a number of questions because of the uniqueness of deep water horizon. It's the first ultra-deep oil spill in the world history that that is 1500 meters or a mile deep or deeper. It was an enormous amount of oil that came out of the hole depending on who you talk to about about 4 million barrels. //. It lasted for 87 days. So it triggered a number of really important questions.

Steve Murawski: 00:05:18 Like, for example, where is the oil, where is or was the oil? // 00:08:14And obviously you can see oil at the surface from satellites and aircraft and, and whatnot. But given the extreme depth, there was a nagging question about whether or not this oil was actually making its way to the sea bottom, which is, you know, everybody learned in sixth grade science that oil floats, right? Well, maybe not so much. And so a major early question was, you know, what's the quantity of oil on the sea bottom and how did it get there? And, and that's triggered a number of questions that I'm sure we will talk about.

What about dispersants? About 1.8 million gallons of, of dispersing chemicals was used. And is that, was it effective particularly used at the wellhead? Is it problematic? Does it make oil more toxic than just oil itself? Is it dangerous to humans? So those questions are certainly important. Is the seafood safe to eat? There was lots of questions regarding protection of seafood safety. //and then really other than sort of the impacts on the ecosystems, the big question that we all struggle, have struggled with for a decade is, is the government and the oil companies better prepared for an oil spill of this magnitude now than they were 10 years ago?

David Levin: 00:06:25 And I mean, do we feel that they are at this point?

Steve Murawski: 00:06:32 Yes and no. // if we have another spill of, of the same type in the deep water, the natural playbook would be to look back at Deepwater Horizon and use the same methods. But the new oil spill will be different. It could be up to two miles deep. And so that changes the circumstances dramatically. And we don't know how effective the playbook from Deepwater would be under a new scenario. It's often said that military generals often prepare for the next war by fighting the last one. And that may be the case for deep oil spills as well, that we are now prepared for a Deepwater horizon spill. But are we prepared for the next set of circumstances which may be different?

// ISABEL ROMERO //

David Levin: 00:07:50 Well, let's get into a little bit about how you started piecing together what happened immediately after the spill to kind of gauge what the response should be or could have been.

David Levin: 00:16:22 Isabel, Can you tell me a little bit about the connections that you started to make between the health of animals living on and around the sea floor and what you were finding in the sediments after Deepwater Horizon?

Isabel Romero: 00:16:37 Yes, for sure. So one of our first studies looked at, “where did the oil go?”. So we created these large-scale maps to find where were the critical areas and we found that half of the oil that was spilled actually reached the sediments. So when we know that about 200,000 barrels of oil reach the sea floor // from coastal to deep areas, we know that a lot of the pelagic organism were exposed too.

David Levin: 00:20:04 Pelagic being animals living near the sediments.

Isabel Romero: 00:20:07 Yeah, it could be from invertebrates to fishes, to very important fishes, like red snapper, tile fish, 00:17:33, and what we found is that // different communities in different areas // all have very similar // contaminants, which is incredible, which means that the exposure and the impact of the oil spill were much larger we thought. // There is these huge amount of oil spill in the environment, right? There are still effects that we haven't figured out yet, but we need to first establish what is the new baseline. So I'm collecting fish around the gulf, collecting invertebrates around the gulf and also contaminants in order to understand that. And there are some similarities, similarities between the Northern and the Southern Gulf of Mexico that we've seen so far. 00:20:39

David Levin: 00:21:53 what do you mean by a baseline? And why is that important to have now?// Is this just sort of a, a way of checking on, okay, here's the health of the entire Gulf right now ,and now we have a benchmark to compare it to in the future?

Isabel Romero: That is exactly—like, we didn't know what was the concentration levels of the, some of the toxic compounds that you can find in the oil and these animals. // this is critical because the oil the Gulf of Mexico has large of natural oil seeps and the animals can have some signature of this, but the animals have been able to adapt to these low concentrations over time. // But understanding that is important in order for you to establish an impact after a large event. So we want to prepare for a future large spill event, we need to know what is the new baseline, because, a lot of other oil that was spilled during the //Deepwater horizon oil spill is still in the Marine environment. So understanding this new baseline // we can be better prepared for, the next spill if it happens.

David Levin: 00:23:32 So this is kind of checking in to see what's the new normal in the Gulf now and how might this change in the future?

Isabel Romero: 00:23:37 Yes. And also to know like what is happening to that oil is still the same is it transformed? Is it not? And what could we expect to happen in the next five, 10, or 5 years. // It looks like the recovery process will take at least one decade more from now. // we have seen that some of the concentration toxic compounds are starting to go lower in concentrations but not in, in hatch and hatch eggs, which means that the next generation of fishes or invertebrates from the pelagic column have been compromised. // which means that they // could have some problems in the reproduction for the next generations and it will take a few, at least one decade to recovery. That's what we think.

Steve Murawski: 00:25:14 To follow up. Just to follow up on this there are some estimates that given the fact that we can estimate how much sediment fluxes to the bottom on a daily and an annual basis, that it may take 50 to a hundred years to actually bury that oil deep enough so it won't interact with biota. So it's going to be a long time before deep water horizon oil is out of the system.

Isabel Romero: 00:25:39 But as well, now we're discovering that that's the process, if the sentiment is not being moved. If nothing is touched, nothing is moved, yeah, it will take 50 years or more to recover, to be buried and not be affected. But there are natural processes and as well as exploration, human exploratin on the bottom of the, of the ocean in the Gulf of Mexico.

David Levin: 00:26:36 So you're still essentially seeing remnants of the spill on the upper level of sediments that can get kind of churned back up? Is that what you mean?

Isabel Romero: 00:26:47 Yes, yes, // and so what we trying now to understand is the processes itself, how long it takes, where the oil is moving down slope what happens to the water column? The exposure to animals. // We honestly, we still are our studying in and understanding.

//DANA WETZEL //

David Levin: 00:28:03 Dana, I, I'd like to ask you a couple of questions here and pick up with you at that because // you've really been a major part of figuring out how it actually impacts those species.

David Levin: 00:31:02 tell me a little bit about the laboratory studies you are doing, and that you've done in the past, taking fish, feeding them oily food, for lack of a better term, or putting controlled amounts of oil in the tank with them. //

Dana Wetzel:

00:28:44 Well, you know the impacts from an oil spill are really difficult to measure in organisms simply because of natural environment is so very complex, right? What we really need to understand is what is the comprehensive assessment of the status of the population. The way you get to that is you look at the quality of the health and you look at acute and a chronic responses or exposures and then you look at the short and the longterm effects. // those estimates really most of all come from acute exposure in a laboratory.

00:34:21 We looked at three different pathways of exposure. We looked at just oil in the water column. We look to add contaminated feed and we looked at oil sediment just to see is there potentially a difference in the exposure route. And perhaps a difference in the species. We looked at Redfish, we looked at flounder and we looked at pompano.

So what we have been looking at in these fishes, is once they're exposed to oil, what happens in their system? how are they compensating for the exposure?

00:43:52 Does the ability to compensate or fight off this exposure result in negative consequences? And we're seeing that they do. We saw a suppression of their immune function. We saw a decrease in their overall body mass. We looked at ratios of RNA to DNA to see, you know, was protein being produced and it wasn't being produced as it was in controls.

00:31:18 We saw abnormal development in these early life stages. The spine was curved. The heart was misformed. Their growth was abnormal. We also saw that there was some impairment to their ability to swim and to forage. We saw a whole lot of different ancillary assessments that one might think aren't necessarily important because they're not outright killing the organism, but really these consequences can manifest later on in the ability for the animal to survive.

David Levin: 00:41:34 Can You tell me a little bit about what you've learned today that we, we didn't really understand when we started that, that all of your laboratory studies and work with CIMAGE has started to uncover?

Dana Wetzel: 00:41:47 So I think one of the things that we have found to be a constant in the studies that we have done is that oxidative stress is a very real and very potent impact on these fish, whether it's through food, through, a water, aqueous exposure, or through contaminated sediments.

David Levin: 00:42:13 Can you explain what that is? Just for our listeners?

Dana Wetzel: 00:42:16 Sure. All right. I// So what that means is, organisms everywhere, are exposed to different // stressors. Okay? So whether it's the sun radiation from the sun, whether it's an oil contaminant, //. Those exposures actually cause your cells to oxidize, and that's damaging to the cells. It's damaging to your DNA. It's not a good thing, // oxidative stress can lead to compromised immune system. It can lead to suppress the ability to reproduce. DNA damage. All these things that you really don't want to have going on are happening. //

Dana Wetzel: 00:45:21 And I'll give you an example. I'm on a red drum study that we're writing about now. We exposed red fish to oil for a period of four days, and then we had six days where there were, there was no exposure.

Dana Wetzel: 00:46:25 And what we found was that there were 120 different pathways in that organism, in that red drum that were significantly altered because of the exposure to oil. // And those pathways involved amino acid building, the synthesis of fatty acids and a number of other molecules. Those were suppressed, those pathways were suppressed. We also found that, you know, there was a suppression in cellular growth and, and cell proliferation. We found that pathways were suppressed that allowed for the ability to repair cells, repair injury. So I think, I think the, the ability now to look at such a broad range of questions and health consequences because of the increase in technology in the application and what we've learned from other researchers doing this, this work is just absolutely fascinating.

//MICHAEL SCHLUTER//

David Levin: 00:51:50 Hmm. That's actually a, a good time for me to bring in Michael Schluter into the conversation. Because obviously where oil goes from an underwater blowout, especially a deep underwater blowout, is going to be a huge factor in figuring out how it's gonna impact the ecosystem. So I'm wondering, first of all, Michael, if you can describe what you've been doing with CIMAGE, it's, you've been studying how deep water blowout actually happens and where that oil kind of goes. Cause the, the obvious thought is, well, oil goes up, but that we found that's not the case.

Michael Schluter: 00:52:34 Yes David; we were a little bit interested in this kind of // movement of oil droplets in, in the ocean. And this accident happened in a very deep situation under 1,500 meter in death. And, under these conditions, we have a very high pressure of // nearly 80 times the pressure in your tire, in your car. And so the question is what happens if oil exits in such a harsh environment to the ocean? And that's something we wanted to find out. If there's any influence of the pressure on the oil on, on the blow out. And especially also is there any influence of pressure on the micro organisms under these conditions that have to degrade the oil?

David Levin: 00:54:03 How do you start to tease that apart? I mean, can you describe what's happening, what you needed to do in the lab to, to replicate that kind of a blowout?

Michael Schluter: 00:54:17 Yeah. You know, from the mechanical point of view, it's very difficult to take such high pressures under control. So first of all, you need to containment that that you can, can set under such a high pressure. So it's a, it's a containment out of a stainless steel with a wall thickness of nearly seven centimeters. So it's a very big and heavy machine that you need to create such high pressure under seawater. // And this is another problem; You need some, some artificial water that is reproducible for the experiments and you need low temperature like on the deep ocean. So 40 degrees Celsius. So the whole system has to be cooled down and to pressurize to 150 bar. And then of course, it's dark inside. So you need some opportunities to measure the blow out that happens under these conditions.

David Levin: 00:55:41 So you effectively have a heavy tank that you're putting under deep pressure and then releasing oil underneath it. Almost like a little mini blowout.

Michael Schluter: 00:55:52 Exactly. the problem is to catch the blow out under this condition. As I mentioned, you need a very big and heavy machine and this means that the volume of this vessel was only about a 100 liters and you're very instructed, restricted in space. So we used a quite small mini blowout under these conditions.

David Levin: 00:56:37 And you found [inaudible] and I know you found that this did not just spray out from the sea floor, that there was, there were sort of some unexpected behaviors to the oil. Can you describe what you ended up finding from that?

Michael Schluter: 00:56:53 under the real conditions and the deep sea you would have for reservoir that is also filled with, with gas, most of the methane gas. And this means if you have under a very high pressure in the reservoir, the oil and the methane gets together that probably the gas, it's dissolved in the oil. So the oil is almost saturated with this methane gas. Now what happens if the pressure is released on this gas-saturated oil droplet, you get a degassing of the oil. And this might happen quite a fast and this might remind you a little to an Cappucino where you use milk and the milk is foamed up by steam, and to a similar situation we have now for the oil. So the gas-saturated oil, in a sudden pressure release, you get some kind of foaming of oil. And this leads of course to more emotion than just oil. //

David Levin: 00:58:43 And that sort of led to there were layers of oil under the surface. Is that right? That, that not all of it rose up all the way to the surface, it was sort of retained at different levels?

Michael Schluter: 00:58:57 Yeah, that's right. They cost you half off course, a certain occurrence in the ocean and depending on the size of the oil droplets, they are a rising slower or faster. So the bigger droplets are rising faster, the lower droplets, the smaller droplets are rising slower. And from the observations in the Gulf of Mexico, it was clear that the oil droplets are appearing at the surface after a very short time, which means the oil droplets should be quite large. And this has been modeled. But from the new perspective, if we have this kind of emulsion and much smaller droplets due to these degassing effects, then the oil droplets are much smaller and can be carried by the ocean currents much further. And this is something that was very important to know the in more detail. And this is why we worked together very closely with Claire Paris from the university of Miami. Because she was able to to calculate the migration of the oil droplets by the different kinds of currents, taking into account the size of the oil droplets, the particles, and to the density of the oil droplet particles.

//// MURAWSKI ////

David Levin: 01:00:13 So knowing where the oil is going, what's happening to the mixture of the methane and the oil, how it reacts in three dimensional space in the Gulf obviously has a, a big effect on what type of // animal life is affected and where. Steve, one of the big goals of CIMAGE is to make a model // of how a blowout like the Deepwater Horizon would affect species throughout the Gulf. // How did the work that Michael was doing help you understand how to create a model like that?

Steve Murawski: 01:01:05 So in C IMAGE, we've have a number of modeling efforts and as, as Michael described, he's been using the, the first principles that he's derived for deep oil spills from the experiments to feed into models that Dr Claire Paris and her colleagues at the university of Miami had been developing to understand what we call the near-field, which is right around the oil spill coming out of the bottom, to the far field—that is, how it's transported. And one of the critical issues that Michael and his staff have developed and understood is that under the conditions of live oil, which had never been done before—handling oil and methane gas individually has been done but never pressurized to these high levels. It's very dangerous.

Steve Murawski: 01:02:02 What they've discovered is that when the oil spill, like deep water horizon, // gas was coming out of the oil very rapidly. // That process of rapid degassing actually creates this fine aerosol of particles that can remain essentially suspended in the water column and not reach the surface. // So the models that have been fed by these important laboratory experiments are actually super critical in terms of understanding the fate of that oil and the parts of the ecosystem that would actually be impacted.

Steve Murawski: 01:03:11 That being said, there are other classes of models that look at the ecological relationships between things as Isabel pointed out the small fishes that existed 1500 meters migrate to the surface every night. They in turn feed larger, you know, predatory fishes. And so trying to understand the totality of those impacts, particularly as one species relates to another, is the the realm of a different set of models that Dr. Cameron Ainsworth at the University of South Florida has developed to try to understand that. So this is why the center for integrated analysis and *modeling* is what it is. We are trying to actually develop tools that give us a realistic understanding in the event of this next oil spill of what we can anticipate in the short term and in the longterm ecosystem impacts.

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Steve Murawski: 01:06:29 And the interesting thing is it's not just the Gulf of Mexico. The oil industry in the world is moving to much deeper water. So there are three major domains of, of deep oil. Now. One is the Gulf of Mexico, particularly United States, Gulf of Mexico. One is off Brazil and one is off West Africa. And so how would those spills behave in those different circumstances? We're trying not just to understand the Gulf, but this is a larger set of processes and that's has been our challenge.

David Levin: 01:07:34 So how transferrable is what we know now to those other locations?

Steve Murawski: 01:07:54 That's a really good point. And so you have to kind of break this down to what pieces of this are absolutely transferable and which are dependent on the particular circumstances. Right? So the work that Michael and his colleagues have done in the Oracle cork that Danna and her cause had done in the laboratory is basically looking at first what we call first principles. That is what are the underlying laws that describe the behavior of these systems? So those kinds of analyses should be directly transferable. I mean the behavior of oil at 1500 meters is pretty much going to be the behavior of oil at 1500 meters, no matter where you are. And at those depths, the temperature is pretty uniform in the, in the world, four and a half degrees centigrade, et cetera.

What isn't a transferable necessarily is the type of oil that's involved because the oil is coming out of a deep reservoir depending on where it is.

Steve Murawski: 01:08:51 It can be a heavy sour crude, which is a heavy sulfur rich or it could be light, sweet crude like Louisiana. // So we need to adapt to the circumstances of any location in the world as far as that goes. And, and of course the species will be different. And so we need to figure out model species that we can say, Oh, this species is sorta like that one. And we anticipate the behavior of the species in a particular area to behave sort of like the other species.

David Levin: 01:09:29 But given the body of work we have now and the models we have now, do you think that they could be adapted for those sorts of environments?

Steve Murawski: 01:09:37 Certainly. And //, we actually look at spills beyond the deep beyond the Gulf of Mexico. We simulated one off the far Western tip of Cuba, which is technically the North part of Cuba is technically in the Gulf of Mexico. The South part is in the Caribbean. And we saw that oil transported both the Caribbean and through the Florida straits, we also simulated w a spill off West Africa. And so that's // using the same models that we talked about and same oil behavior that we had.

David Levin: 01:10:24 This is sort of a question for all of you now that now that we have done this research, now that we've sort of incrementally increased our knowledge in all these different areas, where do we go from here? What are the big questions that we really want to uncover in the future or need to uncover not just for spills in the Gulf but for spills anywhere? Steve, you can jump in. Sure. [laughs]

Steve Murawski: 01:10:49 So, so obviously this work is never done. This is a really, really complex and complicated thing to, to try to get your arms around. And so we have a number of recommendations of things that, that need follow up following up. A number of these are policy recommendations. That is how should the government oil companies managed their business to be number one, to better prevent deep water blowouts to number two, be prepared to respond to them and to better assess the impacts from them. // Currently the government doesn't require any monitoring of what's being disposed of at the oil site. What's, what the pre-spill conditions are in the water and the biota and the sediments around them. And so if we know that there's potentially going to be a spill there, why not have some monitoring of it so that we can assess this?

Steve Murawski: 01:12:46 That's important. The second thing in the Gulf of Mexico is the Gulf of Mexico is comprised of three countries. Right? we need a much better plan to coordinate among the three countries. The oil policies are different. There is some coordination on the response side, but we should have a better understanding of the Gulf and as an entity and not, you know, I have a relatively good at understanding, say for example, in the Northern and in not in the Southern because we know that these oil spills do not respect territorial boundaries. And so we need a more integrated multinational approach to this. That's certainly important.

Steve Murawski: 01:22:05 I just want to make a final comment and say how proud I am of the coalition of, of groups and people that we put together and, and what they've done together.// many different disciplines working together, many people from many different countries at three different continents. The interaction between professors and researchers and students and graduate students. Lot of different moving pieces to this, but all with the same objective. And that is to try to help make the oil industry and, and oil spill response better, safer, and more targeted to what we need to do. So I just want to reiterate that this is probably one of the best experiences of my professional life and I really appreciate everybody's hard, hard efforts.

David Levin: 01:23:00 Well, — that's a perfect spot to wrap this up. // I was hoping I could try kind of just going around to all of you and asking if very briefly, what the big, just a couple of the big questions you still want to know and that you would want to carry forward from the work you've done on CIMAGE. Let's start with Isabel. Let's start. Oh, very short.

Isabel Romero: 01:23:30 Well, we didn't know what happened to those chemicals in the water column. We know they are there longer than we thought in the pelagic ecosystem. So we want to understand what does their transformation, what is their fate in the longterm and how these affects population dynamics of the pelagic communities over there. And also where is the oil sitting? It’s staying in the sediments, it’s going to stay in the marshes for decades from now. So we still need to fill a lot of gaps related to the fate, the longterm fate of the oil in the Gulf of Mexico.

Speaker 6: 01:24:13 Hmm.

David Levin: 01:24:14 Steve is a fisheries biologist. what's your big question?

Steve Murawski: 01:24:17 Well given the fact that the oil industry is going deeper and deeper. We ha we know so little about the deep ocean in general. We need a deep ocean observatory. We need to understand, I mean when Isabel and// others go to the deep ocean, every time they go, they find new species. Over half of the known species of fishes, for example, exists in a thousand meters and deeper. So we need a crash effort to understand not only the species and the biodiversity of the deep ocean. // but the processes that, that bring them to the surface and back again and how it interacts with so many moving living pieces in, in the environment.

David Levin: 01:25:16 Michael, what are your big questions?

Speaker 7: 01:25:20 Yeah, my big questions that are also transferrable afterwards to process engineering out of the modeling, enter the scale of this process. And so it would be a very, very important to be able to use just the, the, the properties, material properties and the environmental conditions like pressure, like temperature, and to predict how a substance like these oil mixed with gas behaves under this conditions to transfer this to any scale, to transfer this to any place on earth, that that would be very important for us to, to know this in detail and to be able to model this in detail because if we are able to do that and we can also transfer this to any process in industry and of course we'll have lots to come to much more sustainable and renewable processes.

David Levin: 01:26:14 [Inaudible] And Dana, I very briefly, your big question.

Dana Wetzel: 01:26:19 I think for me what I'm interested in is we sort of loosely define that an area in an ecosystem has recovered or it'll take 10 years for it to recover, but I'm not really sure I understand what that means. Recovery. And so my interest is in, in better defining what we may be doing to populations from oil spills. How are the populations adapting? Are they, you know, adapting in ways that you know, might change their interaction with other species, with how they interact with their present ecosystem, you know, sort of what, what have we influenced in terms of their progeny for the future and what does that mean for the Gulf of Mexico or, or wherever the oil spill is that, that we're concerned with.

David Levin: 01:27:25 Well, I want to thank all of you for joining us today. It has been a real pleasure speaking with you today and over the last seven years hard to believe we have you're coming to a close on CIMAGE, but hopefully I know I've not heard the last of any of you and there's going to be some very interesting research to come in the future.

David Levin: 01:28:23 All right, that's a wrap. Thank you again.