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VIA USPS & E-MAIL (wahlstrom-ramler.meghan@epa.gov)

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Re: National Pollutant Discharge Elimination System (NPDES) Permit and Rivers and Harbor Act Section 10 Permit for Kampachi Farms – Velella Epsilon (VE) Offshore Aquaculture Project

Dear Ms. Wahlstrom-Ramler,

Friends of Animals[1] submits these comments in response to EPA's release of its Draft Environmental Assessment for the Velella Epsilon Offshore Aquaculture Project (hereinafter "Draft EA"). The Velella Epsilon (VE) project is the first of its kind in both the Gulf of Mexico and in federal waters. Such novelty should make analyses of unknown effects **more** thorough and comprehensive. Yet, EPA has decided to forgo a detailed Environmental Impact Statement and has failed to take a hard look at the impacts of this unprecedented aquaculture project in its Draft EA.

Our oceans are currently being depleted worldwide faster than they can recover, resulting in an overfishing crisis.[2] But Friends of Animals believes (and Congress demonstrated through multiple, overlapping pieces of legislation) that the protection of our natural environment and its wildlife is more important than the human demand for fish, fur, or

[1] Friends of Animals is a non-profit international advocacy organization incorporated in the state of New York since 1957. Friends of Animals has nearly 200,000 members worldwide. Friends of Animals and its members seek to free animals from cruelty and exploitation around the world, and to promote a respectful view of non-human, free-living and domestic animals.

[2] Jason Link & Reg Watson, *Global ecosystem overfishing: Clear delineation within real limits to production*, 5 SCI. ADV. 6 (2019).

feathers. EPA has statutory duties under multiple environmental laws. Obeyance to these laws must take precedence over commercial interests in harvesting fish.

EPA has failed to adhere to the National Environmental Policy Act by giving short shrift to the VE project in the form of a Draft EA. Friends of Animals asks EPA to draft an Environmental Impact Statement and further look at potential damaging consequences of the proposed VE project.

In addition, approving the NPDES permit would violate the Endangered Species Act, the Magnuson-Stevens Fishery Conservation and Management Act, and the Clean Water Act.

LEGAL BACKGROUND

A. National Environmental Policy Act

Congress enacted the National Environmental Policy Act (NEPA) in 1970 to ensure the federal government considers the environment impact of its activities before acting. NEPA is "often called the 'Magna Carta' of Federal environmental laws."[3]

NEPA requires an acting agency to prepare a detailed environmental impact statement (EIS) for federal actions that significantly affect the quality of the human environment. The EIS should include "(i) the environmental impact of the proposed action, (ii) any adverse environmental effects which cannot be avoided should the proposal be implemented, [and] (iii) alternatives to the proposed action."[4]

Whether an agency action meets the "significant" standard to require preparation of an EIS requires "considerations of both context and intensity."[5] The context of the action includes factors such as "society as a whole (human, national), the affected region, the affected interests, and the locality."[6] The intensity of an action refers to the "severity of the impact" and requires consideration of several factors, including the degree to which the effects are highly uncertain or involve unique or unknown risks; the precedential effect of the action; whether the action is related to other actions with cumulative significant impacts; and the degree to which the action may adversely affect an endangered or threatened species. [7]

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[3] Council on Environmental Quality, *Welcome*, NEPA.GOV, https://ceq.doe.gov/ (last visited Jan 15, 2020).
[4] 42 U.S.C. § 4332(2)(C).
[5] 40 C.F.R. § 1508.27.
[6] 40 C.F.R. § 1508.27(a).
[7] 40 C.F.R. § 1508.27(b).

B. Endangered Species Act

The Endangered Species Act (ESA) was passed in 1973 to prevent extinction of various organisms and protect the ecosystems which sustain them.[8] The plain intent of Congress was "to halt and reverse the trend towards species extinction, **whatever the cost**."[9]

The ESA requires federal agencies to ensure their actions do not threaten the existence of listed species or their habitats.[10] It also prohibits a person from taking a listed animal without a permit. Taking is defined as "harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct."[11]

C. Clean Water Act

In 1972, Congress significantly amended the Federal Water Pollution Control Act of 1948. The law became commonly known as the Clean Water Act (CWA).[12] The law applies to all waters of the United States, which include "relatively permanent, standing or continuously flowing bodies of water 'forming geographic features' that are described in ordinary parlance as 'streams,' 'oceans, rivers, and lakes.'"[13]

The CWA makes it illegal to discharge any pollutant into navigable waters, unless a permit is obtained. Under the CWA, EPA manages the National Pollutant Discharge Elimination System (NPDES), which allows issuance of a permit to lawfully discharge pollutants.[14] The issuance of such a permit is at the crux of the Proposed Action.

NPDES permits "**will contain limits** on what you can discharge, monitoring and reporting requirements, and other provisions to ensure that the discharge does not hurt water quality or people's health."[15]

In addition, the CWA prohibits unreasonable degradation of the marine environment. Sections 402 and 403 of the CWA require a NPDES permit for a discharge into the

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[8] Environmental Protection Agency, *Summary of the Endangered Species Act*, https://www.epa.gov/laws-regulations/summary-endangered-species-act (last updated Jul. 5, 2019).
[9] *Tennessee Valley Authority v. Hill*, 437 U.S. 153 (1978) (emphasis added).
[10] Environmental Protection Agency, *Summary of the Endangered Species Act*, https://www.epa.gov/laws-regulations/summary-endangered-species-act (last updated Jul. 5, 2019).
[11] 16 U.S.C. 1532(19).
[12] Environmental Protection Agency, *Summary of the Clean Water Act*, https://www.epa.gov/laws-regulations/summary-clean-water-act (last updated Mar. 11, 2019).
[13] *Rapanos v. United States*, 547 U.S. 715, 739 (2006).
[14] Environmental Protection Agency, *Summary of the Clean Water Act*, https://www.epa.gov/laws-regulations/summary-clean-water-act (last updated Mar. 11, 2019).
[15] Environmental Protection Agency, *NPDES Permit Basics*, https://www.epa.gov/npdes/npdes-permit-basics (last updated July 12, 2019) (emphasis added).

territorial seas (baseline to 12 nautical miles, or farther offshore in the contiguous zone or the ocean). Before issuing a NPDES permit, discharges must be evaluated against EPA's published criteria for a determination of unreasonable degradation.

The NPDES implementing regulations at 40 C.F.R. § 125.121(e) define unreasonable degradation of the marine environment as the following: (1) Significant adverse changes in ecosystem diversity, productivity, and stability of the biological community within the area of discharge and surrounding biological communities; (2) threat to human health through direct exposure to pollutants or through consumption of exposed aquatic organisms; or (3) loss of aesthetic, recreational, scientific or economic values, which is unreasonable in relation to the benefit derived from the discharge.

D. Magnuson-Stevens Fishery Conservation and Management Act

Congress passed the Magnuson–Stevens Fishery Conservation and Management Act (MSA) in 1976. MSA gives the National Marine Fisheries Service (NMFS) authority to regulate the fisheries of the United States, including all "catching, taking, or harvesting of fish."[16]

In 2016, NMFS promulgated regulations authorizing a new plan to allow permits for aquaculture facilities in the Gulf of Mexico.[17] In 2018, the District Court of Eastern Louisiana ruled that aquaculture does not qualify as "fishing" under the MSA.[18] The Court stated that there was a "clear indication that Congress did not intend for the MSA to grant NMFS the authority to regulate aquaculture."[19]

FACTUAL BACKGROUND

Kampachi Farms, LLC (hereinafter "Kampachi Farms") applied for an NPDES permit to operate the Velella Epsilon facility or VE project. The VE project would consist of a mesh net pen enclosure, housing approximately 20,000 different members of the species *Seriola rivoliana.*

The VE Project would be the first of its kind in federal waters in the Gulf of Mexico. The VE Project would discharge several types of effluents into the Gulf of Mexico approximately forty-five miles southwest of Sarasota, Florida, and would thus require an NPDES permit under the CWA to operate.

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[16] 16 U.S.C. §1802(16)(a).
[17] NOAA Fisheries, *NOAA expands opportunities for U.S. aquaculture* (Jan. 11, 2016), https://www.fisheries.noaa.gov/media-release/noaa-expands-opportunities-us-aquaculture.
[18] *Gulf Fishermens Ass'n v. Nat'l Marine Fisheries Serv.*, 341 F. Supp. 3d 632, 638 (E.D. La. 2018).
[19] *Id.* at 640.

DISCUSSION

A. EPA should consider its obligations under the National Environmental Policy Act.

1. The Proposed Action meets the level of significance that triggers preparation of EIS.

The proposed action in the approval of the NPDES permit for Velella Epsilon (VE) could result in major environmental impacts and warrants preparation of an EIS. Simply put, the Draft EA is inadequate and ineffective. EPA tellingly refers to this legislatively-mandated Environmental Assessment as "voluntary."[20] While the VE project does not reach sufficient minimum harvest weight[21] to qualify as a Concentrated Animal Aquatic Production (CAAP) under the CWA, the intensity of the proposed action indicates that the action necessitates further review via an EIS.

a. VE involves unique or unknown risks - 1507.28(b)(5)

The effects of the VE project involve unique and unknown risks. If allowed to move forward, VE would be the first offshore aquaculture in federal waters. It would also be the first offshore aquaculture in the Gulf of Mexico, an area the EPA has deemed "critical" to improve water quality.[22] For example, the impacts involve unique and unknown risks to a variety of threatened and endangered animals, unique and unknown risks involving nutrient discharge, and unique and unknown risks from pharmaceutical discharge (*see* analysis below).

b. This action will establish a precedent - 1507.28(b)(6)

The EPA states that the Draft EA will "help streamline the NEPA process for any future aquaculture permitting actions."[23] By making the Draft EA a guide to be considered in subsequent similar actions, EPA has explicitly made this a precedent-setting action.

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[20] Environmental Protection Agency, *Draft Environmental Assessment, NPDES Permit and Rivers and Harbors Act Section 10 Permit for Kampachi Farms – Velella Epsilon Project* 2 (2019).
[21] CAAP facilities must produce 100,000 pounds of aquatic animals annually to fall under the national standards of performance in 40 CFR Part 451. VE will produce 88,000 pounds annually. *See* Draft EA at 11.
[22] Environmental Protection Agency, *Why is Improving Water Quality in the Gulf of Mexico so Critical?*, https://www.epa.gov/gulfofmexico/why-improving-water-quality-gulf-mexico-so-critical (last updated May 30, 2017).
[23] Environmental Protection Agency, *Draft Environmental Assessment, NPDES Permit and Rivers and Harbors Act Section 10 Permit for Kampachi Farms – Velella Epsilon Project* 2 (2019).

The potential for precedent might be more nebulous if future operations were unforeseeable. However, future operations that could result from a successful demonstration of the VE Project are almost certain.

In fact, the EPA itself states that they "believe[] it is reasonably foreseeable that the growth of the aquaculture in the Gulf **will occur** at future point."[24] The reasonableness of these future operations occurring only emphasizes the precedential nature of the Proposed Action.

c. EPA failed to fully analyze the cumulative impacts of the Proposed VE project, along with past and present pollution, climate change, and potential future aquaculture facilities - 1507.28(b)(7)

The Council on Environmental Quality (CEQ) defines cumulative effects as "the impact on the environment which results from the incremental impact of the action when added to other past, present, and **reasonably foreseeable future actions** regardless of what agency (Federal or non-Federal) or person undertakes such other actions."[25]

In the Draft EA, EPA only takes a cursory look at the cumulative impacts of one currently-existing facility in the Gulf of Mexico: Manna Fish Farms. If the VE project was the only foreseeable aquaculture facility being added in the Gulf, this scope of cumulative effects might be appropriate. However, as discussed above, it is reasonably foreseeable that future facilities **will** be built in the Gulf.

EPA drives this point home when they refer to the VE project as a "pilot-scale" facility, i.e. a smaller system that will provide knowledge to help build full-scale production systems. This represents a second set of cumulative impacts from future actions that have gone ignored: effects from larger facilities, as opposed to simply additional facilities that will be the same size as the VE Project.

EPA ignores the cumulative impacts from additional, larger future aquaculture facilities – whose permit processes EPA will "help streamline" – when discussing the impacts of the Proposed Action. This lack of foresight directly contravenes EPA's duties under NEPA, and further raises the intensity of the Proposed Action.

EPA also fails to consider the cumulative impacts of increasing pollution, acidification, and climate change. EPA may not simply list past and current activities impacting the area. They

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[24] Environmental Protection Agency, *Draft Environmental Assessment, NPDES Permit and Rivers and Harbors Act Section 10 Permit for Kampachi Farms – Velella Epsilon Project* 49 (2019).
[25] 40 C.F.R. Section 1508.7 (emphasis added).

must also consider how all these factors interact with one another, and how the VE project could exacerbate the problems already facing the area. As mentioned above, the EPA has deemed the Gulf of Mexico "critical" to improve water quality and any additional pollution could have significant impacts to the area.

In addition to ESA-listed species, there are numerous species designated by the State of Florida as threatened or as a species of concern that the VE project will likely impact, such as the American oystercatcher, black skimmer, Florida sandhill crane, least tern, little blue heron, reddish egret, and the West Indian manatee. EPA failed to take a hard look at the cumulative impacts to these species.

EPA must consider the cumulative impacts of pollution, ocean acidification, and climate change of the VE project on threatened and endangered species, and species of special concern.

d. This Action May Adversely Affect Endangered or Threatened Species - 1507.28(b)(9)

Lastly, EPA acknowledges that the known behavior of several ESA-listed species takes them near the chosen site for the Proposed Action. These include, *inter alia*, species of fish (smalltooth sawfish, giant manta ray, and oceanic whitetip shark), marine mammals (manatees, sperm whales, Bryde's whale, Atlantic spotted dolphin, and common bottlenose dolphin), sea turtles (green sea turtle, hawksbill, Kemp's ridley, leatherback, and loggerhead), and birds (piping plover and red knot).

The Draft EA's most glaring weakness vis-à-vis ESA-listed species is the complete omission of the submersible fish pen's ability to act as a Fish Aggregating Device (FAD). FADs can be man-made or natural, but in either case rely on fishes' natural fascination with floating objects. Fishers have known about and exploited this behavior "for centuries."[26] There is no excuse for this phenomenon to be absent in the Draft EA. In fact, NOAA stated it best – in a reported cited in the Draft EA – when it admitted, "[l]ittle research has documented the extent to which marine predators target wild fish around farms, but **this would be useful** for understanding ecological interactions between farming and marine life."[27] EPA has not conducted or produced any additional research to glean this useful information. Nor have they disclosed why they could not conduct additional research on this important impact.

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[26] Steve Beverly et al., *Anchored fish aggregating devices for artisanal fisheries in South and Southeast Asia: benefits and risks*, THE FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, http://www.fao.org/3/a-i3087e.pdf (2012).

[27] Price, C.S. and J.A. Morris, Jr., *Marine Cage Culture and the Environment: Twenty-first Century Science Informing a Sustainable Industry*. NOAA Technical Memorandum NOS NCCOS iv (2013) (emphasis added).

FADs have the potential to harass or harm protected species in multiple ways. First, FADs attract fishers who catch the fish attracted to the net pen. The fishing industry has taken advantage of this phenomenon for generations. Indeed, Kampachi Farms touts this ability on their website, claiming that their Hawaii net pens were "highly popular with the local Kona fishing community."[28] Kampachi Farms co-founder Neil Sims stated that at least three types of fishers (local recreational, charter boat, **and** commercial fishers) were catching fish "hand over fist."[29]

The net pen's ability to act as a FAD also attracts sightseers. Kampachi Farms again attempts to frame this in a positive light, stating that it "proved to be exciting dive sites for snorkel tours."[30] Sims reiterates this point, stating, "[l]ocal diver and snorkel tour operators brought their passengers out to dive on the offshore pen sites."[31]

i. Fish

In dismissing the possibility of adverse effects on fish, EPA ignores the certainty that the net pen will act as a FAD. This makes it more likely that the facility will attract predators. The EPA states that the whitetip shark can be found in waters as shallow as 37 meters. The VE project site is on the 40-meter isobath. EPA also states that the oceanic whitetip shark is an "opportunistic feeder." EPA did not address the FAD potential of the net pen when it comes to assessing adverse impacts on this species. It simply states that the shark is "not likely" to occur near the project.

Another threat to the oceanic whitetip shark is bycatch. Bycatch tends to be worse when fishers use purse seine, which is common in commercial fishing. At a minimum, fishers should be taught proper methods for handling and releasing bycatch. Once again, EPA does not mention this threat in the Draft EA, let alone proper methods to avoid or mitigate this potential disaster.

The EPA invokes the hollow doctrine of "not likely" in its assessment of adverse impacts on the giant manta ray. After admitting that the giant manta ray could encounter the facility,

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[28] Kampachi Farms, Inc., *Velella Epsilon: Pioneering Offshore Aquaculture in the Gulf of Mexico* (Nov. 2, 2017), http://www.kampachifarm.com/blog/tag/Sustainability.
[29] Dale White, *U.S. Environmental Protection Agency accepting pro and con public comments about the concept*, HERALD TRIBUNE (Sept. 27, 2019, 9:36 AM), https://www.heraldtribune.com/news/20190926/floating-fish-farm-in-gulf-proposed-southwest-of-sarasota.
[30] Kampachi Farms, Inc., *Velella Epsilon: Pioneering Offshore Aquaculture in the Gulf of Mexico* (Nov. 2, 2017), http://www.kampachifarm.com/blog/tag/Sustainability.
[31] Dale White, *U.S. Environmental Protection Agency accepting pro and con public comments about the concept*, HERALD TRIBUNE (Sept. 27, 2019, 9:36 AM), https://www.heraldtribune.com/news/20190926/floating-fish-farm-in-gulf-proposed-southwest-of-sarasota.

EPA states only that "long term impacts are not expected." EPA's analysis fails to fully consider and disclose the potential immediate and direct impacts of the VE project on the giant manta ray. Moreover, the EA limits its consideration of impacts to the first eighteen months (the permit is valid for five years, discussed below) and ignores the cumulative impacts of additional, larger aquaculture facilities spread throughout the gulf.

EPA also fails to consider the impact of the VE project on the fish that will be confined in the net. Captive aquaculture systems negatively impact captive fish causing chronic stress, overall decrease in health status and immune responses.[32] In particular, the Draft EA needs to consider and disclose the impact of the VE Project on the fish in the net pen. Many of these fish are transferred from facilities on land, which also exacerbates the stress and health impacts of the VE project. In addition, noise from service vessels as well as from increased boat and recreational activity all impact the fish and need to be considered. Finally, fish in such a confined area are more susceptible to disease and parasites. Due to the open nature of the pen, this means that **all** nearby fish, including ESA-listed species, have the possibility to contract any disease or parasite in the pen. For reasons discussed in Section (C)(2) below, fish escape represents another threat by which parasites or disease can be spread to other fish in the vicinity.

ii. Marine Mammals

EPA states that dolphins are "attracted to concentrated food sources." A net pen full of fish qualifies as such a source.[33] EPA also acknowledges that vessel strikes represent a serious risk for dolphins.[34] Yet, EPA failed to connect the dots with the net pen acting as a FAD. FADs attract dolphins just like they attract fish.[35]

As discussed above, the FAD will bring both various fishers and various tourism-related activities right up to the VE project's vicinity. These additional vessels have the potential to strike dolphins and were not considered when EPA discussed adverse effects on the protected dolphin species. EPA's suggestion that vessel captains slow to a no wake does not suffice, as it relies on the behavior of an unconnected, disparate group of VE employees, fishers, and tourists.

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[32] Craig Radford and Matthew Slater, *Soundscapes in Aquaculture Systems*, 11 AQUACULTURE ENVIRONMENT INTERACTIONS 53, 53-62 (2019).
[33] Environmental Protection Agency, *Draft Environmental Assessment, NPDES Permit and Rivers and Harbors Act Section 10 Permit for Kampachi Farms – Velella Epsilon Project* 38 (2019).
[34] *Id.*
[35] John R. Hunter, et al., *Association of Fishes with Flotsam in the Offshore Waters of Central America*, 66 FISHERY BULLETIN 22 (1966).

Likewise, gawking tourists will raise the chance that dolphins become habituated to anthropogenic sources of food. As EPA admits, dolphins who grow familiar with human contact have increased "risk for boat strike or gear entanglement."[36]

Moreover, noise from the facility, from vessels going to the facility, as well as increased commercial and recreational activity is likely to negatively impact marine mammals. EPA failed to consider how the VE project will impact the acoustic habitat and the marine life in the Gulf of Mexico. Notably, EPA recognized that disturbance and ocean noise may impact marine mammals but failed to adequately consider **how** it would impact them. It failed to disclose the range and intensity of sounds that are likely to come with the VE project. This information is critical because noise disturbance can significantly impact threatened and endangered animals as well as species of special concern. Open systems such as the VE project have been the loudest among aquaculture production systems examined and the majority of ambient noise recorded in net pens falls within the 100 to 500 Hz range.[37] This is within the range that could impact marine mammals. For example, fin whales and baleen whales are impacted by low frequency noises.[38] Baleen whales have very specialized skulls that can capture the energy of low frequencies and direct it toward their ear bones to hear. If the sounds waves are longer than the whale's body, they can vibrate its skull in a process known as bone conduction.[39] Simulation studies also found that a fin whale's bone conduction mechanism is 4x more sensitive to low-frequency sounds than the pressure mechanism that goes through the tympanoperiotic complex (TPC-which holds the whale's ear bones on its skull).[40]

iii. Sea Turtles

The Draft EA states that sea turtles are attracted to aquaculture facilities "as potential sources of food, shelter, and rest."[41] All five of the ESA-listed sea turtles face a dual threat of baited hooks and vessel-based behavior disturbance. Sadly, the ability of the net pen to act as a FAD exacerbates both possibilities.

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[36] Environmental Protection Agency, *Draft Environmental Assessment, NPDES Permit and Rivers and Harbors Act Section 10 Permit for Kampachi Farms – Velella Epsilon Project* 28 (2019).
[37] Craig Radford and Matthew Slater, *Soundscapes in Aquaculture Systems*, 11 AQUACULTURE ENVIRONMENT INTERACTIONS 53 (2019).
[38] Laura Geggle, *All About the Bass: How Baleen Whales Hear Very Low Frequencies,* LIVE SCIENCE, (January 29, 2015); available from: https://www.livescience.com/49636-baleen-whales-skull-acoustics.html
[39] *Id.*
[40] *Id.*
[41] Environmental Protection Agency, *Draft Environmental Assessment, NPDES Permit and Rivers and Harbors Act Section 10 Permit for Kampachi Farms – Velella Epsilon Project* 40 (2019).

Bringing eager fishers to the area will almost certainly increase the number of hook-and-line fishers in the area, as similar devices did in Hawaii. This is a grave and direct threat to individual sea turtles. As the EPA states, sea turtles are "known to bite baited hooks and can be hooked incidentally."[42] Bringing more fishers to the net pen will significantly raise the likelihood that sea turtles will be caught. The Draft EA omits the higher chance for incidental hooking entirely.

Vessels in the area also pose a risk of disturbance by stress to the turtles.[43] For the sea turtle, it makes no difference whether this vessel contains fisher or tourist. Thus, sea turtles will have a much higher chances of disturbances with both fisher vessels and tourist vessels crowding around the VE project. The Draft EA refers to the "limited trips to the site," as if VE staff would be the only vessels near the net pen. For reasons discussed above, this is not the case. Again, the Draft EA does not mention the additional FAD-related vessel traffic.

iv. Birds

Of the fourteen ESA-listed birds in the eastern Gulf of Mexico, the Draft EA singles out only two species. The Draft EA recognizes two important points: (1) that migratory birds and seabirds will be attracted to the site due to the presence of fish, and (2) that these birds will be threatened by entanglement and diving to access fish underwater. Even if the piping plover and red knot are the only federally listed birds to ever encounter the VE project, EPA must fully consider the impact to these birds. In addition, Florida has itself listed several "species of special concern" that occupy the southwestern Florida coast.

One must look no further than EPA's suggested course of action to see that protection is insufficient. Shockingly, the Draft EA suggests that VE staff suspend all activity if a protected species "comes within 100 m of the activity."[44] Only a course of no action would be more inadequate than this method. This suggestion once again completely ignores the fact that, as a FAD, the VE project will also attract boatloads of tourists and various types of fishers. All these people would need instruction to suspend all **their** surface activities should an ESA-listed bird come within one hundred meters of their activity.

Training people to recognize protected birds presents additional problems with this plan. Even if all staff, tourists, and fishers know to suspend activity if they see a protected bird, it is unlikely that they will know of and be able to identify protected birds. Red knots and

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[42] Environmental Protection Agency, *Draft Environmental Assessment, NPDES Permit and Rivers and Harbors Act Section 10 Permit for Kampachi Farms – Velella Epsilon Project* 40 (2019).
[43] *Id.*
[44] *Id*. at 42.

piping plovers do not carry large signs, or even display highly unique visual features. Even if one knew what to look for, identifying such birds might not be easy even for a seasoned birder equipped with binoculars on stable terrain. To suggest that staff, tourists, and fishers, occupied with their own activity on the open ocean, can and will identify protected birds at one hundred meters with the naked eye defies logic.

While it is unclear whether suspension of surface activities will even reduce the threat of entanglement, this suggested course of action ignores the times when **no** staff will be present. Birds will be attracted to the site regardless of the human presence. Any plan that relies on the VE staff will not be implemented when there is not a staff member present. EPA does not quantify how often staff will be present; they only repeat the phrase "given the limited trips to the facility."[45] The EPA must reassess the VE project's potential to adversely affect ESA-listed bird species.

2. EPA should thoroughly analyze the impacts of the proposed action.

As discussed above, the proposed action warrants an EIS. However, regardless of whether EPA prepares an EA or an EIS it must take "a hard look" at the impacts of an action prior to making an irreversible and irretrievable commitment of resources. NEPA requires EPA to adequately evaluate all potential environmental impacts of proposed actions. To meet this obligation, EPA must identify and disclose to the public all foreseeable impacts of the proposed action, including direct, indirect, and cumulative impacts.

Additional NEPA analysis is needed on the following: (1) the timeframe of the permit and project; (2) the potential for VE to contribute to an ongoing red tide crisis on the Southwest coast of Florida; (3) the amount and type of pharmaceuticals; and (4) the effects of increased pollution in the Gulf of Mexico on marine life and humans.

These impacts deserve a full study by independent scientists and should be disclosed to the public for additional comments. Aquaculture in the open ocean represents a sufficiently unknown threat EPA should require additional scientific data before approving any permit.

3. EPA should revisit and clarify the timeframe of the Draft EA.

The Draft EA is confusing and misleading as to its scope. For much of the Draft EA, the VE project is described as having a deployment period of eighteen months."[46] Yet, the Draft EA

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[45] Environmental Protection Agency, *Draft Environmental Assessment, NPDES Permit and Rivers and Harbors Act Section 10 Permit for Kampachi Farms – Velella Epsilon Project* 39, 40, 54, (2019); *see also* Draft Biological Evaluation 21, 22, 23 (2019).

[46] Environmental Protection Agency, *Draft Environmental Assessment, NPDES Permit and Rivers and Harbors Act Section 10 Permit for Kampachi Farms – Velella Epsilon Project* 9, 36, 39, 40, 41, 53, 54 (2019).

also admits that the NPDES permit is valid for five years.[47] Kampachi Farms will have the legal authority to continue using the net pen system for five years. This means that the VE project could be duplicated up to two more times within the five-year span. There is no indication that Kampachi Farms sees this as a one-off experiment. To the contrary, Kampachi Farms has described this as "pioneering" and a "demonstration." Co-founder Neil Sims stated that he wants to "engage [local communities] in the discussions about how this industry might move forward."[48]

Surprisingly, the Draft EA states point blank that EPA believes it is "reasonably foreseeable" that the aquaculture industry will experience growth in the future. Yet, the Draft EA mentions nothing about the cumulative impacts from any such growth. By narrowly confining the effects of the VE project to eighteen months, EPA has failed to take an accurate assessment of the full, five-year scope of the Proposed Action. It has also ignored the potential precedent this could set for further projects and the cumulative impacts of the aquaculture industry in the Gulf of Mexico.

Additionally, EPA should not allow the VE project to deploy additional cycles of the facility until a review with clear evidence of no impacts has occurred. EPA should not allow perfunctory findings of NLAA (not likely to adversely affect) to create precedent with additional deployments or new facilities.

4. EPA should take a hard look at the possibility of the VE project to contribute to catastrophic harmful algal blooms caused by *Karenia brevis*.

a. The VE project is being thrown into an area already decimated by HABs.

The Draft EA briefly discusses the yearlong harmful algal blooms (HABs) caused by the species *Karenia brevis*. These HABs caused Florida to suffer losses of almost $150 million from fish deaths, marine animal deaths, and the resulting loss of tourism. The 2017-2018 HAB hit hardest in Southwest Florida, or as the Draft EA puts it, "from Pinellas to northern Collier counties."[49] In October 2019, another bloom occurred in the same area, killing fish, eels, dolphins, and even protected loggerhead sea turtles.[50] As recent as January 10, 2020,

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[47] *Id.* at 3, 7, 48, 52.
[48] Kampachi Farms, Inc., *Velella Epsilon: Pioneering Offshore Aquaculture in the Gulf of Mexico* (Nov. 2, 2017), http://www.kampachifarm.com/blog/tag/Sustainability.
[49] Environmental Protection Agency, *Draft Environmental Assessment, NPDES Permit and Rivers and Harbors Act Section 10 Permit for Kampachi Farms – Velella Epsilon Project* 15 (2019).
[50] Doug Stanglin, *Red tide, the toxic algae bloom that kills wildlife, returns to southwest Florida*, USA TODAY (Nov. 13, 2019, 12:20 PM), https://www.usatoday.com/story/news/nation/2019/11/13/red-tide-florida-toxic-algae-bloom-returns-southwest-beaches/4177117002/.

K. brevis was found in "low" concentrations of 10,000 – 100,000 cells/liter (level 3, with level 5 being the worst) offshore of Collier county.[51] Shellfish are no longer safe for human consumption at 5,000 cells/liter.[52]

The VE project, while offshore, sits roughly equidistant from Pinellas county and Collier county. That is, the VE project site lies squarely in the middle of the most affected areas in Florida.

Furthermore, this area is of special concern to the EPA itself. On the EPA's website discussing the **entirety** of the Gulf of Mexico, EPA singles out just two specific areas of concern. One of those areas is the North Water Tower Project (NWTP) in North Sarasota, FL.[53] Not only is Sarasota county roughly in the middle of the Pinellas-Collier corridor, it is also the mainland reference point for the VE project, commonly described as forty-five miles southwest of Sarasota. It would be hard to come up with a less desirable location for a new industry to apply for discharge permits.

b. Scientists has conclusively shown that excess nutrients such as nitrogen and phosphorous contribute to red tide HABs.

While excess nitrogen and phosphorous sources (stormwater runoff, fertilizer runoff, faulty wastewater systems, etc.) may not cause the formation of HABs, scientists believe those excess nutrients worsen the severity and duration of HABs.[54]

K. brevis blooms originate 10-40 miles offshore in the Gulf of Mexico. They **require** nitrogen and phosphorous to grow and survive.[55] It may be "impossible to link a red tide bloom to one particular source of nitrogen or phosphorus," but it is undeniable that these two elements contribute to and amplify HABs.[56]

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[51] Florida Fish and Wildlife Conservation Commission, *Red Tide Current Status*, https://myfwc.com/research/redtide/statewide/?redirect=redtidestatus (last updated Jan. 10, 2020).
[52] Sea Grant Florida, *Understanding Florida's Red Tide* (Dec. 12, 2018), https://www.flseagrant.org/news/2018/12/understanding-floridas-red-tide.
[53] Environmental Protection Agency, *Why is Improving Water Quality in the Gulf of Mexico so Critical?*, https://www.epa.gov/gulfofmexico/why-improving-water-quality-gulf-mexico-so-critical (last updated May 14, 2020).
[54] Sea Grant Florida, *Understanding Florida's Red Tide* (Dec. 12, 2018), https://www.flseagrant.org/news/2018/12/understanding-floridas-red-tide.
[55] *Id*.
[56] *Id*.

c. The primary pollutants of aquatic net pens are nitrogen and phosphorous.

With aquatic net pens, most of the nitrogen pollution comes from the organic matter in waste food and feces. About seventy-eight percent of nitrogen consumed by the fish is released to the environment.[57] As with nitrogen, most phosphorous discharge comes from waste food and feces.[58] An average of seventy-one percent of phosphorous is released to the environment.[59]

Given the high likelihood that these nutrients will be discharged into the open ocean, EPA should require numeric effluent limitations, along with downstream water monitoring. Yet, the NPDES permit lacks both. EPA relies heavily on Best Management Practices (BMPs) to control the discharge of pollutants. Not only are BMPs difficult to monitor, they are wholly ineffective for a brand-new industry that does not have a clear set of practices to follow. EPA leaves much of these practices to the discretion of Kampachi Farms.

The Draft Biological Evaluation (BE) and Draft Ocean Discharge Criteria Evaluation (ODCE) mention several times how VE's discharge will include a "comprehensive environmental monitoring plan."[60] However, their plan does not sufficiently monitor down-stream levels. The only locations involved in this "comprehensive" monitoring plan are (1) a baseline, up-stream location, and (2) "near the cage."[61] So sure is EPA that **all** pollutants, nutrients, and pharmaceuticals will be harmlessly dispersed that they do not bother monitoring **any** locations other than an up-stream baseline and the immediate vicinity of the net pen. This ignores the possibility for currents and winds to act as an effluent conveyor belt, as is known to occur with red tides that start away from land.

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[57] Environmental Protection Agency, *Draft Environmental Assessment, NPDES Permit and Rivers and Harbors Act Section 10 Permit for Kampachi Farms – Velella Epsilon Project*, Draft ODC Evaluation 35 (2019).
[58] *Id.* at 36.
[59] Islam, M., *Nitrogen and phosphorus budget in coastal and marine cage aquaculture and impacts of effluent loading on ecosystem: review and analysis towards model development*, 50 MARINE POLLUTION BULLETIN 48-61 (2005).
[60] Environmental Protection Agency, *Draft Environmental Assessment, NPDES Permit and Rivers and Harbors Act Section 10 Permit for Kampachi Farms – Velella Epsilon Project*, Draft ODC Evaluation 46 (2019).
[61] Environmental Protection Agency, *Draft Environmental Assessment, NPDES Permit and Rivers and Harbors Act Section 10 Permit for Kampachi Farms – Velella Epsilon Project*, Draft ODC Evaluation 48 (2019).

d. Ocean currents are predominantly southeast and northeast, which in both cases will send streams of discharge to Florida's HAB-ravaged west coast.

Red tides travel inshore in wind and water currents.[62] In Appendix A, the Draft EA mentions current velocity measurements from the closest NOAA buoy anchored to the site of the Proposed Action.[63] At all three depth measurements (four meters, twenty-two meters, and forty-four meters), the buoy showed a significant current in the southeast direction.[64]

A separate EPA study of ocean currents at the Tampa Ocean Dredged Material Site also showed that the current flow off the west Florida coast was "predominantly in the south-southwest direction."[65] However, this same report showed that north-northeast currents dominated in the spring months.[66]

The Draft EA mentions the effects of local currents several times. Typically, the Draft EA discusses currents to suggest a reason why the pollution (of nutrients, pharmaceuticals, or other waste) will not present much of a problem: currents will safely disperse the pollutants elsewhere.[67] This begs the question: to where exactly are these pollutants being dispersed? Dispersing in a northeast direction will point towards Sarasota and the North Water Tower Project (recall that the site is described as "southwest" of Sarasota). Dispersing in a southeast direction will point to Fort Meyers and Collier County: some of the areas most affected by *K. brevis* in the last two years.

These current directions, combined with the fact that *K. brevis* populations already naturally exist off Florida's west coast, present a dangerous mix of possibilities. *K. brevis* has the potential to start feeding – and blooming – from nutrients much further out, making its eventual landfall even more dangerous. EPA did not discuss this possibility in the Draft EA, and instead heavily relied on dispersion to discount these potential impacts.

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[62] Mote Marine Laboratory and Aquarium, *Florida Red Tide*, https://mote.org/pages/florida-red-tide1 (last visited Jan. 14, 2020).
[63] Environmental Protection Agency, *Draft Environmental Assessment, NPDES Permit and Rivers and Harbors Act Section 10 Permit for Kampachi Farms – Velella Epsilon Project*, Appendix A, Baseline Environmental Survey Report 25 (2019).
[64] *Id.*
[65] Environmental Protection Agency, *Draft Environmental Assessment, NPDES Permit and Rivers and Harbors Act Section 10 Permit for Kampachi Farms – Velella Epsilon Project*, Appendix C, Draft Ocean Discharge Criteria Evaluation 10 (2019).
[66] *Id.*
[67] Environmental Protection Agency, *Draft Environmental Assessment, NPDES Permit and Rivers and Harbors Act Section 10 Permit for Kampachi Farms – Velella Epsilon Project*, 33, 52, 53, 54 (2019).

Dispersing sediment to the bottom of the ocean floor does not help either. The upwelling of dense, nutrient-rich water to the ocean surface remains a "necessary condition for *K. brevis* along the west Florida coastline."[68]

e. EPA should mandate phytoplankton monitoring

To help combat the new threats associated with the Proposed Action, EPA should enhance the standard level of monitoring with new monitoring methods. At a minimum, this should include monitoring for nearby phytoplankton. These already-existing phytoplankton could easily be fueled by nutrient discharge. By monitoring for phytoplankton (especially *K. brevis*), EPA can help prevent the facility from exacerbating HABs via inevitable nutrient discharge.

5. EPA should provide guidelines and additional monitoring for the use of pharmaceuticals.

Using the same dispersion analysis, EPA discounts the possibility of **any** adverse effect from the use of pharmaceuticals. The Draft EA states that Kampachi Farms has indicated that pharmaceuticals "will likely not be used."[69] This represents an ideal situation for a first-of-its-kind facility and ignores a staple of aquaculture: antibiotics. The very next sentence of the Draft EA indicates that Kampachi Farms will have free reign to dose the water with as much therapeutics, antibiotics, drugs, and other treatments as they see fit. The EPA only requires that these be reported after the fact.[70] EPA's subsequent approval or disapproval will do nothing to ameliorate potential harm from streams of antibiotics reaching Florida's west coast.

EPA states no suggested limit, or even guidelines, as to what kind of loading rates Kampachi Farms should ideally achieve when pharmaceuticals become necessary. The Draft EA does fully disclose what kind of therapeutics, antibiotics, drugs, or other treatment should be used or avoided. The Draft EA looks at studies concerning only one antibiotic, Oxytetracycline (OTC), and buries that in the appendices, not the Draft EA itself.

Furthermore, EPA cites studies from more than thirty years ago, suggesting that the Draft EA relies on stale data. In fact, the Draft Ocean Discharge Criteria Evaluation (Draft ODCE)

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[68] National Centers for Coastal Ocean Science, *Seasonal Forecasting of Karenia brevis Red Tide Blooms in the Eastern Gulf of Mexico*, https://coastalscience.noaa.gov/project/seasonal-forecasting-of-karenia-brevis-red-tide-blooms-in-the-eastern-gulf-of-mexico/(last visited Jan. 21, 2020).
[69] Environmental Protection Agency, *Draft Environmental Assessment, NPDES Permit and Rivers and Harbors Act Section 10 Permit for Kampachi Farms – Velella Epsilon Project*, Appendix C, Draft Ocean Discharge Criteria Evaluation 43 (2019).
[70] *Id.*

contains more studies published in the 1970s than in the 2010s. More than two-thirds of the studies that EPA cites in the Draft ODC were published before 1990 and are not directly applicable to the impacts of this new VE project.

EPA should also require full qualitative and temporal records of all antibiotics used. As the permit stands, simply requiring type and total volume will not suffice. EPA must include further reporting that discloses the specific type and rate of discharge for each pollutant. Otherwise, Kampachi Farms could disguise heavy doses with additional periods of smaller doses. Additionally, EPA should analyze the impact from **all** potential pesticides or antibiotics, not just one.

This reporting should include arrayed monitoring sites in the benthic zone to determine accumulation rates. Additionally, benthic testing should include more than just biomass, which can mask changes to the entire community. The testing plan discussed in the Draft Permit will only measure very near to the pen, and lacks a specified, definitive sampling pattern.

B. The Biological Evaluation does not adequately consider the impacts of the proposed VE project, and EPA is required to formally consult with NMFS and FWS under Section 7 of Endangered Species Act.

EPA must undertake formal consultation with NMFS and FWS pursuant to Section 7 of the ESA in order to analyze the impact of the proposed VE project on threatened and endangered species. EPA should complete formal consultation and release a draft biological opinion for public comments before moving forward with the proposed project. As discussed above in Section (A)(1)(d)(i)-(iv), the VE project is likely to adversely affect listed species and critical habitat in numerous ways. The Biological Evaluation (BE) does not adequately consider these impacts. It ignores the risk that the facility will act as a FAD, and it selectively relies on old and inapplicable studies from other areas.

Particularly, the BE fails to fully consider the impact of entanglement, vessel strikes and noise disturbance. The BE erroneously relies on reporting from different Velella projects (Gamma and Delta) to conclude that this project will not adversely impact threatened or endangered species. However, these other aquaculture facilities were not located in the Gulf of Mexico, did not impact the same species, and should not be used to conclude that there will be no adverse impacts for the VE project.

Notably, the proposed project is likely to adversely impact threatened and endangered species through vessel strikes, entanglement and noise and light disturbance. As mentioned above, the facility will attract additional vessels and ships, which in turn can attract fish

and whales, and this is likely to increase vessel strikes.[71] Moreover, the problem will be exacerbated by the fact that animals will also be attracted to fish in the net pen.

In fact, many of the listed species in the area have been entangled, harmed, and even killed in other aquaculture facilities, including humpback whales and leatherback sea turtles.[72] Increasing water nutrient could also harm whales, fish, and reptiles in the area and limit available prey species due to increased pollution. This will also increase the risk of more severe and frequent dead zones.

The BE also includes conflicting statements about how far out the water quality effects are expected to occur and fails to include any scientific information or analysis to support its finding that this will not adversely impact threatened and endangered species.

Finally, the BE fails to consider how noise related to aquaculture activities may have a variety of attraction and repulsive effects on the invertebrates, fish, birds, and marine mammals in the area.[73] In short, there is no support for the BE's finding that the VE project is not likely to adversely affect the 26 species identified in the BE.

C. EPA should consider its obligations under the Clean Water Act (CWA).

The Clean Water Act (CWA) established the National Pollutant Discharge Elimination System (NPDES) to "protect and improve water quality by regulating point-source discharges."[74] These permits must comply with EPA's ocean discharge criteria for

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[71] Jason Nark, *Whales are dying along East Coast-and scientists are racing to know why*, NATIONAL GEOGRAPHIC (Mar. 13, 2019), https://www.nationalgeographic.com/animals/2019/03/humpback-whales-unusual-mortality-event.

[72] *See, e.g.*, Megan Thomas, *2nd humpback death in 2 weeks worries experts, farmed salmon industry*, CBC NEWS (Nov. 30, 2016), https://www.cbc.ca/news/canada/british-columbia/humback-whale-deaths-1.3874915; Glenda Luymes, *Dead humpback whale found entangled in empty aquaculture lines*, VANCOUVER SUN (Nov. 20, 2016), https://vancouversun.com/news/local-news/dead-humpback-whale-found-entangled-in-empty-aquaculture-lines; Price, C.S., et al., *Protected Species & Marine Aquaculture Interactions*, NOAA Technical Memorandum NOS NCCOS 211, 27 (2017), https://coastalscience.noaa.gov/data_reports/protected-species-and-marine-aquaculture-interactions.

[73] *See, e.g.,* Myriam D. Callier, et al, *Attraction and repulsion of mobile wild organisms to finfish and shellfish aquaculture: a review,* REVIEWS IN AQUACULTURE Vol. 10, Issue 4 (2017), https://onlinelibrary.wiley.com/doi/10.1111/raq.12208; Craig Radford & Matthew Slater, *Soundscapes in aquaculture systems*, 11 AQUACULTURE ENVTL. INTERACTIONS 53 (2019); Ted Cranford & Petr Krysl, *Fin Whale Sound Reception Mechanisms: Skull Vibration Enables Low-Frequency Hearing*, 10 PLOS ONE 1 (2015); NATIONAL RESEARCH COUNCIL, LOW-FREQUENCY SOUND AND MARINE MAMMALS: CURRENT KNOWLEDGE AND RESEARCH NEEDS (1994), https://doi.org/10.17226/4557.

[74] 33 U.S.C. § 1342.

preventing unreasonable degradation.[75] Nutrients and fish escapes comprise the most relevant pollutants for the VE project.

The regulations further define ten factors that should be considered in determining whether a discharge will cause unreasonable degradation. These regulations require that EPA base its decision on these ten factors, including most relevantly: (1) the potential transport of such pollutants by physical processes, (2) the potential direct and indirect impacts on human health, and (3) the impact on existing commercial fishing.[76] These factors indicate that the VE project will cause unreasonable degradation to the marine environment.

1. **EPA did not consider the potential for physical transport of nutrients thoroughly enough.**

EPA must consider the potential for physical transport of nutrients under 40 CFR 125.122. As discussed in Section (A)(4)(d), the facility has a significant and unaddressed potential to transport waste streams with the predominant current direction. EPA acknowledges this by declaring that the "physical transport of these waste streams is considered to be the most significant source for dispersion of the wastes…"[77] Yet, the Draft EA sets nothing in place to prevent, or even monitor, these waste streams. The monitoring plan embedded in the NPDES permit has a narrow scope: one site up-stream (presumably where no discharge will flow), the cage site itself, and one site a paltry **five meters** downstream.[78]

If EPA had evidence suggesting that pollution streams would conveniently aggregate at that site, we would have a great understanding of the pollution flow. As it is, ocean currents and winds can carry nutrients such as phosphorus or nitrogen in the form of fish feces or food much further than five meters. EPA has ignored the possibility for transport more than five meters away. Whatever direction the prevailing current may be (northeast or southeast), it can very likely transport nutrients towards Florida's west coast.

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[75] 40 C.F.R. § 125.121.
[76] 40 C.F.R. § 125.122.
[77] Environmental Protection Agency, *Draft Environmental Assessment, NPDES Permit and Rivers and Harbors Act Section 10 Permit for Kampachi Farms – Velella Epsilon Project*, Appendix C, Draft Ocean Discharge Criteria Evaluation 46 (2019).
[78] Environmental Protection Agency, *Authorization to Discharge under the NPDES Permit FL0A0001* 6 (2019).

a. EPA should set additional monitoring requirements in place.

Friends of Animals suggests that nutrient gradient tests for both nitrogen and phosphorous be set up in waters around the cages. Standard NPDES monitoring at just one or two points near the cage does not suffice for such a new and untested method of aquaculture.

In addition, EPA should require detailed records of the amount and varieties of feed that are used. This should include information about the composition of the feed. As discussed repeatedly in the Draft EA, uneaten fish food can provide both nitrogen and phosphorus to opportunistic phytoplankton and result in unreasonable degradation of the marine environment. The exact type of fish feed should be specified **before** the facility discharges into the ocean.

2. EPA insufficiently considered the threat of fish escapes.

The CWA prohibits discharging pollutants without a permit. The CWA defines pollutants as, *inter alia*, "biological materials."[79] Several courts have deemed fish to qualify as biological materials.[80] Thus, fish escaping from the VE project qualify as pollution. EPA needs to do more than simply acknowledge the threat of a fish escape.

The Draft EA repeatedly mentions both the potential adverse effects of an escape: loss of genetic fitness to wild fish, spread of disease, competition for food and space, and predation on wild stock.[81] EPA briefly alludes to just one avenue for mitigating this disaster: "good management practices."[82] What constitutes good management? The Draft EA does not say.

In fact, one needs to pore into the Draft NPDES permit to read how cursorily EPA has considered this threat. The permit requires Kampachi Farms to report any fish escape.[83] That will be nice to know when a fish escape occurs, but EPA should require specific measures to prevent fish escape and consider how such escapes would result in an unreasonable degradation of the marine environment. Again, the permit is found to be lacking here. EPA administers no guidelines, no suggested courses of actions, and no procedures of any kind.

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[79] 33 U.S.C. §1362(6).
[80] *See, e.g.*, *Nw. Envtl. Advocates v. EPA*, 537 F.3d 1006, 1021 (9th Cir. 2008); *Nat'l Wildlife Fed'n v. Consumers Power Co.*, 862 F.2d 580, 583 (6th Cir. 1988).
[81] Environmental Protection Agency, *Draft Environmental Assessment, NPDES Permit and Rivers and Harbors Act Section 10 Permit for Kampachi Farms – Velella Epsilon Project* 31, 57 (2019).
[82] *Id.* at 31.
[83] Environmental Protection Agency, *Authorization to Discharge under the NPDES Permit FL0A0001* 6 (2019).

EPA simply defers to Kampachi Farms, and suggests the following to prevent disaster: "The permittee shall… h.) Develop procedures to contain and transfer commercial fish and other aquatic life in a manner which shall prevent the entry of commercial aquatic life into waters of the United States."[84] This is not sufficient, as evidenced by the "large escape event" during Kampachi Farms' Velella Gamma trial.[85] It is simply unacceptable to allow the permittee to call their own shots when it comes to NPDES permits.

EPA must formulate specific guidelines as to how this facility should operate. Similarly, EPA should mandate that Kampachi Farms disclose the full genetic records of the F1 progeny they intend to grow in the facility. Threats to genetic fitness from a fish escape still pose problems. Having full genetic knowledge will help inform an accurate consideration of this threat.

a. EPA has not addressed the role of climate change in extreme weather events which could result in fish escapes.

The Draft EA admits to the potential for extreme weather events, and for this potential to only grow as climate change continues to impact the Gulf of Mexico.[86] After all, warmer waters fuel more powerful hurricanes.[87] NOAA expects the proportion of tropical cyclones (hurricanes) that will reach "very intense" levels to increase.[88]

Once again, however, EPA ends its analysis prematurely. Much like with fish escapes, EPA relies on "mitigation measures in the NPDES" to completely discount any potential for harm. In a display of circular logic, these mitigation measures include the directive to operate the facility in a "sound manner to prevent or minimize the impacts of disasters." The mitigation measures include requirements to "provide a facility-specific analysis of each type of disaster" and "describe the procedures used to prevent, control, and/or minimize the impacts of disasters."[89]

EPA has not made any actual considerations as to how to prepare for the inevitable powerful hurricane in the Gulf of Mexico. Instead, they have again allowed the permittee

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[84] Environmental Protection Agency, *Authorization to Discharge under the NPDES Permit FL0A0001* 18 (2019).
[85] Environmental Protection Agency, *Environmental Assessment*, *Velella Delta Project*, *RIN 0648-XD961* 35 (2016).
[86] Environmental Protection Agency, *Draft Environmental Assessment, NPDES Permit and Rivers and Harbors Act Section 10 Permit for Kampachi Farms – Velella Epsilon Project* (2019).
[87] NOAA, *How does the ocean affect hurricanes?*, OCEAN EXPLORATION AND RESEARCH, https://oceanexplorer.noaa.gov/facts/hurricanes.html (last visited Jan. 28, 2020).
[88] NOAA, *Global Warming and Hurricanes*, GEOPHYSICAL FLUID DYNAMICS LABORATORY, https://www.gfdl.noaa.gov/global-warming-and-hurricanes/ (Dec. 17, 2019).
[89] Environmental Protection Agency, *Authorization to Discharge under the NPDES Permit FL0A0001* 18 (2019).

itself to define the terms of the permit. EPA should make concrete guidelines for proper maintenance of this facility, and EPA should do this **before** issuing an NPDES permit.

3. EPA insufficiently considered the potential impact on human health.

a. The facility poses a substantial risk to contribute to HABs, which negatively impact human health.

The clear weight of the evidence demonstrates that HABs feed off excess nutrients. Just because we can't trace a given HAB to an individual source doesn't absolve nitrogen and phosphorus of their unequivocal role in HABs.

In this vein, EPA uses sleight of hand to distract from nutrient pollution as a legitimate concern. The Draft EA misleadingly states that "no good scientific evidence is available to suggest that macronutrients and micronutrients from fish farming is related to the occurrence of red tides."[90] Nutrients from aquaculture have not caused previous red tides, because there has been no marine aquaculture yet in the federal waters of the Gulf of Mexico. This obscures the widespread scientific consensus that nitrogen and phosphorous **contribute** to the extreme growth of HABs.

The real issue here – one that EPA has not meaningfully addressed – lies with the potential to exacerbate naturally-occurring algal blooms. It is undisputed that the blooms start offshore. Science has conclusively demonstrated that winds and ocean currents bring the blooms in shore.[91] Likewise, there is no debate whether blooms thrive off excess nutrients. This problem extends far beyond the Draft EA's scope of five meters away from the VE facility.

b. The facility poses a risk to transfer parasites or disease to other fish.

Even though the Draft EA mentions the threat of parasites at least three times, EPA did not make any plans to account for this risk. The Draft EA simply states, "[a]ntibiotics are considered a method of last resort and are being replaced by other sound management approaches."[92] The Draft EA does not discuss what these management approaches entail. It is inappropriate to assume that antibiotics will not be necessary in such a new facility.

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[90] Environmental Protection Agency, *Draft Environmental Assessment, NPDES Permit and Rivers and Harbors Act Section 10 Permit for Kampachi Farms – Velella Epsilon Project*, Appendix C, Draft Ocean Discharge Criteria Evaluation 36 (2019).
[91] Rebecca Burton, *Red Tide is Expensive. Here's Why,* UNIVERSITY OF FLORIDA THOMPSON EARTH SYSTEMS INSTITUTE (May 29, 2019), https://www.floridamuseum.ufl.edu/earth-systems/blog/red-tide-is-expensive-heres-why/.
[92] Environmental Protection Agency, Draft Environmental Assessment, *NPDES Permit and Rivers and Harbors Act Section 10 Permit for Kampachi Farms – Velella Epsilon Project* 16 (2019).

EPA should make several additional monitoring requirements. Arrays of control fish should be set out near the VE project and monitored for disease. This will allow EPA to determine if any parasites are being transferred out of the mesh pen. Additionally, EPA should require testing to be done of wild fish populations near the cage. Closely related fish who aggregate nearby, such as blue runner or banded rudderfish, should be monitored for disease to ensure nothing is escaping from the facility.

D. EPA should recognize that, under the Magnuson-Stevens Act, NOAA and NMFS lack legal authority to regulate aquaculture as fishing.

The Magnuson-Stevens Act (MSA) gives NMFS authority to regulate fisheries. However, offshore aquaculture facilities are not fisheries. MSA only grants the NMFS authority to issue regulations involving "fishing."[93] Aquaculture can only be described as "fishing" in the same sense that animal agriculture can be described as "hunting." Aquaculture is not fishing.

A recent case out of the U.S. District Court for the Eastern District of Louisiana has demonstrated that Congress did not grant NMFS, a division of National Oceanic and Atmosphere Institute (NOAA), authority to extend their oversight to aquaculture.[94]

The court in *Gulf Fisherman's Association* found that NMFS may not stretch the definition of "harvesting," one of the statutory definitions of fishing, to include aquaculture.[95] The legislative history supports this idea, and many of the principles and guidelines of the MSA do not apply to aquaculture.[96]

Despite this ruling being handed down in late 2016, the Draft EA incorporates NMFS' *ultra vires* documents relating to aquaculture: the 2008 PEIS for proposed aquaculture regulations in the Gulf of Mexico EEZ, and NMFS' 2016 final rule for regulating offshore aquaculture in the Gulf of Mexico.[97]

NMFS does not have ground on which to assert authority and should not be allowed to distort the MSA to promulgate rules for aquaculture in the United States. New industries such as marine aquaculture **should** have regulations to help prevent environmental catastrophe. Now that NMFS' regulations have been vacated, no valid or appropriate

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[93] 16 U.S.C. § 1802(16).
[94] *Gulf Fishermens Ass'n v. Nat'l Marine Fisheries Serv*., 341 F. Supp. 3d 632 (E.D. La. 2018)
[95] *Gulf Fishermens Ass'n v. Nat'l Marine Fisheries Serv*., 341 F. Supp. 3d 632, 638 (E.D. La. 2018).
[96] *Id.* at 639.
[97] Environmental Protection Agency, *Draft Environmental Assessment, NPDES Permit and Rivers and Harbors Act Section 10 Permit for Kampachi Farms – Velella Epsilon Project*, 11 (2019).

regulations exist for marine aquaculture. EPA should factor in this absence of guidelines when considering the potential impacts of the VE project.

CONCLUSION

In conclusion, Friends of Animals strongly opposes the sufficiency of the Draft Environmental Assessment. EPA's quick dismissal of a wide variety of environmental ills and statutory requirements flies in the face of their duty as stewards of the environment. Friends of Animals requests that EPA conduct a complete and through Environment Impact Statement to understand the true potential for negative impacts of the VE project in the Gulf of Mexico. Friends of Animals recommends that EPA consider what the ESA and CWA statutorily require. Finally, EPA must also realize that both NOAA and NMFS lack authority to regulate this uncertain and unconventional aquaculture industry.

Thank you for the opportunity to comment, and please contact me if you have any questions or concerns.

Sincerely,

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REFRENCES CITED

NOAA Expands Opportunities for U.S. Aquaculture

January 11, 2016

Groundbreaking rule opens the door for seafood farming in federal waters of the Gulf of Mexico.

NOAA filed a final rule today implementing the nation's first comprehensive regulatory program for aquaculture in federal waters. The groundbreaking rule creates a coordinated permitting system for the Gulf of Mexico, opening the door for the region to expand seafood production and create new jobs in an environmentally sustainable manner.

"As demand for seafood continues to rise, aquaculture presents a tremendous opportunity not only to meet this demand, but also to increase opportunities for the seafood industry and job creation," said Kathryn Sullivan, Ph.D., NOAA administrator. "Expanding U.S. aquaculture in federal waters complements wild harvest fisheries and supports our efforts to maintain sustainable fisheries and resilient oceans."

Aquaculture is the practice of raising marine species in controlled environments. In the U.S., federal waters begin where state jurisdiction ends and extend out to 200 miles offshore. In this case, federal waters begin three nautical miles off Louisiana, Mississippi, and Alabama and nine nautical miles off Texas and the west coast of Florida.

"While this framework is the first of its kind in federal waters, the states already support many successful and thriving aquaculture operations in their waters," said Eileen Sobeck, assistant NOAA administrator for fisheries. "Allowing this type of seafood production will not only reduce U.S. dependency on imports, but also provide a domestic source of sustainable fish protein and create jobs."

The new rule authorizes NOAA Fisheries to issue permits to grow species such as red drum, cobia, and almaco jack in federal waters in the Gulf for an initial period of 10 years. The rule took into account thousands of public comments.

The permit process includes comprehensive safeguards to ensure healthy oceans and coasts and considers other uses of ocean space, such as fishing. The rule implements environmental safeguards, including a baseline survey, monitoring, and reporting requirements. In addition to a NOAA permit, farming fish in federal waters also requires permits from the U.S. Environmental Protection Agency and the U.S. Army Corps of Engineers. NOAA Fisheries is working with these agencies to set up a coordinated permitting process for the Gulf.

”This is all about managing and expanding seafood farming in an environmentally sound and economically sustainable way,” said Michael Rubino, director, NOAA Fisheries Office of Aquaculture. “The permit process we’ve laid out accounts for the region’s unique needs and opens the door for other regions to follow suit.”

Right now, there are no commercial aquaculture operations in federal waters. But three offshore mussel farms received federal permits from the U.S. Army Corps of Engineers last year – two off Massachusetts and one off California. The Army Corps and U.S. Environmental Protection Agency are also considering an application for a company seeking to farm fish in federal waters off California.

Commercial farming of marine species, such as oysters, clams, mussels and salmon, have operated in state waters for many years. For example, U.S. aquaculture products generated $1.4 billion in value in 2013—20 percent of total U.S. seafood production and fishery products by value.

Learn more about U.S. marine aquaculture ›

Read an interview with Michael Rubino, Ph.D., director of the NOAA Fisheries Office of Aquaculture ›

Last updated by NOAA Fisheries Public Affairs on October 13, 2020

EPA United States Environmental Protection Agency

Why is Improving Water Quality in the Gulf of Mexico so Critical?

Water sampling in Pearl River County, MS

The Clean Water Act provides authority and resources that are essential to protecting water quality in the Gulf of Mexico and in the larger Mississippi River Basin. The EPA regional offices and the Gulf of Mexico Program work with states to continue to maximize the efficiency and utility of water quality monitoring efforts for local managers by coordinating and standardizing state and federal water quality data collection activities in the Gulf region. Enhanced monitoring and research is needed in the Gulf Coast region to make data more readily available.

Water Quality Projects in the Gulf of Mexico

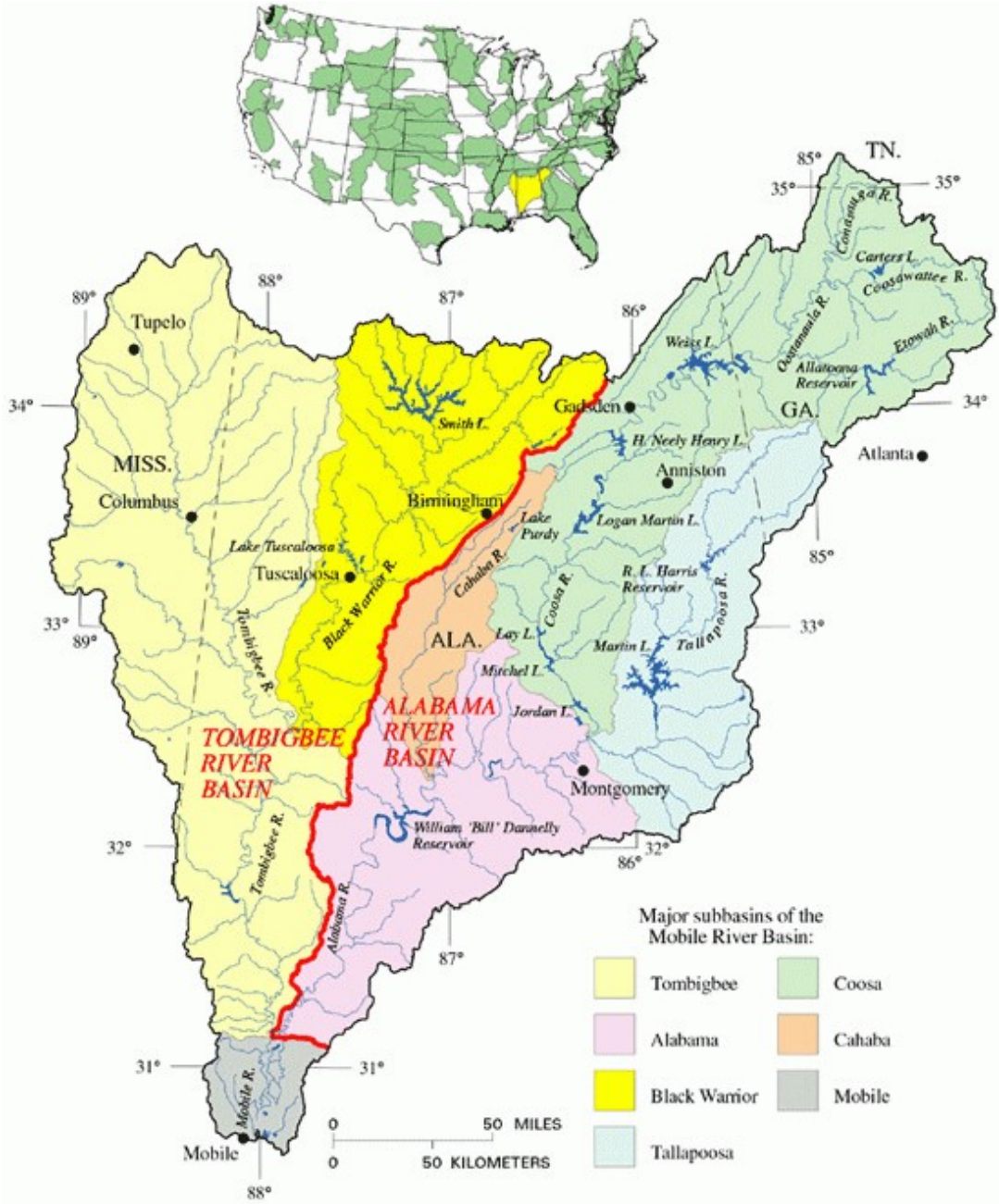
Lowry Park Zoo

Lowry Park Zoo and the Gulf of Mexico Program have entered into a cooperative agreement along with other partners such as Hillsborough County and the Tampa Bay Estuary to develop a water resource master plan for the zoo to reduce nutrients. In the area surrounding the zoo, there is an abundance of nutrients being deposited into the watershed. One of the causes of excess nutrients is the deferred maintenance of area residential septic tanks systems, which results in toxic water.

Through this cooperative agreement, Lowry Park Zoo will develop a master plan to assist the zoo in becoming a self-contained site. The goal of the plan is to reduce the amount of wastewater being discharged

into Hamilton Creek, a tributary to the Hillsborough River that discharges into Tampa Bay.

Characterizing and Addressing Contamination from Septic System Effluent in the Lower Black Warrior River Watershed



Black Warrior River Basin Map Courtesy of U.S. Army Corps of Engineers, Mobile District

The University of Alabama's Department of Civil, Construction and Environmental Engineering and the GMP will bring together five major stakeholders to characterize and address one of the great environmental and public health challenges in rural Alabama. The soil and geological conditions and economic realities of the Lower Black Warrior River watershed, make it very difficult for the operation of onsite wastewater treatment systems, such as residential septic tank systems.

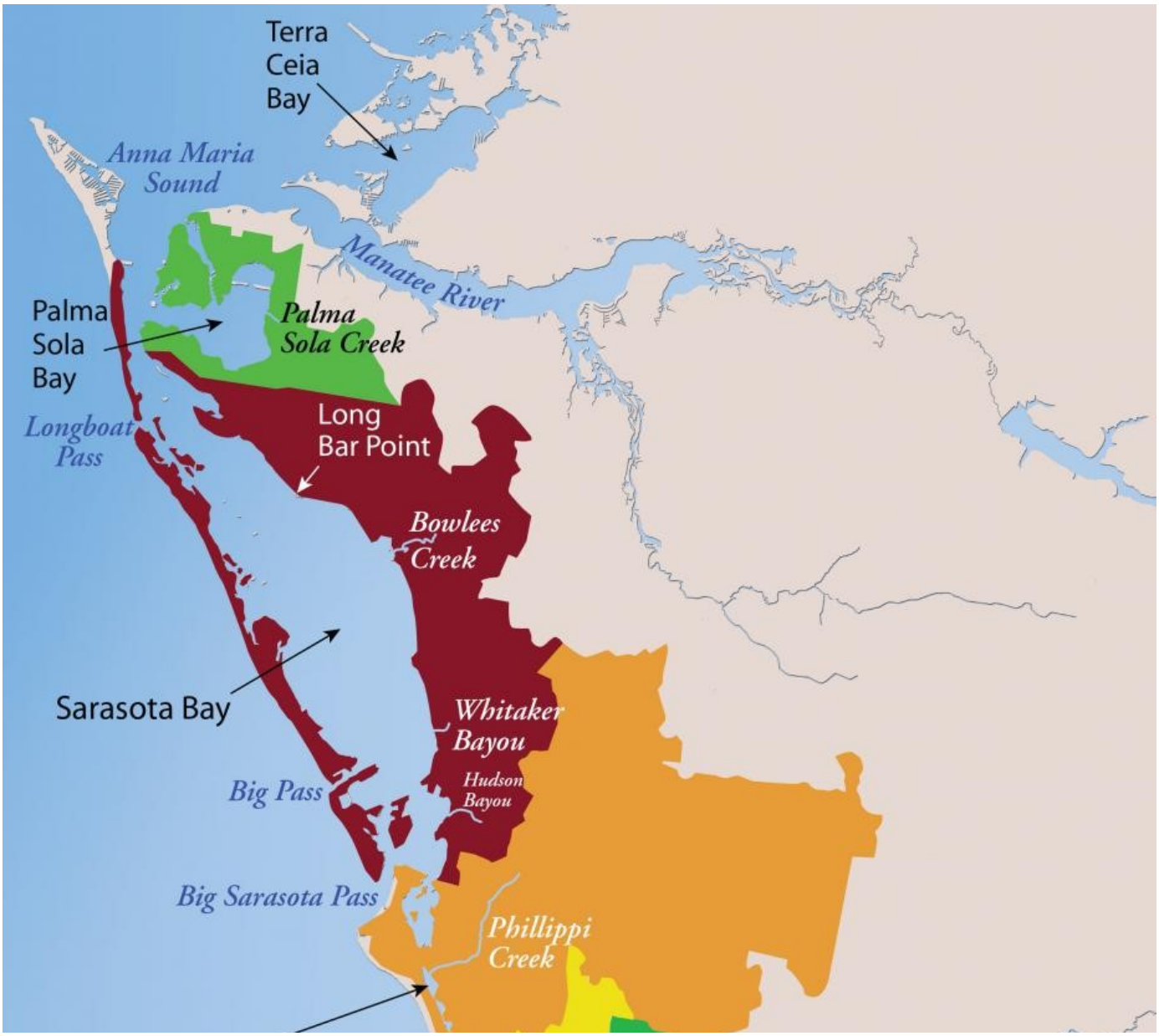
Poorly treated or untreated residential wastewater is a major issue and creates a hazard for both the local and

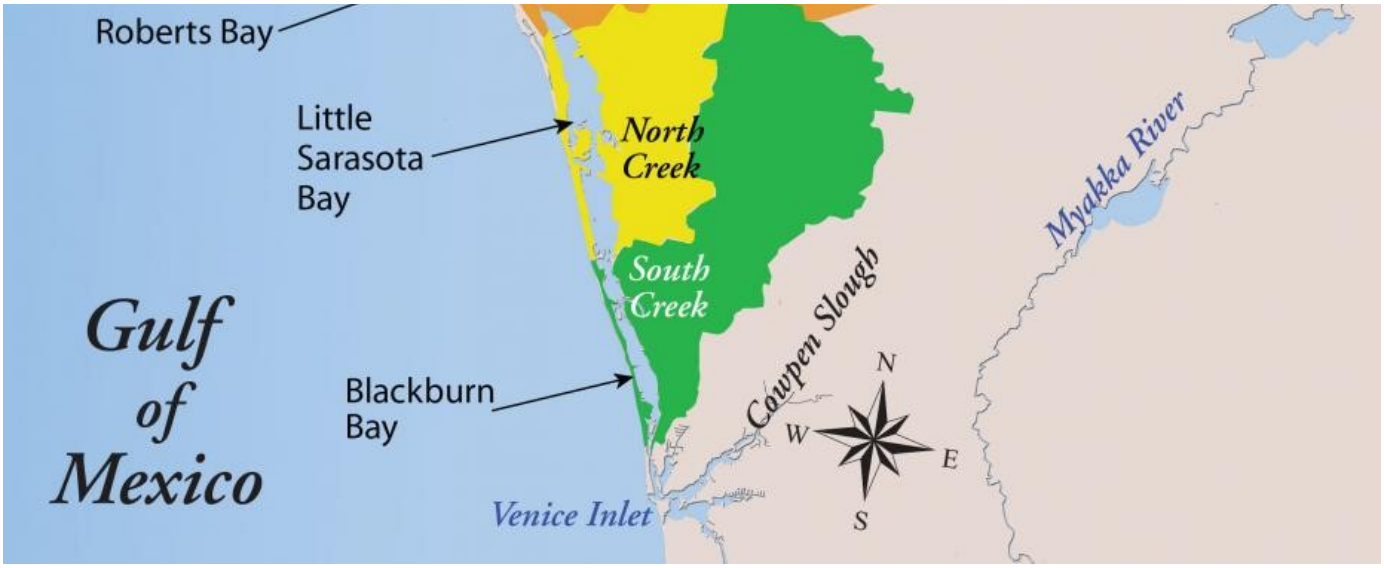
regional water resources and more importantly, to the overall public health of the community. Although this issue is widely acknowledged, the scope of the adverse impacts, the geographic areas of the greatest threats, and the feasibility and effectiveness of possible solutions have not been adequately addressed. In addition, the lack of safe and affordable sanitation options for the rural economically disadvantaged creates a major environmental justice issue.

The objectives of this project are to:

- characterize the mobility of septic system effluent in sites representative of the soil and geological conditions in the Lower Black Warrior River watershed
- use these results to identify the locations where septic systems are most likely to impact water bodies
- implement an effective program to educate, encourage and promote homeowners with septic systems near these water bodies to carry out timely pumping-out and maintenance on their systems
- establish a committee of stakeholders and researchers to evaluate and report on the feasibility of connecting more communities to public sewers or establishing small decentralized community-scale wastewater treatment solutions

North Water Tower Park Community Restoration and Education Initiative





Sarasota Bay Estuary Program (SBEP) and the Gulf of Mexico Program (GMP) are partnering to continue addressing the issue of stormwater as a major pollutant at the North Water Tower Park (NWTP), which is a 20-acre park located in North Sarasota, Florida. Treatment of this stormwater is vital to protecting the local water body and restoring areas where it has caused adverse environmental impacts.

Currently, the stormwater draining from the North Trail and adjacent properties is routed through an undersized pipe to a canal. From there, the stormwater flows into Whitaker Bayou, which is a major tidal tributary into Sarasota Bay. At this time, there is very little retention time for the stormwater to soak into the ground.

This project will physically redesign certain areas to be improved “Low Impact Design” which will better retain the stormwater in a beneficial way. Bioswales, which are storm runoff conveyance systems that provide an alternative to storm sewers, will be designed and planted with native vegetation. By returning the land surface to a more natural setting with the bioswales, the natural connectivity will improve habitat and provide better and safer access for the neighborhood.

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RAP PUBLICATION 2012/20

Anchored fish aggregating devices for artisanal fisheries in South and Southeast Asia: benefits and risks

MINISTERIO DE ASUNTOS EXTERIORES Y DE COOPERACIÓN
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RAP PUBLICATION 2012/20

Anchored fish aggregating devices for artisanal fisheries in South and Southeast Asia: benefits and risks

Steve Beverly, Don Griffiths and Robert Lee

THE FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
REGIONAL OFFICE FOR ASIA AND THE PACIFIC
BANGKOK, 2012

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Foreword

For centuries fishers have known that fish are attracted to and congregate around naturally occurring floating objects. By fishing close to these, they can often bring back fish for their families. They have also learned that by placing their own floating objects in the sea that fish would aggregate around them making catching easier. These man-made objects are called Fish Aggregating Devices or FADs and they can be either drifting or anchored.

Since FADs can improve fish catches, governments and national fisheries agencies in the Asia region are examining the merits of using anchored FAD programmes. Their policy objectives are typically improved food security through better availability of localized aquatic animal protein, increasing the reliability of income from fishing for artisanal fishers and the creation of employment in coastal areas through fish and aquatic product trading and processing.

In the last decade or so, FADs for both artisanal and commercial/industrial fisheries have proliferated in Asia and the Pacific region. In some areas this has caused concern about the potential negative impacts on fisheries and the marine environment. This has led environmental and conservation groups to lobby for FAD-free caught tuna, particularly in industrial type tuna fisheries.

This publication responds to requests from governments within the region for additional information on the use of anchored fish aggregating devices for artisanal fisheries. It was produced by the Spanish-funded and FAO-executed Regional Fisheries Livelihoods Programme (RFLP), which is conducting activities in Cambodia, Indonesia, the Philippines, Sri Lanka, Timor-Leste and Viet Nam.

The book highlights the potential benefits of well co-managed anchored FAD programmes, which can contribute to overall food security. It covers the planning and background research requirements and emphasizes the importance and need for holistic and inclusive community consultation and monitoring processes and the development of enabling policies. The book also covers the environmental concerns and possible negative ecosystem impacts of unplanned and poorly managed programmes, which inevitably lead to unsustainable resource exploitation and financial and economic losses.

An Advisory note was also developed as a summary and findings of this book to promote responsible planning, implementation and monitoring of anchored fish aggregating devices for artisanal fisheries in line with the FAO Code of Conduct for Responsible Fisheries (http://www.fao.org/docrep/005/v9878e/v9878e00.HTM). It provides recommendations to governments, fisheries agencies, donors and other key stakeholders on the technical, socio-economic and environmental aspects to be considered before deciding on whether to embark on a FAD programme.

Hiroyuki Konuma
Assistant Director-General and Regional Representative
FAO Regional Office for Asia and the Pacific

aggregating near a barramundi farm, and concluded that most of the fish there were Siganid herbivores seeking shelter and feeding on fouling organisms (McKinnon et al. 2008).

Negative interactions with wild fishes have also been observed. For example, bluefish are reported to seasonally aggregate around and invade fish cages in the Mediterranean (Sanchez-Jerez et al. 2008). Of the 23 farms surveyed, bluefish aggregations were detected at 16, but only four farms reported significant impacts to the cultured fish. In addition to direct predation on the cultured fish, these four farms reported decreased productivity due to stress and additional costs associated with removal of bluefish and net repair. While marine cages primarily provide a habitat and foraging opportunity for fish, Nash et al. (2005) suggest

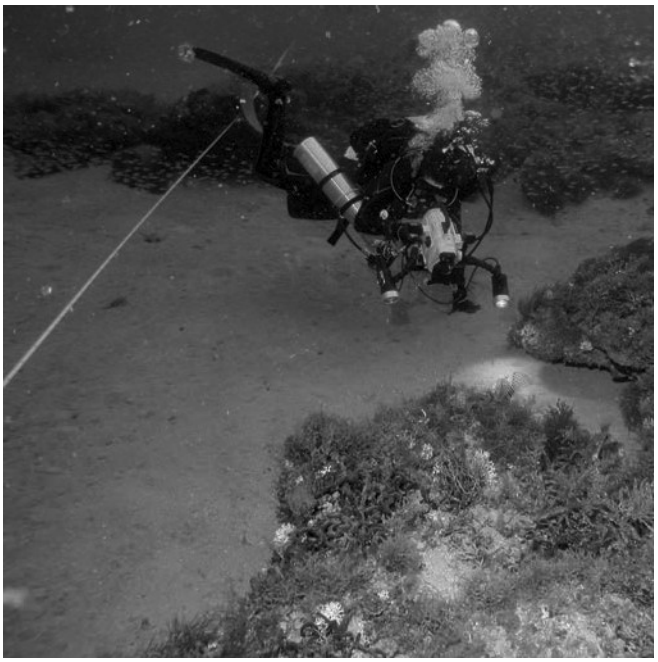


Photo courtesy of NOAA.

that lights used at salmon cages to extend the photoperiod for growth enhancement may attract fish at night, possibly interfering with juvenile migratory fishes. Other documented negative interactions include entanglement of wild fish (Huntington et al. 2006) and exposure to antibiotics and other chemicals (Fortt and Buschmann 2007, for example). The potential for wild fish to consume medicated feed and then be captured for human consumption, and the possibility of disease transfer from farmed fish (Braaten 2007) may also be important issues to consider.

Fish Community Effects

The effect to fish communities has been investigated at larger scales. Machias et al. (2004) studied the species composition of demersal fish assemblages in the Aegean Sea prior to and 12 years after the deployment of commercial fish cages. Fish abundance increased by a factor of four within the bay, the number of species caught increased from 37 to 42 and the trophic level value increased from 3.59 to 3.79 after the onset of marine cage culture. Traditional diversity indices showed that despite some differences in species composition, the overall fish community structure after the establishment of fish farming was not phylogenetically impoverished. The average lengths and weights of several fish species were also compared and fish were found to be either similar in size or larger after the farm was established. The results were thought to reflect an overall benefit to the local fish community at a regional scale, most likely due to nutrient driven increases in primary production. In another study, Machias et al. (2005) conducted trawls near (within three nautical miles) and far from (> 20 nautical miles) Greek fish farms. They found that the abundance and biomass of wild fish was greatest close to the fish farms compared to nearby reference sites without cages and at the distant sites. Although seasonal and substrate differences in fish abundance were evident, the Shannon-Wiener diversity indices showed no deleterious effect due to fish farms. Increased abundance of several important commercial fish species was also documented. These observations were bolstered by an analysis of the relationships between 18 years of data fish farming activity and fish landings (Machias et al. 2006) throughout Greece. The researchers found no negative correlations between farming activity and fisheries landings, and there were strong indications of increased fisheries production in areas with farms (presumably as a result of nutrient discharge).

The secondary role of fish cages as FADs, especially near reef habitat and in the open ocean, warrants further research (Holmer 2010) and keeping track of wild fish aggregates at open ocean cage facilities is recommended as part of standard environmental impact monitoring procedures (Lee and O'Bryen 2007, Holmer et al. 2008). Dempster et al. (2006) point out that the unintentional role of sea cages as FADs may have significant conservation impact to marine fisheries and they encourage banning commercial and recreational fishing activities around farms and the designation of these areas as Marine Protected Areas. A similar recommendation was made by researchers in Turkey (Akyol and Ertosluk 2010) as a result of their study of fish farmers who set traps near fish cages. This lucrative, but illegal, harvest of aggregating fish has been the basis of conflict with local artisanal fishers who are not allowed to fish near the cages.

Sharks

There is little published information about the interactions of sharks and marine cage farms, but they have been documented as being attracted to fish cages in the Pacific Northwest (Nash et al. 2005), Puerto Rico (Alston et al. 2005), The Bahamas (Benetti et al. 2005), Latin America (Rojas and Wadsworth 2007) and Australia (Australian Government 2009). Because sharks pose a threat to the stocked fish and potentially divers, dangerous species may be destroyed. In Australia, an estimated 20 great white sharks a year are killed at marine aquaculture farms (Australian Government 2009). Siting of a salmon farm off South Africa within an ecologically significant great white shark congregation area and eco-tourist destination elicited major negative public response (Scholl and Pade 2005) and the farm was later closed. A recent telemetry study of sand and tiger sharks near fish cages off Hawaii found that sharks did aggregate near the cages with some individuals being recorded for the entire term of the 2.5 year study (Papastimatiou et al. 2010). These animals were considered to pose minimal threat to humans. The economic and ecological potential risk of large scale fish releases due to sharks tearing nets may be a concern as the industry moves into offshore sites (Holmer 2010) depending on the types of nets and locations used.

Photo courtesy of NOAA.

Deterring shark predation at marine cage sites can likely be accomplished by the use of tear-resistant nets. Sharks guards are small rigid mesh nets installed at the bottom of a fish cage to prevent sharks from damaging nets while attempting to feed on dead fish that have fallen to the bottom (Jamieson and Olesiuk 2002). Good husbandry practices such as removing sick or dead fish promptly from cages is also an effective predator deterrent. Given the recent global interest in shark population declines and the need to implement conservation efforts, the potential impacts of marine cage culture to sharks is likely a fruitful area for research.

Marine Mammals

The interactions of marine mammals with marine fish cages and efforts to minimize potential problems are recognized, but there is little recent published, peer-reviewed literature that specifically addresses the issue. Marine mammals such as seals, sea lions, cetaceans and otters at fish cages can represent a threat to cultured fish of direct predation, injury, stress mediated increased susceptibility to disease, decreased growth due to stress, and escapement loss through torn nets (Nash

et al. 2000, Jamieson and Olesiuk 2002, Würsig and Gailey 2002, Rojas and Wadsworth 2007, Belle and Nash 2008). Reciprocally, marine aquaculture operations may displace marine mammals from their foraging habitats (Markowitz et al. 2004, Cañadas and Hammond 2008) or cause other disruptions to their behavior (Early 2001). Entanglement in nets or lines around fish farms may cause injury, stress or death to marine mammals.

Nash et al. (2000) provide a summary of information to assess the risk associated with aquaculture and marine mammal interactions in the Pacific Northwest salmon industry. Loss due to direct predation, fish injury or stress and escapement can account for losses of up to 10% in terms of fish and represents significant financial loss. Pinniped attacks on cage divers have also been reported. The authors conclude that physical barriers including rigid netting around cages are the best management options to decrease harm along with siting of cages offshore far away from haul out sites and rookeries.

A report by Jamieson and Olesiuk (2002) provides a thorough review of pinniped interactions with salmon farms in Canada, the financial impacts to the industry, methods for non-lethal intervention and the ecological implications of lethal deterrents to the seal and sea lion populations. The authors summarize estimates from the 1980-90s for damages caused by pinnipeds at salmon farms around the world. Losses range from a few thousand fish up to 10% of the stocked fish. Damages may be only a few thousand dollars for an individual farm, but can total millions of dollars for a single country in a year. The growth of the fish farming industry and concomitant expansion of pinniped populations has tended to increase the number of interactions, but lethal control methods are less viable than previously due to ecosystem conservation objectives and regulatory protection. Typically, only single individuals may be killed and only after multiple forays into the farm with repeated attempts to deter the animal. They note that the U.S. has even stricter regulations with respect to lethal removal. Nonlethal interventions include harassment by boat or with noise (such as underwater seal firecrackers), aversive conditioning, predator (killer whales) models or sounds, and the use of acoustic devices and relocation. Often, harassment techniques are effective in the short term, but may be less efficacious over time as animals become habituated. Acoustic deterrent devices (ADD and AHDs) are designed to cause auditory discomfort to pinnipeds by emitting sound underwater at a range of frequencies. However, these devices have also been shown to deleteriously impact non-target marine mammals.

Würsig and Gailey (2002) provide useful information on the conflicts between aquaculture and marine mammals and potential resolutions. They report on the damage and financial loss that marine mammals, especially pinnipeds, may inflict on commercial fish farms. The need for non-lethal management options to reduce conflicts is recognized, with the goal of decreasing impacts to non-target animals and preventing the killing, both licensed and illegal, of pinnipeds. Six options for reducing marine mammal impacts are discussed: harassment, aversive condition, exclusion, non-lethal removal, lethal removal and population control. Harassment by chasing, explosives, and ADDs has been found to be only somewhat effective and generally only in the short term until animals become habituated. In fact it is possible that over time noise harassment devices may actually become attractants to habituated individuals who come to recognize the sound as an unpleasant dinner bell. Predator models and sound devices (imitating killer whales for example) are also not very effective.

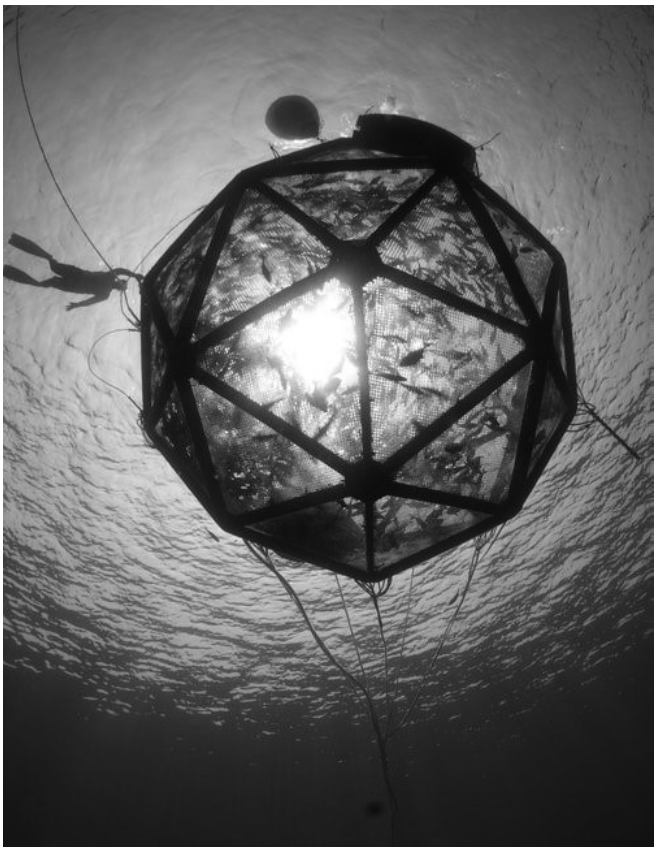
Good husbandry practices such as removing sick or dead fish promptly from cages is also an effective predator deterrent.

Velella Epsilon: Pioneering Offshore Aquaculture in the Gulf of Mexico (/blog/2017/11/2/velella-epsilon-pioneering-offshore-aquaculture-in-the-gulf-of-mexico)

Neil Sims (/blog?author=58a67c0fd1758efb58f2ec32) · November 2, 2017 (/blog/2017/11/2/velella-epsilon-pioneering-offshore-aquaculture-in-the-gulf-of-mexico)

As part of a national initiative to increase U.S. aquaculture production in the next four years, Kampachi Farms has been awarded a grant in partnership with Florida Sea Grant (https://www.flseagrant.org/news/2017/10/sea-grant-awards-9-3m-to-support-aquaculture-research/) to trial a new Velella net pen pilot project in the Gulf of Mexico.

Kampachi Farms has successfully deployed (http://www.kampachifarm.com/projects/) smaller Aquapod™ demonstration fish pens off the coast of Kona, Hawaii. The Velella Beta-test was awarded one of TIME Magazine's 25 Best Inventions of the Year (https://www.undercurrentnews.com/2012/11/05/drifting-fish-farm-hailed-as-one-of-the-best-inventions-of-the-year/), and was featured on a National Geographic special hosted by Dr. Robert Ballard. The Velella Beta-test and the Velella



Gamma project were both also highly popular with the local Kona fishing community, as the net pen arrays acted as Fish Aggregating Devices (FADs), and proved to be exciting dive sites for snorkel tours.

In 2016, NOAA Fisheries finalized a Rule that would allow commercial aquaculture operations to be permitted in U.S. federal waters in the Gulf. However, no applications have been received for such projects yet, according to Jess Beck-Stimpert, an aquaculture coordinator with NOAA Fisheries.

“This demonstration pen would therefore be the only permitted structure in Gulf waters,” said Beck-Stimpert.

One of the major barriers to commercially expanding open ocean aquaculture in the Gulf of Mexico has been its arduous permitting process.

Neil Anthony Sims, CEO for Kampachi Farms stated, “The primary goal of the demonstration project is to help the local communities in the Gulf of Mexico to understand the ancillary benefits that offshore aquaculture can bring to fisheries and to recreational tourism.”

Kampachi Farms also intends to start discussions with State and Federal agencies and the local community about pioneering an application for a commercial aquaculture permit in the Gulf of Mexico. The Velella Epsilon will use a SUBflex submersible net pen system (made by GiliOcean Technology (https://www.giliocean.com/)), on a single-point mooring, which allows the net pens to pivot as the current direction changes. The project will also encourage recreational and charterboat fishermen to use the pen as a FAD, or Fish Aggregating Device. As part of the Sea Grant project, this process, and the community response, will be documented as a reference for future applicants.

Sims explained, “Once the Velella Epsilon has demonstrated the technology and benefits of offshore aquaculture to the local communities, then we will engage them in the discussions about how this industry might move forward. We will also work with the various agencies to identify areas needing further regulation or clarification of agency requirements, or areas where we could eliminate any redundancies. And, we will make our documentation on this process readily available for future

aquaculture industry applicants to use as a template."

For more information on previous Velella Project Trials see our Research Page (http://www.kampachifarm.com/projects/).

Expansion of Offshore Aquaculture as a Conservation Goal (/blog/2017/9/8/conservationists-growing-recognition-of-the-need-for-expanded-offshore-aquaculture)

Neil Anthony Sims (/blog?author=59b343d737c581fbf870e357) · September 11, 2017 (/blog/2017/9/8/conservationists-growing-recognition-of-the-need-for-expanded-offshore-aquaculture)

It is wonderfully refreshing to see the growing, forthright support for offshore aquaculture from marine conservationists – or at least, from the true thought-leaders among the marine conservation NGO community. We in the industry have clung to our beliefs, borne of experience, that offshore aquaculture – if done right – has immense potential to increase the production of delicious, healthful seafood, with minimal footprint on the seas. And this proposition is now increasingly supported by many of our colleagues who might previously have been more reticent, or might even have opposed our efforts.

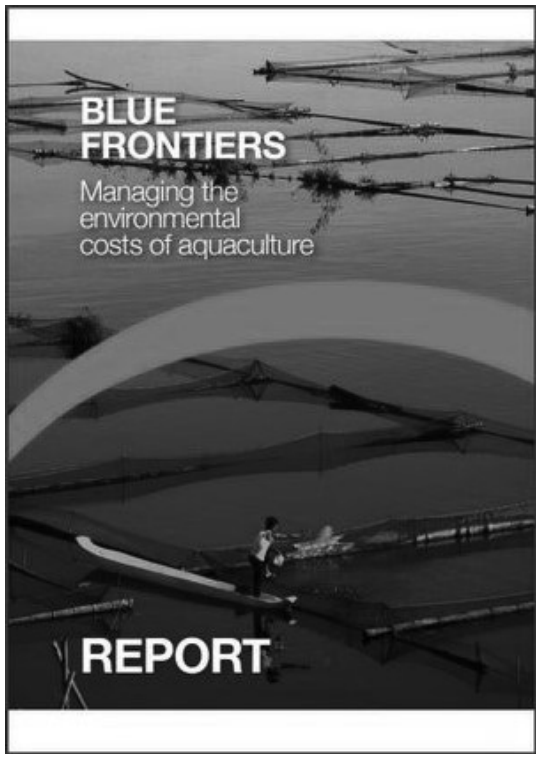
Our earlier pioneering work with Kona Blue Water Farms had shown what was possible. Our submergible net pen array was producing up to 500 tons per year of sashimi-grade kampachi. Extensive monitoring showed no discernible impact on the surrounding water quality, or on wild fish health, or on the spectacularly rich coral-reef that lay a mere half mile inshore from the farm site. It was usually not possible to tell the difference between the water samples that were taken from control sites, up-current of the farm, with those taken from the sample sites down-current of the farm. The coral reef directly inshore is both monitored closely by the Hawaii State biologists (in Aquatic Resources Division), and also scrutinized *every day* by the dive tour operators – sometimes 10 or 15 boats per night - who bring legions of tourists out to the reef to consort with the manta rays.

Kampachi from the first harvest at Kona Blue Water Farms, 2005

As biologists, we understand that all ecosystems have limits to their carrying capacity, and so we have always advocated that significant scale-up of offshore aquaculture should be in deep offshore waters, in areas with brisk currents. But we also felt passionately that the further scale-up offshore *had* to happen; that it was an ecological imperative as well as an economic opportunity. This understanding was rooted both in our training in fisheries science, and in our recognition of future global food needs. We know that mankind has reached "peak fish" with wild stocks. Global catches are flat, at best. Even if we were to restore all wild fisheries to their optimum levels, this would still only meet about 5% of projected global protein needs (Steve Gaines, of UCSB, pers. comm.). The planet's growing population, and the increasingly affluent middle class, are all going to demand more animal protein. From whence will it come?

For many years, most of the environmental NGOs in the marine conservation community were staunchly opposed to the idea of growing fish in the ocean. Admittedly, early aquaculture ventures struggled with limited knowledge about fish nutrition and aquatic animal health, net pen engineering and eco-system area management. But over the past three or four decades, there has been a phenomenal improvement in all areas of fish farming in the marine environment – both in the industry's ability to produce healthy and healthful fish in an efficient manner, with minimal reliance on marine resources such as 'forage' fish, and in the overall management of the industry, to limit impacts to marine ecosystems. Yet many eNGOs still clung to the notion that fish farming in the ocean was somehow bad, while the farming of pigs or cows or chickens was a pastoral ideal to be celebrated and encouraged.

Well, thank goodness for science! Or perhaps, more accurately, let's thank Conservation International (http://www.conservation.org) and Worldfish Center (https://www.worldfishcenter.org/who-we-are) for their diligent adherence to science. In 2011, these two organizations undertook a joint study – Blue Frontiers (http://www.conservation.org/publications/documents/BlueFrontiers_aquaculture_report.pdf) – that compared the Life Cycle Assessments of a range of animal protein production systems, and determined that – hands down, far and away – aquaculture was the least impactful of all. By comparison, they concluded, terrestrial livestock production has



(http://www.conservation.org/publications/documents/BlueFrontiers_aquaculture_report.pdf)

major impacts on greenhouse gas emissions, freshwater availability, and land use. On a finite planet, we simply cannot feed 9 billion people with hamburgers and pork sausages.

It was a powerful piece of science, and it had an immediate impact on policies. Most of the leading eNGOs disbanded their aquaculture offices (which had been purposed to largely slow down aquaculture's growth). Most of the science-driven foundations stopped supporting anti-aquaculture advocacy, and began to quietly promote their more preferred forms of aquaculture: Integrated Multi-Trophic Aquaculture, culture of filter-feeding bivalves and freshwater fish, and Recirculating Aquaculture Systems (RAS). There was even an explicit - but only tacit - acceptance of net pen aquaculture, with the participation of a number of eNGOs in drafting of standards for responsible aquaculture.

Aside: We should give full credit where it is due, here … World Wildlife Fund (http://wwf.panda.org/what_we_do/how_we_work/our_global_goals/markets/mti_solutions/certification/seafood/aquaculture/) (WWF - the panda-bear people) had for years – even before 2011's Blue Frontiers - been supporting the Aquaculture Dialogue process, which provided the foundation for the most rigorous of aquaculture standards - those of the Aquaculture Stewardship Council (https://www.asc-aqua.org/).

However, there was very little outspoken support for helping aquaculture to grow, or for dispelling the negative stereotypes that were firmly established in consumers' minds from the years of besmirching farmed fish. When we asked the CEO of one leading marine conservation organization if – in light of the Blue Frontiers study – he would publicly endorse responsible net pen culture, he very politely but very firmly demurred.

So yet again, let's thank Conservation International (CI) for having the good grace, common sense and integrity to once more lead by example. Recently, in "Human Nature" the Conservation International Blog, Leah Duran outlined the "5 Myths about Farmed Seafood. (http://blog.conservation.org/2017/08/5-myths-about-farmed-seafood/)" And (bless them!), the

Herald-Tribune

Floating fish farm in Gulf proposed southwest of Sarasota

By Dale White
Posted Sep 26, 2019 at 3:01 PM
Updated Sep 27, 2019 at 9:36 AM

U.S. Environmental Protection Agency accepting pro and con public comments about the concept

SARASOTA — A floating fish farm, which could be installed in federal waters of the Gulf of Mexico about 45 miles southwest of Sarasota, is being touted as an advancement in aquaculture by the company that wants to create and operate it. Yet it is also slammed as a potential danger to the ecosystem by environmentalists.

Kampachi Farms of Kailua-Kona, Hawaii, seeks a federal permit for its Velella Epsilon project. The permit is to discharge "industrial wastewater" from "a marine net-pen aquaculture facility."

That facility would consist of a support vessel and a floating cage with a water depth of 130 feet. The cage would contain approximately 20,000 Almaco jack obtained from Florida hatcheries and produce an annual harvest of about 80,000 pounds of fish. It could be anchored to the Gulf's floor and stabilized with buoys.

The farmed fish may be treated with antibiotics and other chemicals that flow into the sea, hence the need for a discharge permit.

"The project is intended primarily as a demonstration to show the local fishing and boating community that there are abundant benefits from offshore fish farming and minimal impacts," Kampachi Farms co-founder and chief executive Neil Anthony Sims said.

Kampachi previously deployed demonstration fish pens off the coast of Kona, Hawaii. According to Sims, that project attracted the attention of a National

Geographic television special by famed oceanographer Robert Ballard and received Time Magazine's recognition as one of the "25 Best Inventions of the Year" in 2012.

The net cages served as a "fish aggregating device," a man-made object that can attract fish. "Local recreational, charter boat and commercial fishermen were catching mahi-mahi, marlin, tuna and wahoo around the Velella pens hand over fist," Sims said. "Local dive and snorkel tour operators brought their passengers out to dive on the offshore pen sites."

The company says it will encourage Sarasota area fishermen to use the pen as a fish aggregating device.

The Florida Institute for Saltwater Heritage, a Cortez-based advocacy organization for the commercial fishing industry, did not immediately respond to requests for comment from the Herald-Tribune.

The organizations Friends of the Earth, the Northwest Atlantic Marine Alliance and the Recirculating Farms Coalition are joining forces to discourage the EPA from granting the permit. They contend chemicals flowing out of the pen could disrupt and pollute the natural ecosystem.

"From the release of untreated fish waste and excess nutrients to the overuse of antibiotics and endangerment of marine life, industrial ocean fish farms are nothing but bad news for our oceans," Friends of the Earth states in a position paper.

The environmental group says seals, whales and other wildlife have become entangled in industrial ocean fish farms in British Columbia and Scotland.

"The EPA is failing coastal communities everywhere by allowing this project to move forward in the Gulf," Hallie Templeton, senior oceans campaigner for Friends of the Earth, said in an announcement. "This fish farm will not only hurt Sarasota's local economy and communities, it will impact the entire Gulf ecosystem and harm native fish throughout the region."

Glenn Compton of the local environmental group ManaSota-88 said that organization will provide "detailed comments" to the EPA prior to the Sunday deadline.

"The value of Florida's biologically sensitive areas and endangered and threatened species should not be put at risk for floating fish farms," Compton said. "We should not risk the productivity of our offshore or estuarine areas, which will ultimately prove to be more important for our future than harmful industrial fish farming. Existing state and federal regulations do not address the significant damage fish farming has on the environment. There is no reason to believe that the EPA will protect Florida's economy and environment from the potential serious environmental damage associated with industrial fish farming. Industrial fish farming will place Sarasota's coastal waters, an area of high environmental sensitivity and marine productivity, at risk. Presently the region supports numerous species of wildlife, major commercial and recreational fisheries and several species of endangered animals."

Sims, however, contends any environmental impacts from a "properly sited and well-managed" pen site should be "almost immeasurable."

"America has a moral obligation to start producing more of its own seafood," Sims said. "We cannot continually rely on importing more and more seafood from other countries — most of which is farmed. We are just eating other people's lunch. Where is the morality, or the economic sense, in that?"

Sims emphasized that the project is a demonstration which will be monitored by "universities and other third-party entities. ... And the Sarasota community will also be able to see for themselves. They can troll around the pen to catch a mahi-mahi, watch us feed the fish or put on a snorkel and jump into the water. We want the community to come on out and see what we are doing. That's the whole point of a 'demonstration.'"

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AQUACULTURE ENVIRONMENT INTERACTIONS
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Soundscapes in aquaculture systems

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ABSTRACT: Sound in aquaculture production systems remains poorly understood in terms of both biological effects and engineering possibilities. Open systems such as net pens and traditional ponds are increasingly being complemented by recirculating aquaculture systems (RAS). Each of these systems create soundscapes, which may have a significant effect on the high-value commercial species being farmed. The current study compared recordings of soundscapes from commercial net pens, earthen ponds, and concrete and high-density polyethylene RAS holding systems. Calibrated measurements of each acoustic habitat revealed the range and intensity of sound in each system type. Spectra of each type of holding system were overlaid with the hearing ranges and sensitivity levels of 4 commonly aquacultured fish, common carp *Cyprinus carpio*, European perch *Perca fluviatilis*, red sea bream *Pagrus major* and Atlantic salmon *Salmo salar*, and 1 crustacean, common prawn *Palaemon serratus.* The majority of ambient noise recorded in RAS systems and net pens fell within the 100 to 500 Hz range at or near fish hearing thresholds. While RAS systems are a markedly louder environment for species otherwise held in earthen ponds, the net pen environment clearly represents the most variable and loudest aquaculture holding system, reaching noise levels capable of eliciting a measurable physiological response in many species and revealing a likely source of chronic stress. The long-term stress response of culture animals and performance cost of inappropriate soundscapes remains undetermined. A precautionary approach and optimised system engineering is recommended to reduce the sound impact on culture animals to optimise growth performance.

KEY WORDS: Hearing thresholds · Noise · Stressor · Recirculating aquaculture systems · RAS · Net pen · Pond

1. INTRODUCTION

Rapidly expanding aquaculture is an essential contributor to food security and economic growth worldwide; however, optimal animal welfare and ethical aquaculture methods are key to achieving sustainable production and maintaining consumer demand (Ashley 2007, FAO 2016). There are numerous stressors to animals held in captive aquaculture systems and, while their effects vary, if not managed correctly these typically lead to poor welfare and compromised fish health, ultimately affecting economic profitability and risking alternative purchase responses from high-end consumers (Olesen et al. 2010). Some stressors associated with aquaculture may be unavoidable, and the fundamental goal for successful growth and production is the optimisation of strategies and practices to effectively manage or mitigate stress (Lucas & Southgate 2012). One stressor of increasing interest in aquaculture is noise from biotic, and more importantly, abiotic and anthropogenic sources (Popper 2003). Hearing thresholds, where sound has been shown to elicit a physiological response, have been determined and reported for a large number of aquaculture-relevant species (Ladich & Fay 2013). In previous physiological studies, high anthropogenic noise levels have been shown to alter fish behaviour (Sand et al. 2000, Zhou et al. 2016), decrease growth

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(Filiciotto et al. 2013), damage hearing (McCauley et al. 2003) and increase stress responses (Wysocki et al. 2006), all of which may impact aquaculture production efficiency.

Potentially stressful soundscapes from production systems for commercially valuable aquaculture species remain, however, poorly investigated. There is a lack of information on aquaculture soundscapes and, in particular, a dearth of studies related to the variety of commercial production systems worldwide. Previous studies on noise and aquaculture species welfare in response to underwater sound are largely eco-physiological and relate to bentho-pelagic fish exposed to randomised anthropogenic noise in open seas and coastal areas (Filiciotto et al. 2013). Other preliminary studies of aquaculture species are limited to responses to extreme anthropogenic noise events, such as pile-driving and sounds exceeding 170 dB re µPa (Edmonds et al. 2016, Zhou et al. 2016). Bart et al. (2001) showed that the sound produced in concrete tanks and ponds and fiberglass tanks are loudest in the low-frequency region (25 to 1000 Hz) and within the hearing range of teleosts. Playbacks of soundscapes intended to simulate offshore (boat noise) and onshore (concrete tank) aquaculture environments have recently been shown to significantly affect oxidative status and immune/stress indicators in juvenile bream *Sparus auratus* (Filiciotto et al. 2017). Long-term exposure to inappropriate soundscapes, which can cause chronic stress in laboratory-held rats *Rattus norvegicus domesticus* and compromise animal health and welfare in farmed pigs *Sus scrofa domesticus*, remain uninvestigated in aquaculture species (Van Raaij et al. 1996, Talling et al. 1998).

Aquaculture animals are exposed to a series and variety of system soundscapes throughout their production cycle. Pond and sea cage/net pen systems dominate finfish production worldwide (FAO 2016). Net pens are the primary method of production for salmonids and marine finfish; in excess of 5 million t of Atlantic salmon *Salmo salar* are produced per year worldwide in temperate and sub-polar waters (FAO 2016). Also, large-scale European sea bass *Dicentrarchus labrax* and sea bream *Sparus aurata* net pen operations exist in the Mediterranean (Barazi-Yeroulanos, 2010). Earthen-lined and concrete pond systems in Asian nations are overwhelmingly the largest producers of finfish (FAO 2016). They are also pivotal in production of several species of shrimp and other high-value invertebrates worldwide with export markets of several million tonnes annually (FAO 2016). Recently, industry growth has been starkly impacted by space limitations and disease, while food safety and environmental concerns have impacted consumer acceptance (Ha et al. 2013). There is growing demand for ecologically sustainable, ethically produced high-end aquaculture products (FAO 2010, 2014). With increasing commercial pressure to efficiently use limited open aquaculture sites for ongrowing only, juvenile and early adult life-stage finfish are increasingly being held for longer periods in land-based recirculating aquaculture systems (RAS) (Joenson 2016). RAS systems are also increasingly important for the full production-cycle holding of high-value invertebrate species such as whiteleg shrimp *Litopenaeus vannamei*, as well as finfish, e.g. yellowtail kingfish *Seriola lalandi*. Each of these systems represent acoustic habitats worthy of more in-depth investigation in aquaculture research due to their potential link to possible behavioural or physiological effects on culture animals which may impact performance characteristics.

In the following study, passive acoustic recordings were made in 4 holding systems representing commercial aquaculture production worldwide: offshore net pens in New Zealand, onshore earthen ponds in Indonesia and onshore RAS systems constructed from concrete and high-density polyethylene (HDPE) in Germany. The soundscapes of each were compared with reported sound sensitivity thresholds for the most important aquaculture species available. Implications for production system choice and species limitations are reported.

2. MATERIALS AND METHODS

2.1. Locations and production systems

Passive acoustic recordings of underwater sound were performed in operating RAS, pond and net pen aquaculture systems. In all cases, except in ponds, continuous 24 h recordings were made using a ST300 hydrophone (Oceaninstruments; flat frequency response 20 Hz to 60 kHz) at 48 kHz, giving an upper analysable frequency limit of 24 kHz. All hydrophones were calibrated using a sound calibrator (G.R.A.S. Type 42AB) producing a 1 kHz signal at 114 db re 1µPa. In ponds, due to access and time constraints, only 3 representative ca. 2 min recordings were made from 3 ponds during normal operation. The pond recordings were made during daytime with fully operational paddlewheels at and directly after feeding. Paddlewheels run 24 h d^{-1} at the site, feeding is by hand 4 times daily. No aeration, pump-

ing, physical intrusion or water disturbance is possible at the ponds.

RAS measurements were made at the Garnelen Farm Grevesmühlen, situated at Am Baarssee 5, 23936 Grevesmühlen, Germany, between 16 and 19 June 2017. The farm consists of twin RAS systems, located indoors, with a total volume of 200 m^3. While RAS systems vary widely, particularly in terms of depth and tank size and make, the systems at Grevesmühlen are broadly representative of RAS systems used around the world in terms of sound sources. Each system consists of a moving-bed RAS biofiltration system, a solids removal drum filter connected to 2 large free-standing tanks each of ca. 80 m^3 total volume and tank dimensions ca. 35 × 5 × 1 m (length × width × height) and filled to a water depth of ca. 0.7 m. One system is made of ultra-high density cement slabs with a wall thickness of 50 mm, the other system is made of HDPE plate with a thickness of 10 mm. Whiteleg shrimp *Litopenaeus vannamei* are held at densities of up to 3.5 kg m^{-3} or ca. 150 animals m^{-2} within the tanks. In addition to standard filtration components, potential sound sources in the RAS systems include water pumps, air injection systems and reverse flushing spray units on the drum filters. Hydrophones were hung midwater (0.4 m depth and 0.3 m to the nearest surface) centrally in tanks at 3 points equidistant from tank walls but at increasing distance along the tank length from the water processing system/pump house.

Recordings in pond systems were made at a small commercial whiteleg shrimp *L. vannamei* facility in Kraksaan, Probolinggo/Malang, East Java, Indonesia, on 20 November 2017. The farm consists of 5 polyethylene film-lined earthen ponds of ca. 2000 m^2 connected by single supply and drainage channels to an estuarine water supply. Pond dimensions are ca. 40 × 50 × 3 m (length × width × height) and are filled to a water depth of ca. 1.5 m. Ponds were initially stocked with ca. 250 shrimp m^{-2}. Potential sound sources in the pond systems are limited to surface aeration units (paddlewheels) only. Hydrophones were hung midwater (0.5 m depth and 0.75–1.0 m to the nearest surface) in ponds at 3 points (from access walkways above the ponds) equidistant from pond walls and from paddlewheels.

Recordings were made at 3 points (1 in the centre of the farm and 2 at farm edges) at the NZ King Salmon Farm at Ruakaka Bay, Marlborough Sounds, New Zealand, between 6 and 11 December 2016. Recordings were also made at 3 reference sites to compare the sound generated by the farm to ambient/background marine sound. The farm consists of 12 net pens with a surface area of 225 to 250 m^2 and a depth of 15 m mounted on a floating barge and floating HDPE walkway system. Net pens were stocked with varying densities and sizes of Chinook salmon *Oncorhynchus tshawytscha.* In addition to the floating structures and the stocked fish, potential sound sources included access vessels, an associated feed barge, oxygen storage, compressed air automated feeders and a temporary handling facility linked to the site. Hydrophones were hung at 3 points to a depth of ca. 2.5 m at the pen edge (1 m to the nearest surface), within a net pen and from an access walkway ca. 1 m beyond the pen edge. Recordings at reference sites were made at 2.5 m depth. Reference sites were a navigation buoy (nav. buoy) within the shipping lane of an associated sound (representative of a highly anthropogenically impacted soundscape), a jetty mooring (jetty) in a quiet bay 1.2 km from the farm and a mooring buoy (mooring) ca. 2 km from the farm (representative of background noise levels).

2.2. Sound processing and analysis

For net pen and RAS data, RMS levels of the power spectral density (PSD), 1st, 5th, 50th, 95th and 99th percentiles and spectra probability density (SPD) were calculated for each tank position as 5 min averages of the 24 h recording. The percentage of recordings with boat noise in them was determined on these 5 min averages. To compare the ponds from Indonesia to those of the RAS systems from Germany and net pens from New Zealand, RMS levels of the PSD were plotted. All sound spectral analyses were carried out in MATLAB using scripts adapted from PAMGuide (Merchant et al. 2015). These spectra were visually assessed to examine general trends in acoustic behaviour. In order to determine the actual impact on key aquaculture species, both physiological and behaviourally determined hearing threshold data from the literature was manually overlaid onto PSD plots of soundscapes in each aquaculture system. Key species selected were common carp *Cyprinus carpio*, Atlantic salmon *Salmo salar*, European perch *Perca fluviatilis*, red sea bream *Pagrus major* and common prawn *Palaemon serratus*.

3. RESULTS

Overall, sound levels were consistently higher at the net pen farm, ranging from 107 to 112 dB re 1µPa, depending on hydrophone position within the farm.

These levels were higher compared to 2 of the control sites, jetty and mooring, which ranged from 98 to 99 dB re 1µPa (Table 1). The location of the hydrophone in the RAS system affected overall sound levels: closer to the pump house was louder than the opposite end of the tank. Type of tank also affected the sound levels, with HDPE being on average slightly quieter than concrete tanks (Table 2). The quietest system was the earthen pond (Table 2).

Table 1. Sound levels (dB re 1µPa) at the 3 locations within the salmon farm aquaculture site and 3 control sites in Marlborough Sounds, New Zealand. RMS: root mean square ± SE; 95%: 95th percentile; 5%: 5th percentile; Boat N.: percentage of recordings with boat noise

	Inside farm	Farm #1	Farm #2	Reference sites		
				Jetty	Mooring	Nav. buoy
RMS	107 ± 1	112 ± 1	110 ± 1	98 ± 1	99 ± 1	107 ± 1
Median	108	112	109	99	100	109
95%	120	128	125	110	112	120
5%	87	90	88	77	76	86
Boat N. (%)	65	65	65	11	8	52

PSD levels at the nav. buoy associated with a shipping channel (Fig. 1F) site were similar to all locations at the salmon farm site. All sites exhibited a large amount of variability in PSD levels, with differences between the 1st and 99th percentiles ranging from 20 to 60 dB. The inside net pen farm site (Fig. 1C) had an unusual notch in the PSD between 200 and 700 Hz which was not observed at any of the other recording sites. Both the outside net pen farm sites (Fig. 1A,B) had higher PSD levels between 20 and 1000 Hz compared to the mooring and jetty sites, which only had increased low-frequency PSD levels between 30 and 100 Hz. Above 1000 Hz, the net pen farm sites were also louder than all control sites.

The only notable differences between the 2 RAS systems was that the concrete tanks were louder on average and that position in relation to the pump house influenced the recorded sound levels. Below 1000 Hz, there was <1.5 dB difference between the 1st and 99th percentiles, indicating there was little variation in PSD in both the indoor tank types and hydrophone position in relation to the pump house. However, above 1000 Hz, there was large variation between 5 and 20 dB between the 1st and 99th percentiles (Fig. 2). On average, the variability of measured sound in net pen systems was much greater than in the indoor RAS systems.

The short-term analysis of the earthen pond recordings showed that sound levels were markedly lower compared to the indoor RAS system and the outdoor net pen farm (Fig. 3). In the frequency band 30 to 300 Hz, the outdoor pond system was on the order of 10 to 30 dB quieter than both indoor RAS systems and the outdoor net pen system (Fig. 3).

Both the indoor RAS systems and the outdoor net pen farm produced significant noise at low frequencies, <500 Hz, which fall within the most sensitive part of the hearing range of the large majority of aquaculture species (Figs. 4 & 5). For example, the noise produced by indoor RAS systems and outdoor net pen systems met or exceeded the physiological and behaviourally determined hearing thresholds of common carp, Atlantic salmon and European perch at 100 Hz (Figs. 4 & 5). The earthen pond shrimp system did not exceed the hearing thresholds of the 5 represented aquaculture species except the common carp between 500 and 1000 Hz.

4. DISCUSSION

Quantifying the full range of soundscapes in aquaculture production systems is essential to understanding the role of sound as a potential stressor to varying (motile) aquaculture species. In this study, original recordings were analysed, not only from land-based systems (concrete RAS, HDPE RAS and earthen ponds) but also sea-based systems (net pens), showing that net pen culture systems were considerably louder and more variable compared to RAS and earthen pond systems, with earthen pond systems being the qui-

Table 2. Sound levels (dB re 1µPa) at the recirculating aquaculture system (RAS) site in Grevesmühlen, Germany, and the pond aquaculture site in East Java, Indonesia. RMS; root mean square ± SE; 95%: 95th percentile; 5%: 5th percentile; HDPE: high-density polyethylene

	Concrete			HDPE			Earthen pond
	Closest pump house	Mid-tank	Farthest pump house	Closest pump house	Mid-tank	Farthest pump house	
RMS	103 ± 1	100 ± 1	96 ± 1	102 ± 1	98 ± 1	96 ± 1	75 ± 1
Median	103	101	96	102	99	95	
95%	106	102	98	103	99	97	
5%	102	100	94	100	97	94	

ASSOCIATION OF FISHES WITH FLOTSAM IN THE OFFSHORE WATERS OF CENTRAL AMERICA

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ABSTRACT

During April, May, June, and October, 1963, a total of 70 purse seine collections were made of the fishes associated with floating objects. Nearly all of these collections were from the offshore waters of Costa Rica. Twelve families of fishes (Lobotidae, Carangidae, Coryphaenidae, Mullidae, Kyphosidae, Pomacentridae, Scombridae, Blenniidae, Stromateidae, Mugilidae, Polynemidae, and Balistidae) and 32 species were represented in the collections. Most of the species were present during both spring and fall, and nearly all of the fishes were juveniles.

Nine of the 32 species, including the 2 most abundant ones, *Caranx caballus* Günther and *Selar crumenophthalmus* (Bloch), were carangids. The lengths of two species, *Abudefduf saxatilis* (Linnaeus) and *Seriola* sp. were greater the farther an object was located from shore. Some species such as *C. caballus, Psenes pacificus* Meek and Hildebrand, and *Canthidermis maculatus* (Bloch) were present in almost a complete series of juvenile stages; others as *Chromis atrilobata* Gill, *Pseudupeneus grandisquamis* (Gill), and *Agonostomus monticola* (Bancroft) were represented by only a single juvenile stage. More fishes were collected under large objects than under small objects. The total number of individuals present near moored objects after 5 days did not differ from the numbers present after 20 or more days. The coloration of fishes was related to their association behavior. Silvery colored fishes did not remain as close to the object as did the more darkly colored species. Most adult fishes, which did not remain as near the object as did juveniles, appeared beneath an object only intermittently. *Canthidermis maculatus*, however, maintained close contact with drifting objects both as adults and juveniles.

Observations of the behavior of species are discussed in relation to the mechanisms for the association of fish with flotsam that have been postulated by other authors. None of their hypotheses was supported by our data. Additional mechanisms were postulated.

The association of fishes with floating objects has been exploited by a number of fisheries. Japanese pole-and-line fisheries and American purse seine and live-bait fisheries take advantage of the association of yellowfin tuna, *Thunnus albacares* (Bonnaterre), and oceanic skipjack, *Katsuwonus pelamis* (Linnaeus), with algae, logs, and other flotsam (Uda, 1933; McNeely, 1961). Uda and Tsukushi (1934), and Yabe and Mori (1950) reported that log-associated schools of tuna provide a consistently higher yield per unit fishing effort than unassociated schools.

Moored rafts of bamboo or palm fronds are used to attract dolphin-fish, *Coryphaena hippurus* (Linnaeus), in seine fisheries of Japan (Kojima, 1955, 1956, 1960a, 1960b, and 1961). Moored cork-slabs serve the same purpose for Maltese fishermen (Galea, 1961). Two types of palm-frond rafts are used by Indonesian fishermen to attract various clupeids, scombrids, *Decapterus* spp., and other carangids (Hardenberg, 1950; Soemarto, 1960). In addition to these commercially important species, many others of lesser or no commercial value are also encountered (Murray and Hjort (1912), Yabe and Mori (1950), Uchida and Shojima (1958), Besednov (1960), Kojima (1960a), Mansueti (1963), and Gooding and Magnuson[1]).

Note: Approved for publication March 8, 1966.

[1] Reginald M. Gooding and John J. Magnuson—Observations on the ecology and behavior of fishes around a drifting raft near Hawaii during the first 48 hours adrift. Manuscript, Bureau of Commercial Fisheries Biological Laboratory, Honolulu, Hawaii.

Gooding and Magnuson reviewed the hypotheses that have been advanced to explain this habit: (1) attraction by food (smaller fish, algae, decaying palm fronds, and plankton made more visible by the shade of the object); (2) negative phototaxis in response to the shadow cast by the object; (3) shelter from predators; and (4) use of the object as a spawning substrate. They also suggested an additional hypothesis that floating objects are cleaning stations where pelagic fishes go to have their parasites removed by other fish.

This paper provides information on the ecology and behavior of fishes associated with floating objects in the offshore waters of Central America. Special attention is given to the frequency, abundance, and size of the species which compose flotsam-associated aggregations and how these characteristics are related to the location and size of the object. These studies are the framework upon which future behavior investigations will be based. The aim of our program is to determine whether a device can be designed that will be maximally efficient in aggregating tuna and skipjack. The potential value to the tuna fishery of establishing such devices has been discussed by Alverson and Wilimovsky (1963).

PROCEDURES

Nearly all of our studies were in the offshore waters of Costa Rica (fig. 1) because yellowfin tuna and skipjack are often associated with the flotsam in this region (logbook records obtained through the courtesy of the Inter-American Tropical Tuna Commission). Several collections were near the coast of southern Mexico and 1 near Cocos Island. Samples were collected by encircling flotsam and its associated fauna with a small 7/16-inch (11 mm.) stretch-mesh purse seine, 12 feet deep (3.7 m.) and 110 feet (33.5 m.) long (Aasted, MS.)[2]. An average of 66 percent of the fishes observed beneath an object were captured in the seine. Fish larger than 100 mm. standard length may have escaped the net, and fish smaller than 15 mm. occasionally swam through the webbing. When the net was set, fish tended to stay near the flotsam or even swim upward. Thus, fish swimming at a depth greater than the maximum depth of the seine also may have been caught. Sampling errors due to fish escaping from or entering the seined cylinder of water were probably small.

[2] Donald C. Aasted, A miniature purse seine for capturing small pelagic fishes. Manuscript, Bureau of Commercial Fisheries Tuna Resources Laboratory, La Jolla, Calif.

Twenty-three purse seine collections of fishes were made during April, May, and June, 1963, and 47 during October. Of these samples, 62 were of fishes associated with naturally occurring flotsam, and 8 were of fishes collected beneath moored logs, buoys, and other objects.

After a collection was made, the success of the set was estimated, the object was described and measured, and motile and attached organisms were preserved. In the October studies, to determine the rate and direction of movement of drifting materials, all objects were tagged and marked with a small flag prior to release. Underwater observations and cinematic photographs were used to describe the behavior and estimate the abundance of fishes.

CHARACTERISTICS AND DISTRIBUTION OF FLOTSAM

Far more drifting materials were in the study area in October than in the spring. The Gulf of Nicoya was littered with floating logs and other plant debris. The greater abundance of flotsam in October was not surprising because rainfalls are usually heaviest during this period (Peterson, 1960).

Fish were not seen beneath the flotsam in the Gulf and were only rarely associated with inshore logs between Cape Blanco and Piedra Blanca (fig. 1). Northwest of this area, however, nearly every drifting object encountered had its own associated fish population. Most often these objects were aggregated in areas of current convergence.

During April, May, and June, currents in the area usually set northwest at an estimated 2 knots; currents also set northwest during October but were not as strong. Three logs tagged in October and later recovered had drifted northwest at 0.28, 0.45, and 0.33 knot.

Only one of the drifting objects sampled had attached invertebrates—goose barnacles, *Conchoderma virgatum* (Spengler). This species and other goose barnacles of the genus *Lepas* were found in quantity on moored objects after 14 or more days.

Adult and megalops grapsoid crabs of the genus *Plagusia* were numerous on nearly all logs. Individuals in the megalops stage frequently were swimming near drifting objects.

SEASONAL VARIATION IN OCCURRENCE OF FISH

Over 12,000 fishes were captured beneath floating objects in this study; 12 families and 32 species were

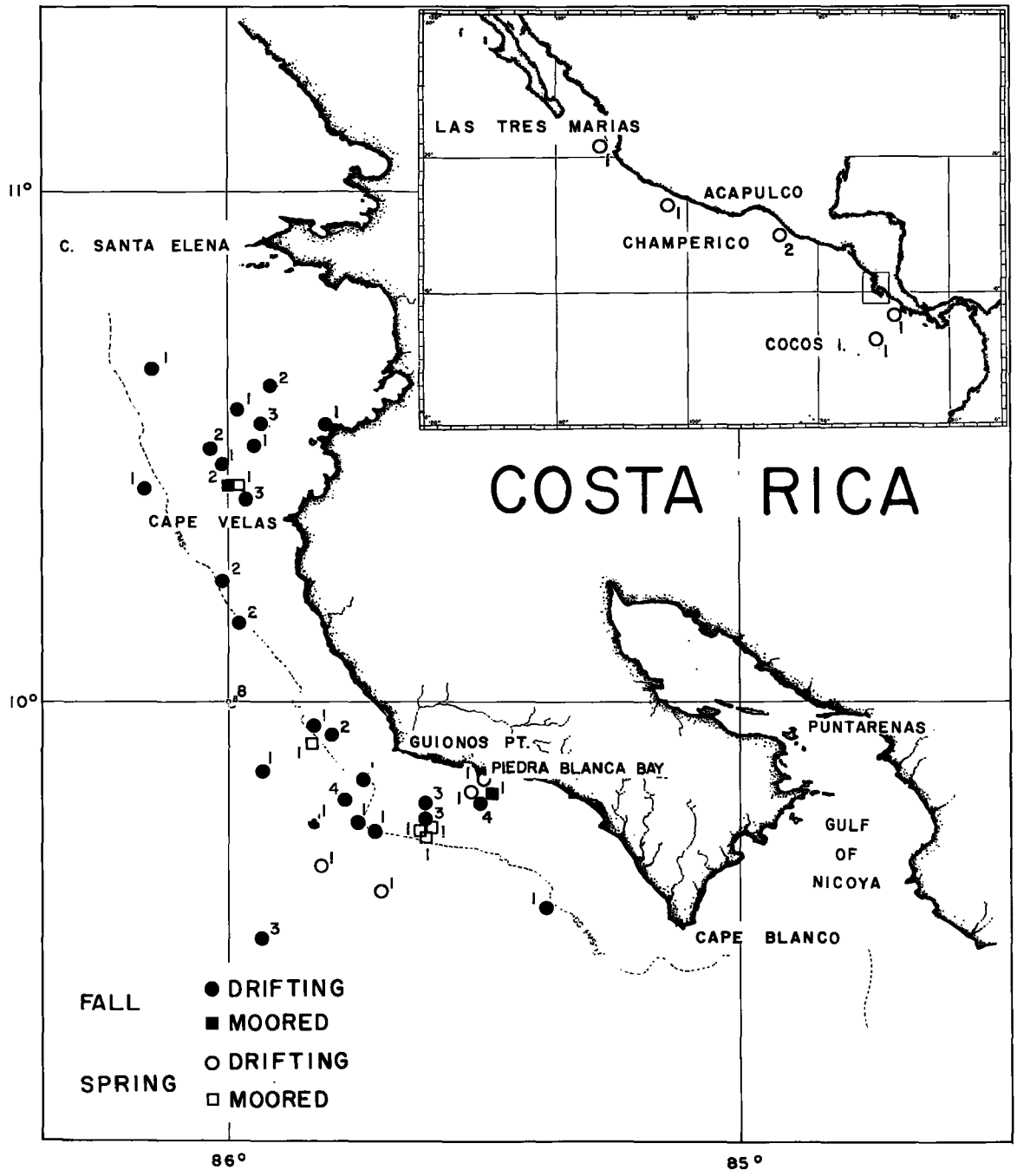

FIGURE 1.—Positions of collections made of fishes beneath flotsam in April, May, and June 1963 (spring) and October 1963 (fall). Numerals indicate number of collections made in each locality. Inset at top shows location of study area and position of the six collections made outside this area.

represented. The scientific name, family, and season of occurrence of these species are presented in table 1. Abbreviated names are used in the text and subsequent tables.

There was little seasonal variation in the occurrence of species. Twenty-four of the total of 32 species were captured or observed during both spring and fall. The seasonal occurrence of adult

All About the Bass: How Baleen Whales Hear Very Low Frequencies

By Laura Geggel January 29, 2015

A fin whale skull helped researchers study the acoustical properties of whale skulls.

(Image: © SDSU)

Baleen whales, the largest creatures on Earth, can send extremely low-frequency underwater calls to one another. But little is known about how they actually process these sounds. Now, researchers have found that the whales have specialized skulls that can capture the energy of low frequencies and direct it toward their ear bones to hear.

Baleen whales, which use baleen plates in their mouths to filter out tiny organisms and other food from the ocean, have two ways of hearing sound, the researchers found. If the sound waves are short — that is, shorter than the whale's body — the sound's pressure waves can travel through the whale's soft tissue before reaching the tympanoperiotic complex (TPC), which holds the whale's rigid ear bones on its skull.

But if the sound waves are longer than the whale's body, they can vibrate its skull in a process known as bone conduction. These longer wavelengths can be amplified, or louder, when they vibrate the skull, the researchers said. [Images: Sharks & Whales from Above]

In 2003, despite rescue efforts, a young fin whale (*Balaenoptera physalus*) died after it beached itself on Sunset Beach in Orange County, California. The researchers saved the whale's head and used it in their study. The whale's head was placed in a CT scanner so that it could be modeled on a computer. The resulting model included the whale's skin, skull, eyes, ears, tongue, brain muscles and jaws, and allowed the researchers to simulate how sound might travel through the whale's head.

The model may only show the fin whale's anatomy, but the scientists hope to study other types of baleen whale species, including blue whales, minke whales, right whales and gray whales, the researchers said.

Before running the simulations, the researchers used a method known as finite element modeling, which breaks down the model skull into tiny pieces and tracks how they work with one another. It's almost like dividing the whale's head into Lego blocks, said San Diego State University biologist Ted Cranford, one of the study's researchers. During simulation trials, the distinct "blocks" allowed them to see how each component of bone vibrated at different frequencies.

A labeled, computer model skull of the fin whale (Balaenoptera physalus). (Image credit: SDSU)

"At that point, computationally, it's just a simple physics problem," Cranford said in a statement. "But it's one that needs lots and lots of computational power. It can swamp most computers."

The simulations showed that the whale's bone-conduction mechanism is about four times more sensitive to low-frequency sounds than the pressure mechanism that goes through the TPC. In fact, the lowest frequencies used by fin whales (10 hertz to 130 hertz) is up to 10 times more sensitive in cases of bone conduction, the researchers found.

"Bone conduction is likely the predominant mechanism for hearing in fin whales and other baleen whales," Cranford said. "This is, in my opinion, a grand discovery."

The new finding may help strengthen the case for laws that limit the amount of man-made noise pollution thought to interfere with the whales' underwater calls, including noise from commercial shipping, military exercises and drilling operations for oil and natural gas, the researchers said.

"What our contribution does is give us a window into how the world's largest animals hear, by an odd mechanism no less," Petr Krysl, an engineer at the University of California, San Diego, said in a statement. "This research has driven home one beautiful principle: Anatomic structure is no accident. It is functional, and often beautifully designed in unanticipated ways."

The study was published online today (Jan. 29) in the journal PLOS ONE.

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MOST READ MOST SHARED

1 These tiny, little-winged dinosaurs were probably worse at flying than chickens

USA TODAY

NATION

Red tide, the toxic algae bloom that kills wildlife, returns to southwest Florida

Doug Stanglin USA TODAY

Published 12:20 p.m. ET Nov. 13, 2019 | **Updated 2:56 p.m. ET Nov. 13, 2019**

Southwest Florida is warily watching the approach of another red tide invasion to its shores one year after a toxic algae bloom cost the tourist and fishing industry millions of dollars in losses.

While algae blooms are essentially tiny plants in the ocean that provide food for animals, harmful algal blooms, or HABs, multiply out of control, producing toxic or harmful effects for people, fish, shellfish, marine mammals and birds.

Red tide, caused by the organism Karenia brevis, occurs naturally in the Gulf of Mexico but is thought by many water quality scientists to be fed near shore by excess nutrients coming from the historic Everglades, which stretches from just south of Orlando to the Florida Keys.

Farm runoff containing nitrogen and phosphorus also feeds the bad algae and triggers explosive growth.

The Florida Fish and Wildlife Conservation Commission reports a new outgrowth of a troubling bloom along parts of the southwest Florida coast last week, particularly around Sarasota, Charlotte, Lee and Collier counties.

While this year's bloom, so far, is not as extensive or deadly as last year's, the outbreak is strong enough to kill various wildlife species that depend on coastal food and habitat.

"We have definitely been seeing red tide patients for several weeks now," said Joanna Fitzgerald, director of the Conservancy of Southwest Florida's von Arx Wildlife Hospital in Naples. "The main ones are the double-crested cormorants (seabirds). They're the big (indicator species). When you see them stumbling along the beach, you know what's going on."

What is red tide? A look at how red tide sparked a state of emergency in Florida last year

In a 1996 bloom, 149 manatees died off the coast of Florida while more than 740 bottlenose dolphins died from 1987 to 1988 after eating contaminated fish, according to Smithsonian Ocean.

The bad blooms can also be an irritant for swimmers, causing eye, skin and respiratory ailments, and are particularly dangerous to consumers of tainted shellfish.

Red tide may be most severe for people with preexisting respiratory conditions, such as asthma, according to the National Oceanic and Atmospheric Administration.

Last year, Florida businesses reported nearly $150 million in losses from the killing of fish and other marine creatures that had littered beaches and drove off tourists.

The scope of a threat from red tide is how tightly the microscopic cells are concentrated in the ocean waters. The cells are normally found in concentrations of 1,000 cells per liter of water or less, which is harmless. But once it hits 10,000 cells per liter of water, fish begin to die and humans and other animals can experience breathing irritation, the Florida Fish and Wildlife Commission says.

In last year's red tide calamity, counts of 1 million cells per liter and higher were reported from the Tampa Bay area south to Everglades National Park.

That bloom spread as far as the east coast and Panhandle, killing millions of fish and eels, hundreds of dolphins and sea turtles, untold numbers of birds and even a 27-foot whale shark.

In Lee County – the epicenter of the bloom – the recreational fishing industry and the local tourism- and real estate-driven economy were hard hit, leaving beachfront restaurants and hotels largely empty.

The lifespan of blooms is highly unpredictable. After one moves into an area, it steadily grows and within a few weeks, can reach concentrations deadly for fish. In the development stage, winds and currents shift the bloom around and – if it moves inshore – nutrient runoff may spur its further growth.

More: Red tide appears to be strengthening along the Southwest coast

The Florida wildlife commission says a bloom can linger in coastal areas for days, weeks or even months.

Such blooms are “a national concern because they affect not only the health of people and marine ecosystems, but also the 'health' of local and regional economies,” according to NOAA.

In Washington, the House passed a bill in September aimed at finding a solution to the red tide plague. A Senate committee was scheduled to take up a similar bill this week.

Contributing: Chad Gillis, Fort Myers News-Press

Editor's note: This post originally appeared on UF/IFAS Blogs

By: Lisa Krimsky, Betty Staugler, Brittany Hall-Scharf, Krista Stump and Rebecca Burton

Florida's lingering red tide has left many concerned residents with unanswered questions. Over the past 14 months since the bloom began off the coast of Southwest Florida, residents have voiced concerns about fish kills, economic impacts and environmental damage. Mixed messages from a variety of sources has made this already difficult situation even more confusing.

Using up-to-date, science-based information, faculty with UF/IFAS Extension and Florida Sea Grant have written this blog post to answer some of the most frequently asked questions about red tide.

What is red tide?

Red tides are caused by an accumulation of a type of microscopic organism called a dinoflagellate, which is found in lakes, rivers, estuaries and the oceans. The particular dinoflagellate that causes Florida's red tide blooms is *Karenia brevis*.

It's important to note that not all red tides are caused by the same species, nor are they always red. Most dinoflagellates are harmless. Though some, including *K. brevis*, produce neurotoxins that can cause respiratory problems in humans and attack the central nervous systems of fish and other wildlife. Many scientists refer to blooms of *K. brevis as* harmful algal blooms (HABs) due to the impacts they can have on the environment, humans, and our coastal economies. Though HAB is the preferred terminology, this post includes the term red tide as it is recognizable to the public and media.

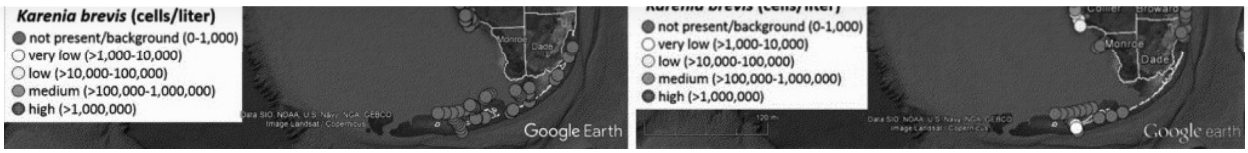


Figure 1: Red tide status map for October 2017 and November 2018.Source: FWRI

What causes red tide?

Red tide blooms are exclusively initiated in the Gulf of Mexico, where *K. brevis* is almost always present at low and harmless concentrations. Red tides are not uncommon and occur almost annually in the Gulf, particularly in the Tampa Bay to Charlotte Harbor region. The first scientifically documented red tide bloom in Florida dates back to 1844, predating extensive human development.

Florida's red tides can appear throughout the year, though they usually peak late summer to early fall and can last from a few days to months. The current Florida red tide started in October 2017 and to date, is still present on the west coast (Figure 1). Since the Florida Fish and Wildlife Conservation Commission Fish and Wildlife Research Institute (FWRI) started monitoring red tides in 1954, only four previous blooms have lasted longer (Figure 2). Though, this one is still ongoing.

Figure 2: Longest documented Florida red tide blooms on record. *2017-2018 bloom on-going. Data: FWRI

Red tide blooms originate naturally 10-40 miles offshore in the bottom waters of the Gulf of Mexico. *K. brevis* cells that hang out at the bottom are brought to the surface by a phenomenon known as upwelling, a process in which deep, cold and

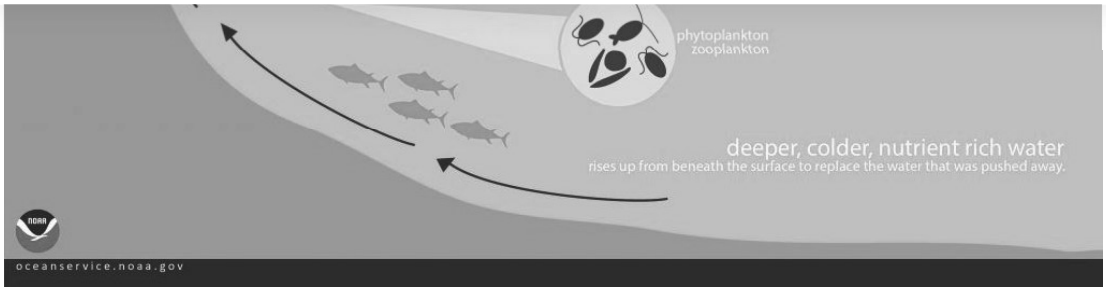


Figure 3: This graphic shows how displaced surface waters are replaced by cold, nutrient-rich water that "wells up" from below. Conditions are optimal for upwelling along the coast when winds blow along the shore. Source: NOAA

algae, requires three things to grow and survive: optimal light, temperature and nutrients, specifically nitrogen and phosphorus. The sources of these nutrients vary among the offshore, nearshore, and estuarine environment. Nutrient sources also vary spatially, or north to south. In other words, nutrient sources in Sarasota may differ from those further south in Fort Myers.

K. brevis, unlike other phytoplankton species, can feed on a variety of nutrient sources, in a variety of forms. For this reason, it is impossible to link a red tide bloom to one particular source of nitrogen or phosphorus.

While offshore, a small bloom of *K. brevis* can begin by using the nitrogen produced by the nitrogen-fixing algae, *Trichodesmium.* This is because *Trichodesmium* can "fix" nitrogen or obtain it from the atmosphere and convert it to a form that is usable by *K. brevis.* Other sources of nutrients in the offshore environment include zooplankton and microplankton excretion, grazing food waste, and benthic flux, or the exchange of nutrients from the sediment to the water.

Once the bloom moves nearshore, nutrients associated with decaying red tide and fish kill biomass are among the most significant nutrient sources for blooms. So much so, that red tide has been considered nearly self-sustaining. Nearshore red tide blooms can also obtain nutrients from air pollution, releases from rivers and estuaries, and estuarine flux, or the exchange of nutrients to and from the estuary.

the east coast of Florida.

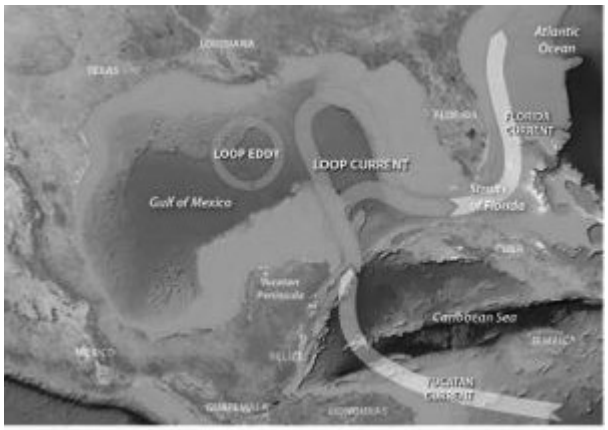


Figure 4: The Loop Current is an area of warm water that travels up from the Caribbean into the Gulf of Mexico. It exists the Gulf through the straits of Florida joining with the Antilles Current to become the Gulf Stream. Source: UCAR and NASA

One thing that makes this year's bloom unique is its presence on the east coast of Florida. Since 1953, there have been only eight other reported blooms on the east coast. Scientists hypothesize that in early October 2018, red tide cells in Monroe County got picked up and transported by the Florida Loop Current to the east coast (Figure 4).

When will the red tides end?

The duration of a bloom is dependent on a variety of chemical, physical and biological factors such as available nutrients and sunlight, temperature, wind, predation by zooplankton, and competition with other species. Therefore, it is hard for scientists to predict when blooms will end.

What are the impacts of a red tide?

K. brevis is considered harmful because it produces a variety of natural toxins, the most important of which are the neurotoxic brevetoxins. Through inhalation, direct contact or ingestion, these toxins, in high enough concentration, can harm and kill fish, birds, and marine mammals. The current red tide has resulted in serious impacts to fish, marine mammals, marine birds, residents and coastal businesses. These types of impacts are typical during severe red tide events. However, more fish have died during this red tide in Lee and Charlotte counties compared to past severe red tide events, and it's not over.

In addition to the impact to sea life, red tides can have human health impacts. Exposure to brevetoxins occur through inhalation or ingestion. *K. brevis* cells are weak, so wave action can

populations may experience chronic pulmonary symptoms, even after leaving the area. During severe red tide events, brevetoxins can be detected 1-2 miles inland from the beach. For these reasons, at-risk populations are cautioned to avoid coastal areas with active red tides.

Red tides can also result in significant economic impacts. Economic costs are associated with four main sectors: recreation and tourism, commercial fisheries, public health, and monitoring and management costs. There is also the potential for a decline in residential home value due to red tide, though these costs have not been examined.

- Red tides are estimated to cause more than $20 million in tourism-related losses in Florida each year.
- The 2015-16 red tide event resulted in a sales loss of $1.33 million to the hard clam aquaculture industry.
- Health costs attributed to medical expenses and lost work days associated with HABs cost the United States $22 million dollars annually. According to the Florida Department of Health, treatment of respiratory illness in Sarasota County during the 2015-16 red tide event averaged $0.5 to $4 million dollars.
- In 1998, clean-up costs associated with the disposal of millions of tons of dead fish and marine life has been estimated to be nearly $163,000 annually for Florida. However, severe events such as the current one can be significantly costlier where totally cleanup costs for all affected areas can reach in the millions of dollars.

Is it safe to eat locally caught seafood when there is a red tide?

Whether or not seafood is safe to eat during a red tide is dependent on the type of seafood being consumed and where it was harvested from.

Filter-feeding bivalves such as clams, oysters, and mussels can accumulate *K. brevis* toxins in their tissues, though there is no evidence that they are susceptible to the toxin themselves. The brevetoxins are tasteless, odorless and are not destroyed by cooking. Commercially available shellfish is safe because it is harvested from areas that are monitored by the Florida

eating the contaminated shellfish. No fatalities have been attributed to NSP to date.

Shellfish require approximately two to six weeks to purge the toxins from their tissues, though this can vary greatly. Once a red tide event has dissipated to less than 5,000 cells per liter, shellfish meat samples are tested for toxicity before harvesting areas can be reopened.

Like oysters and clams, scallops are bivalve molluscs that filter tiny particles from the water column for food. During red tide blooms, the toxins produced by *K. brevis* are also filtered by the scallops and accumulate in their gut. Scallop harvest zones are managed by the Florida Fish and Wildlife Conservation Commission who will close certain scallop harvest areas in response to red tide blooms. Scallops are safe to consume if they are harvested from open scallop harvesting areas during a red tide bloom. However, it is recommended that only the white muscle, and not the whole organism, be consumed.

Other shellfish, such as crabs, shrimp, and lobsters, as well as local finfish are generally safe to eat during red tide blooms because they do not accumulate the toxins in their muscles. However, just like scallops, red tide toxins can accumulate in the guts of finfish or the hepatopancreas (tomalley) of shellfish so these parts should be discarded. In addition, animals found dead or distressed in red tide areas should never be eaten.

Can we stop red tide blooms?

Currently there is no effective way to stop a red tide bloom without potentially causing harm to the overall ecosystem. The harmful effects we experience occurs when red tide toxins are released as the *K. brevis* organism dies. As such, potential controls would need to kill the *K. brevis* organism and remove the toxins from the water — all without causing harm to the ecosystem.

Red tides may be as large as 10,000 square miles – and they occur throughout the entire water column, making irradiation impractical. However, scientists from Mote Marine Laboratory and Woods Hole Oceanographic Institute are currently studying methods to control and mitigate red tide in localized areas such as dead-end canals and small embayments in red tide-affected coastal communities.

Marine Laboratory & Aquarium

Click here to help us address red tide and other urgent challenges facing our oceans. (https://mote.org/pages/help-mote-2018)

There are thousands of species of algae in fresh and marine waters; these organisms form the basis of the food web and provide an important source of the oxygen we need to breathe. While most species are harmless to humans and animals, a growing number of species are being found worldwide that produce toxins that can make humans sick and cause widespread ecological and economic harm. These are known as harmful algal blooms.

Floridians along the Gulf Coast are probably most familiar with *Karenia brevis*, the organism that causes our own red tides, which can result in massive fish kills, the deaths of marine mammals, sea turtles, sea birds and — for humans — neurotoxic shellfish poisoning and respiratory impacts, especially for those with asthma and other chronic respiratory conditions.

Mote researchers from many different disciplines investigate Florida's red tide to understand how blooms form, how they dissipate and what affects the blooms have on human and animal populations. Our holistic approach to understanding red tide is necessary to uncover the environmental impacts of this naturally occurring organism. It is also the key to managing and mitigating the effects of red tide on coastal residents, Florida visitors and animal populations.

Quick Links: Forecasts/Current Conditions

- Florida Fish and Wildlife Conservation Commission Red Tide Task Force (https://myfwc.com/research/redtide/taskforce/)
- Blue Green Algae Task Force (https://floridadep.gov/Blue-GreenAlgaeTaskForce)
- Mote's Beach Conditions Reporting System (https://visitbeaches.org/)
- Florida Fish and Wildlife Conservation Commission Red Tide Status Updates (http://myfwc.com/redtide)
- NOAA Harmful Algal Bloom Operational Forecast System (http://tidesandcurrents.noaa.gov/hab/)

About Florida Red Tide

Florida red tide is a higher-than-normal concentration of a naturally occurring, microscopic algae called *Karenia brevis*, often abbreviated as *K. brevis*. It produces brevetoxins — powerful and potent neurotoxins — that can kill marine animals and be harmful to humans. Red tides form many miles offshore, sometimes causing no impact to humans. However, when red tides travel inshore on wind and water currents, they can cause respiratory irritation among beachgoers, especially those who have underlying lung diseases. The Florida Department of Health advises that people with underlying chronic respiratory problems like asthma or COPD should avoid red tide areas, especially when winds are blowing toxins on or near shore.

- FAQs about Florida red tide (https://mote.org/news/florida-red-tide)
- Mote red tide research (https://mote.org/news/red-tide-research)

- Red tide vs. red drift algae: What's the difference? (https://mote.org/news/red-tide-vs.-red-drift-algae)

Florida Red Tide: How You Can Help

Many community members have asked how they can help, with respect to Florida red tide and its impacts. Thank you very much for asking. Here are practical ideas from the Mote team.

- Learn more. (https://mote.org/florida-red-tide-how-you-can-help)

Reducing harmful impacts from Florida red tide: The Mote-FWC/FWRI Cooperative Red Tide Program

Florida red tide causes adverse impacts to public health, natural resources and the economy. This cooperative effort between Mote Marine Laboratory and the Fish and Wildlife Research Institute of the Florida Fish and Wildlife Conservation Commission is designed to help mitigate the adverse impacts of Florida red tide along the Florida Gulf coast. The Program includes red tide monitoring, research and public outreach and education. This joint research program has resulted in better tools and ongoing monitoring for red tides along the Gulf Coast, along with better predictive capabilities to forecast where the effects of red tides might be felt by coastal populations, along with new public health messages new tools.

- Learn more. (https://mote.org/pages/mote-fwri-cooperative-red-tide-program)

Florida Red Tide Mitigation and Technology Development Initiative (https://mote.org/research/program/Florida-Red-Tide-Mitigation-and-Technology-Development-Initiative)

The Florida Red Tide Mitigation & Technology Development Initiative is a partnership between Mote Marine Laboratory (Mote) and the Florida Fish and Wildlife Conservation Commission (FWC) that establishes an independent and coordinated effort among public and private research entities to develop prevention, control and mitigation technologies and approaches that will decrease the impacts of Florida red tide on the environment, economy and quality of life in Florida.

- Learn more (https://mote.org/research/program/Florida-Red-Tide-Mitigation-and-Technology-Development-Initiative).

Harmful Algal Blooms in the Gulf of Mexico: A Primer

NCCOS RESEARCH PROJECT

Seasonal Forecasting of Karenia brevis Red Tide Blooms in the Eastern Gulf of Mexico

Research Area(s): Stressor Impacts and Mitigation (https://coastalscience.noaa.gov/category/stressor-impacts/) / HABHRCA (https://coastalscience.noaa.gov/category/stressor-impacts/habhrca/), Harmful Algal Bloom Detection and Forecasting (https://coastalscience.noaa.gov/category/stressor-impacts/harmful-algal-bloom-detection-and-forecasting/); Other Topics (https://coastalscience.noaa.gov/category/topics/) / Sponsored Research (https://coastalscience.noaa.gov/category/topics/sponsored-research/), Technology Transfer (https://coastalscience.noaa.gov/category/topics/technology-transfer/)

Region(s) of Study: Waterbodies (https://coastalscience.noaa.gov/region/waterbodies/) / Gulf of Mexico (https://coastalscience.noaa.gov/region/gulf-of-mexico/); U.S. States and Territories (https://coastalscience.noaa.gov/region/us-states-and-territories/) / Florida (https://coastalscience.noaa.gov/region/florida/)

Primary Contact(s): quay.dortch@noaa.gov (https://coastalscience.noaa.gov/contact/quay-dortchnoaa-gov/)

This project began in September 2015 and will end August 2018

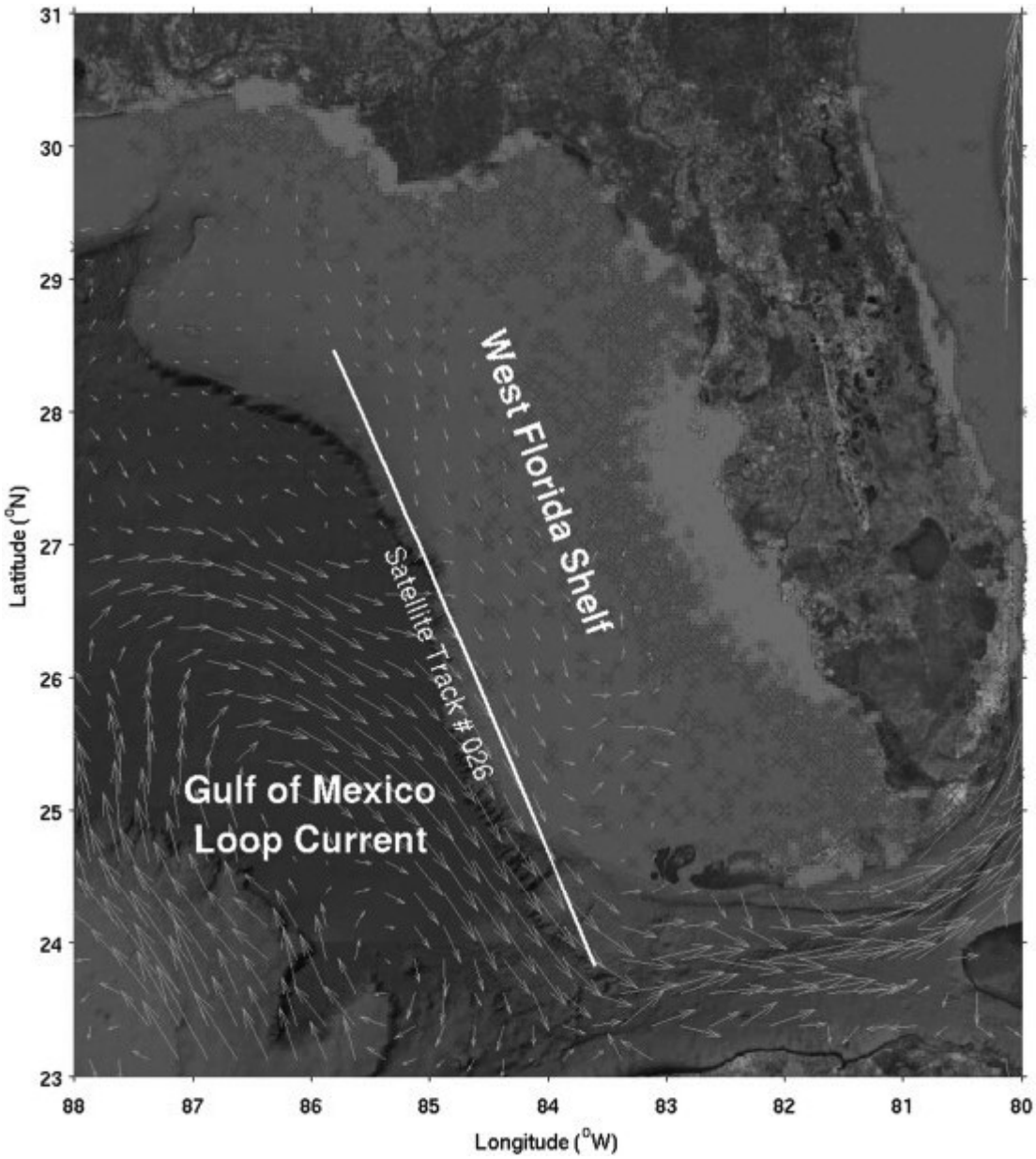
This project is developing modeling tools to improve short term and seasonal predictions of toxic red tide Karenia brevis blooms in the Gulf of Mexico West Florida Shelf. The project provides (1) a transferable tool for seasonal prediction to be used by management agencies and (2) further refines the short-term prediction tool (3.5 days) already developed and in daily operational use. This work allows management agencies to better predict and mitigate the negative effects of red tide blooms.

Why We Care

Blooms *of Karenia brevis* originate offshore in relatively nutrient and silicate-poor waters of the West Florida (continental) Shelf (WFS) before traveling to the Florida coastline by currents and upwelling. Although scientists describe the WFS waters as “oligotrophic’ (having low levels of nutrients), the area supports productive coastal industries, including reef fisheries and tourism. Blooms of *K. brevis*, fueled by nutrients of varying origins, annually threaten these industries. While land-derived nutrients may account for near shore productivity, they do not explain the inter-annual variability in blooms.

In the in (relatively) nutrient poor (termed oligotrophic) offshore waters of the Gulf of Mexico,

scientists believe that the *K. brevis* c ells utilize nutrients from nitrogen fixing single-cell *Trichodesmium* cyanobacteria. Being light sensitive, *K. brevis* cells also receive necessary shading from the overlying



Observations of red tide (*Karenia brevis*) in the eastern Gulf of Mexico from 1953 to 2014. Credit: R. Weisberg, University of South Florida.

Trichodesmium. Once the bloom reaches sufficient concentration to dominate the phytoplankton community, the then mono-specific bloom utilizes all available nutrient sources as well as generating its own nutrient supply using its toxins to kill fish. According to this hypothesis, *K. brevis* blooms observed at the coast are mature blooms that developed in relatively nutrient poor offshore waters where silicate levels were too low for diatoms to compete with *K. brevis*.

Upwelling is a necessary condition for *K. brevis* HABs along the west Florida coastline and elsewhere, but too much upwelling may obviate such occurrences. Transport of blooms to the coast occurs via upwelling circulation generated from southward flowing winds (wind-driven)

and the southward-flowing portion of the Loop Current (Loop Current–driven). Once in shallow water, relatively high concentrations of colored dissolved organic matter can shade blooms. Persistent and intense upwelling of new inorganic (excess) nutrients across the shelf slope favors diatoms over dinoflagellates (e.g., *K. brevis*) and suppresses HAB development. In other words, both the organism's biology and the ocean's circulation physics are necessary conditions for a *K. brevis* bloom, but neither alone are sufficient. These characteristics make it difficult predict blooms and tend to make each bloom somewhat different.

What We Are Doing

The goal of this project is to formalize HAB predictions into more quantitative measures for transition and application within an operational forecasting framework. The project is refining and providing a transferable tool (model) for seasonal prediction for use by management agencies and for the benefit of the broader scientific and public community.

The project scientists seek to understand the role of physical, chemical, and biological variables in the development and progression of *K. brevis* blooms and develop capabilities for both intermediate (seasonal) and short-term (several days) predictions in the eastern Gulf of Mexico. The approach combines *in situ* (field) observations (cell counts, biochemical and circulation data) with satellite remotely sensed data (altimetry, color and temperature) and numerical model simulations (circulation and biochemical). Adding biochemistry and species interactions further refines the short-term (3.5 days) prediction tool already developed and in daily automated use in collaboration with Florida Fish & Wildlife Conservation Commission (FWC).

The research hypothesis is that upwelling is a necessary condition for *K. brevis* to become a HAB along the coast, but too much upwelling leads instead to a diatom bloom. This conceptual model was employed successfully to explain why there was no *K. brevis* bloom in 2010 and then to predict several months in advance that a major bloom would not occur 2013, but then would occur in 2014 and in other coastal regions.

The project is led by Dr. William Weisberg (University of South Florida College of Marine Science) and Dr. Alina Corcoran (FWC Fish & Wildlife Research Institute) and is funded through the NCCOS Prevention, Control, and Mitigation of Harmful Algal Blooms Program (PCMHAB). The project is under the guidance of a four-member Technical Advisory Committee (TAC) to ensure that project work remains germane to the program goals and that appropriate transitions will occur as planned.

Partners

Florida Fish & Wildlife Conservation Commission, Gulf of Mexico Coastal Ocean Observing System (GCOOS), Woods Hole Oceanographic Institution, NOAA Ecological Forecasting Roadmap

Benefits of Our Work

The project allows management agencies (e.g., FWC resource managers, Florida Department of Health, Florida Department of Agriculture and Consumer Services, Florida county agencies) to (1) coordinate and target sampling in under-sampled regions as well as (2) rescue/rehabilitation (e.g., manatee) efforts by focusing resources in critical areas when blooms are predicted. Moreover, the information produced by this project allows managers to prepare for blooms to better mitigate the negative impacts (e.g., coordinate messaging, enacting preparedness networks, preparing outreach documents).

Next Steps

Possible incorporation of project model into GCOOS and other Gulf of Mexico observing systems. Sharing and communicating results with other developing and operational HAB forecast systems around the U.S. (e.g., Gulf of Maine, Pacific Northwest, and California coast).

Honors

In April 2020, a publication from this project (https://coastalscience.noaa.gov/exit?url=https%3A%2F%2Fagupubs.onlinelibrary.wiley.com%2Fdoi%2Fabs%2F10.1029%2F2018JC014887%3Faf%3D was honored by the John Wiley & Sons *Journal of Geophysical Research: Oceans* for being one of the top downloaded in recent journal history. Among work published between January 2018 and December 2019, it received some of the most downloads in the 12 months following online publication.

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ANIMALS

Whales are dying along East Coast—and scientists are racing to understand why

For more than two years, scientists have been working to figure out the underlying cause of this so-called "unusual mortality event."

BY JASON NARK

PUBLISHED MARCH 13, 2019

Virginia Beach, Va.— On a blustery winter afternoon off the coast of Virginia Beach, people are pressing forward on the bow of the Virginia Aquarium and Marine Science Center's whale watching boat as a dorsal fin breaks the surface. Cameras click in staccato for a second or two before the humpback whale dives to feed again.

The relatively small dorsal fin belies the humpback's size. Calves weigh about a ton. Adults can grow heavier than a yellow school bus loaded with kindergarten students. Few things that swim in the sea can break their bones.

A mile to the north, however, by the mouth of Chesapeake Bay, a massive cargo ship is pushing south toward the whales. On this Saturday in late January, these humpbacks are swimming in traffic in the shipping channel that leads vessels to and from some of America's busiest ports. These shipping vessels are one of the few true physical threats to humpback whales.

"Those big ships, they're churning up the water and the fish are coming through and that's what the whales are going for," says Mark Sedaca, captain of the 65-foot Atlantic Explorer on this whale watching trip.

Whale researchers along the Atlantic coast say more stranded whales are showing signs of vessel strikes and fishing gear entanglement than ever before. From January 2016 to mid-February 2019, the National Oceanic and Atmospheric Administration (NOAA) recorded 88 humpback whale strandings with New York, Virginia, and Massachusetts at the top of the list.

closer to shore and drawing whales in too? Was ocean noise disorienting whales?

Not the first “unusual mortality event”

At the time, NOAA officials said those answers were “really hard to know” at such an early stage.The causes of the three previous unusual mortality events ultimately remained “undetermined.”

But three years after the first humpback showed up dead off the coast of Virginia Beach in January 2016, scientists at Virginia Beach aquarium think they’ve figured what might be killing the whales. “The conclusions are that the two overarching causes of it are vessel interactions and entanglements,” says Alexander Costidis, the aquarium’s stranding response coordinator.

But why it’s happening is “a little trickier,” one researcher said. Scientists still don’t understand why whales are swimming closer to ships or whether they detect and try to avoid them in any way.

Costidis’s team investigates every dead whale in the state, and when feasible, performs necropsies, or animal autopsies on them. The team also responds to strandings in North Carolina if needed. The crew, which receives NOAA funding, operates out of a nondescript building alongside a rail line about two miles from the coast. One might assume the building holds highway equipment, not tanks full of loggerhead and Kemp’s ridley sea turtles recovering from a recent cold snap.

When asked what a typical stranding response is like, Susan Barco, the aquarium’s research coordinator, burst into laughter. “Well, first you freak out,” she says. If the whale is dead, the team determines if it’s beached or which beach it could be towed to in order to perform a necropsy. A necropsy is not something elected officials look forward to in beach communities, particularly during summer months when tourists are around. Necropsies involve very sharp knives, pounds and pounds of whale innards, and heavy construction equipment to drag the carcass and later bury it on a beach.

The team looks for propeller strikes, abrasions, and signs of blunt force trauma, such as broken bones, to try to determine what may have caused the whale’s death. Still, many could have been struck after they died. And some whales, Barco says, show signs of healed wounds, suggesting they survived a ship collision or entanglement with fishing gear. If possible, the team also runs tests to evaluate overall health, checks for exposure to pathogens, and also examines the whale’s stomach contents. The scientists are also searching for signs of underlying illness.

“There are things that you can infer, but it is less than precise, and when you throw decomposition on top of that, many times it is guess work,” she says.

Prevention is Difficult

Preventing vessel strikes requires both a deeper understanding of whale biology and deeper awareness of whales from people piloting vessels. NOAA has enacted vessel speed restrictions to protect specific species of whales, such as the endangered North Atlantic right whale, which would also serve to protect other whales. NOAA requires 65 feet or longer to travel 10 knots or less in certain locations, called seasonal management areas. One of those areas is the mouth of Chesapeake Bay.

“As far as they are concerned, they are the biggest thing in the ocean. An adult humpback has no real fear of anything, so why should it have any reason to think some new, loud sound would be anything other than a new, loud sound?” he says. “You’re basically talking about training a whale to adapt to sound, and with whales, it’s usually they get hit once and that’s it.”

A spokesman for the Port of New York and New Jersey, the third largest port in the country, referred questions about whales and vessels interaction to the Coast Guard, which has jurisdiction over the shipping lanes. The Coast Guard enforces rules set forth by NOAA for all boaters, a spokesman said. Vessels must stay 100 yards away from any marine mammal and put engines in neutral when whales approach. Every boater is required “to report when they see endangered whales or whenever they strike a whale.”

New York, according to NOAA, had the most stranded humpbacks in this recent unusual mortality event with 17. Virginia and Massachusetts followed. Researchers say strandings are nearly always fatal, aside from the rare moments when a whale trapped in gear can be freed and is healthy enough to swim off and recover.

Rob DiGiovanni, founder of the Atlantic Marine Conservation Society, a Long Island volunteer organization that responds to strandings, says he’s seen increased numbers of menhaden, the whales’ preferred food source, close to inshore shipping channels. These channels have become “rest stops,” DiGiovanni says, where whales stop and refuel.

“Let’s at least be aware that they’re out there,” DiGiovanni says. “We all drive slower in a school zone, and this isn’t a major impact in our lives. It’s for the good of the animals.”

Three whales have stranded so far this year, according to NOAA, including one in Virginia. All three animals were dead.

On the Atlantic Explorer, Sedaca follows every NOAA guideline, moving away from surfacing humpbacks after a certain time or idling the ship’s engine if they get close. Fresh photos of every distinct dorsal fin are taken to Alexis Rabon, the aquarium’s boat programs coordinator, and she checks them against a database of known whales.

“They’re typically solitary, so when they come through our area, it’s not abnormal just to see one,” she says. “But something that we’ve seen from a few of these individuals, such as the pair we saw yesterday, is that they’ve kind of been joining up with other animals.”

One juvenile whale, Rabob confirms, was seen twice, earlier in January and also that morning. While a local whale watching boat and a recreational boat lingered on the surfacing whale, Sedaca pointed the Atlantic Explorer north toward another reported whale spout in the shipping channel. Costidis said Delaware Bay’s shallow waters almost funnel whales into the deeper shipping channel.

Costidis said the only immediate remedy—less vessel traffic—is “not realistic” but slowing them down could help.

“To some degree,” he said, “dense shipping traffic will likely never be compatible with life for near-shore metropolitan whales."

British Columbia

2nd humpback death in 2 weeks worries experts, farmed salmon industry

'This is not something that is normal,' says B.C. Salmon Farmers Association

Megan Thomas · CBC News ·
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which resulted in deaths, have whale researchers and the salmon farming industry concerned.

A juvenile humpback died last weekend after it became trapped between the inner and outer containment nets at Greig Seafood's Atrevida salmon farm in Nootka Sound.

The death comes just two weeks after another dead humpback was found stuck in equipment at an empty Marine Harvest Canada fish farm on B.C.'s Central Coast. In that case, the whale became entangled in an anchor support line at a site north of Bella Bella.

- **Humpback whale found dead near Klemtu, B.C., says aquaculture company**
- **Humpback rescued from fish farm ropes by fisheries officials**

A third humpback whale was rescued from the same spot in September, but it has not been spotted since, and it's not clear if it survived the injures it suffered.

The cluster of incidents has fish farm operators worried, said Jeremy Dunn, executive director of the B.C. Salmon Farmers Association.

"The farmers are quite upset. This is not something that is normal, and they want to take every step they can to ensure this doesn't happen," he said.

More entanglements likely

But whale researchers warn more entanglements are likely because of the growth in the number of humpback whales on the B.C. Coast.

The juvenile humpback was freed from several ropes at the Marine Harvest aquaculture site in Klemtu, B.C. by Fisheries and Oceans Canada, with help from the company and the Kitasoo First Nation. (Philip Charles)

Humpbacks are particularly at risk from fish farm equipment because they do not have bio-sonar like toothed whales, Hildering said. This makes it less likely they will avoid the equipment when they're diving for food.

- **Researchers fear B.C. coast becoming dangerous for returning whales**

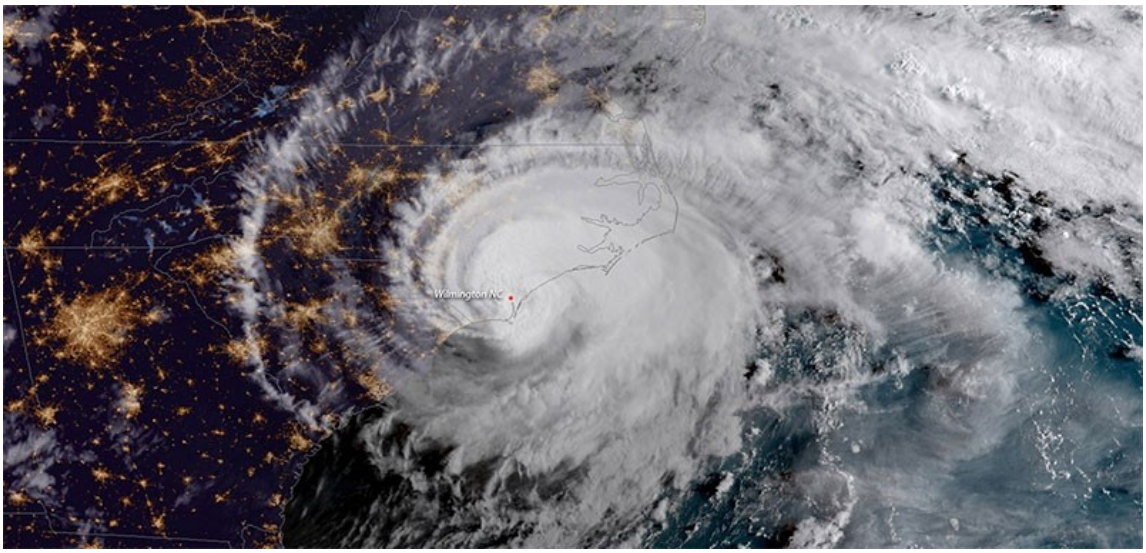
Fish farm industry leaders plan to meet with experts from Fisheries and Oceans Canada (DFO) next month to discuss the recent entanglements and work on ways to prevent them, Dunn said.

"The experts are telling us there are significantly more humpback whales in the environment, and our farmers need to learn more about the whales," he said. "If DFO determines that there should be some changes made to the infrastructure of the farms, I think our members will certainly do that."

But Hildering said finding solutions could prove challenging because humpbacks feed on species such as herring and krill that are often plentiful in areas where fish farms are located.

How does the ocean affect hurricanes?

Hurricanes form over tropical oceans, where warm water and air interact to create these storms.



(media/hurricanes-800.jpg)

GOES-East satellite image of Hurricane Florence making landfall at Wrightsville Beach, North Carolina on Sept. 14, 2018. *Image courtesy of NOAA.* Download image (jpg, 100 KB) (media/hurricanes-800.jpg).

In the Atlantic and Northeast Pacific, we use the term "hurricane" to describe severe storms with high-velocity winds that rotate around a central, low-pressure core. The same type of disturbance in the Northwest Pacific is called a “typhoon” and “cyclones” occur in the South Pacific and Indian Ocean.

In order for a hurricane to form, two things must be present: a weather disturbance, such as a thunderstorm, that pulls in warm surface air from all directions and water at the ocean's surface that is at least 80° Fahrenheit (27° Celsius). Because it is the interaction of warm air and warm seawater that spawns these storms, they form over tropical oceans between about 5 and 20 degrees of latitude. At these latitudes, seawater is hot enough to give the storms strength and the rotation of the Earth makes them spin.

Hurricanes start simply with the evaporation of warm seawater, which pumps water into the lower atmosphere. This humid air is then dragged aloft when converging winds collide and turn upwards. At higher altitudes, water vapor starts to condense into clouds and rain, releasing heat that warms the surrounding air, causing it to rise as well. As the air far above the sea rushes upward, even more warm moist air spirals in from along the surface to replace it.

As long as the base of this weather system remains over warm water and its top is not sheared apart by high-altitude winds, it will strengthen and grow. More and more heat and water will be pumped into the air. The pressure at its core will drop further and further, sucking in wind at ever increasing speeds. Over several hours to days, the storm will intensify, finally reaching hurricane status when the winds that swirl around it reach sustained speeds of 74 miles per hour or more.

Eventually, hurricanes turn away from the tropics and into mid-latitudes. Once they move over cold water or over land and lose touch with the hot water that powers them, these storms weaken and break apart.

Recent studies have shown a link between ocean surface temperatures and tropical storm intensity – warmer waters fuel more energetic storms.

For More Information

Hurricanes (/edu/learning/14_hurricanes/hurricanes.html) – Multimedia Discovery Missions (/edu/learning/welcome.html)

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Global Warming and Hurricanes

An Overview of Current Research Results

Last Revised: Sept. 23, 2020

Notice: A new (2019; 2020) WMO Task Team report on tropical cyclones and climate change has published in the *Bulletin of the American Meteorological Society*.

I) "Tropical Cyclones and Climate Change Assessment. Part I: Detection and Attribution"

- Main report .pdf file for Part I.
- Supplemental Material for Part I.

II) "Tropical Cyclones and Climate Change Assessment: Part II. Projected Response to Anthropogenic Warming"

- Main report .pdf file for Part II.
- Supplemental material for Part II.

1. Summary Statement

Two frequently asked questions on global warming and hurricanes are the following:

- What changes in hurricane activity are expected for the late 21st century, given the pronounced global warming scenarios from IPCC models?
- Have humans already caused a detectable increase in Atlantic hurricane activity or global tropical cyclone activity?

The IPCC AR5 presents a strong body of scientific evidence that most of the global warming observed over the past half century is very likely due to human-caused greenhouse gas emissions. But what does this change mean for hurricane activity? Here, we address these questions, starting with those conclusions where we have relatively more confidence. The main text then gives more background discussion. "*Detectable*" change here will refer to a change that is large enough to be clearly distinguishable from the variability due to natural causes. Our main conclusions are:

- Sea level rise – which very likely has a substantial human contribution to the global mean observed rise according to IPCC AR5 – should be causing higher coastal inundation levels for tropical cyclones that do occur, all else assumed equal.
- Tropical cyclone rainfall rates will likely increase in the future due to anthropogenic warming and accompanying increase in atmospheric moisture content. Modeling studies on average project an increase on the order of 10-15% for rainfall rates averaged within about 100 km of the storm for a 2 degree Celsius global warming scenario.
- Tropical cyclone intensities globally will likely increase on average (by 1 to 10% according to model projections for a 2 degree Celsius global warming). This change would imply an even larger percentage increase in the destructive potential per storm, assuming no reduction in storm size. Storm size responses to anthropogenic warming are uncertain.
- The global proportion of tropical cyclones that reach very intense (Category 4 and 5) levels will likely increase due to anthropogenic warming over the 21st century.
  There is less confidence in future projections of the global number of Category 4 and 5 storms, since most modeling studies project a decrease (or little change) in the global frequency of all tropical cyclones combined.

Likelihood Statements

The terminology here for likelihood statements generally follows the conventions used in the IPCC assessments, i.e., for the assessed likelihood of an outcome or result:

- Very Likely: > 90%,
- Likely: > 66%
- More Likely Than Not (or Better Than Even Odds) > 50%

- In terms of detection and attribution, much less is known about hurricane/tropical cyclone activity changes, compared to global temperature. Recent findings include:
  - In the northwest Pacific basin, there is emerging evidence for a detectable poleward shift in the latitude of maximum intensity of tropical cyclones, with a tentative link to anthropogenic warming.
  - One study finds an increase in the fraction of tropical cyclones reaching at least Category 3 intensity both globally and in the Atlantic basin, over the past four decades. These observed changes have not been compared with modeled responses to historical anthropogenic forcing or to modeled natural variability; they have not been confidently attributed to anthropogenic forcing.
  - A study of rapid intensification of hurricanes finds that the observed increase in an Atlantic rapid intensification metric (1982-2009) is highly unusual compared to one climate model's simulation of internal multidecadal climate variability, and is consistent in sign with that model's expected long-term response to anthropogenic forcing.
  - There is increasing evidence from modeling studies at GFDL/NOAA and the UK Met Office/Hadley Centre (UKMO) that the increase in tropical storm frequency in the Atlantic basin since the 1970s has been at least partly driven by decreases in aerosols from human activity and volcanic forcing. Natural variability may also have contributed to recent changes. The recent GFDL and UKMO studies do not imply that the increase in Atlantic tropical storm frequency since the 1970s will continue into the future: these same models project future decreases in Atlantic tropical storm frequency in response to increasing greenhouse gas concentrations.
  - There is evidence for a slowing of tropical cyclone propagation speeds over the continental U.S. over the past century, but these observed changes have not yet been confidently linked to anthropogenic climate change.
  -
- In summary, it is premature to conclude with high confidence that increasing atmospheric greenhouse gas concentrations from human activities have had a detectable impact on Atlantic basin hurricane activity, although increasing greenhouse gases are strongly linked to global warming. Some possible human influences on tropical cyclones are summarized above. Human activities may have already caused other changes in tropical cyclone activity that are not yet detectable due to the small magnitude of these changes compared to estimated natural variability, or due to observational limitations.

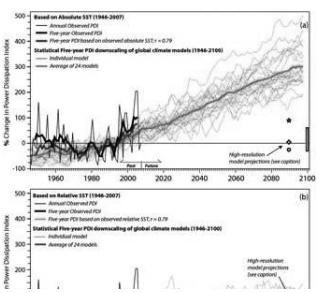
2. Global Warming and Atlantic Hurricanes

A. Statistical relationships between SSTs and hurricanes

Observed records of Atlantic hurricane activity show some correlation, on multi-year time-scales, between local tropical Atlantic sea surface temperatures (SSTs) and the Power Dissipation Index (PDI) — see for example Fig. 3 on this EPA Climate Indicators site. PDI is an aggregate measure of Atlantic hurricane activity, combining frequency, intensity, and duration of hurricanes in a single index. Both Atlantic SSTs and PDI have risen sharply since the 1970s, and there is some evidence that PDI levels in recent years are higher than in the previous active Atlantic hurricane era in the 1950s and 60s.

Model-based climate change detection/attribution studies have linked increasing tropical Atlantic SSTs to increasing greenhouse gases, but proposed links between increasing greenhouse gases and hurricane PDI or frequency has been based on statistical correlations. The statistical linkage of Atlantic hurricane PDI to Atlantic SST suggests at least the possibility of a large anthropogenic influence on Atlantic hurricanes. If this statistical relation between tropical Atlantic SSTs and hurricane activity is used to infer future changes in Atlantic hurricane activity, the implications are sobering: the large increases in tropical Atlantic SSTs projected for the late 21st century would imply very substantial increases in hurricane destructive potential–roughly a 300% increase in the PDI by 2100 (Figure 1a).

On the other hand, Swanson (2008) and others noted that Atlantic hurricane power dissipation is also well-correlated with other SST indices besides tropical Atlantic SST alone, and in particular with indices of Atlantic SST relative to tropical mean SST (e.g., Figure 1b from Vecchi et al. 2008). This is in fact a crucial distinction, because while the statistical relationship between Atlantic hurricanes and local Atlantic SST shown in the upper panel of Figure 1 would imply a very large increases in Atlantic hurricane activity (PDI) due to 21st century greenhouse warming, the alternative statistical relationship between the PDI and the relative SST measure shown in the



THOMPSON EARTH SYSTEMS INSTITUTE

Red Tide is Expensive. Here's Why

by **REBECCA BURTON** • May 29, 2019

UF Thompson Earth Systems Institute

Header image: Florida Sea Grant stock photo.

Last year's red tide was on the minds of many Floridians for more than a year. Would-be tourists who saw images of coasts lined with dead fish canceled their vacations. Fishermen lost their catch. In some areas, coastal property sales plummeted.

In other words, red tides not only wreak havoc on our natural ecosystems, they also put a dent in Florida's pocketbook.

Scientists and economists have been studying the economic impacts of harmful algal blooms like red tide for decades.

We had the chance to interview Chuck Adams, marine economics specialist with Florida Sea Grant, about why these harmful algal blooms place such a burden on Florida's economy.

Need a refresher on red tide first? Visit this post by Florida Sea Grant to learn more: Understanding Florida's Red Tide

Why are red tides so expensive?

Chuck Adams

Adams: *Karenia brevis,* the organism that causes red tide, produces a neurotoxin called brevetoxin, which can harm and kill fish, birds and marine mammals. Economically important finfish are often among the hardest hit.

The same toxins can become airborne through nearshore wave action and create health problems for humans too. Airborne brevetoxins can create respiratory distress, burning of the eyes, coughing and other problems for individuals who are in the proximity or downwind of an intense red tide bloom.

These health issues and the associated foul smell make the beach and nearshore areas an unpleasant place to be during a red tide. As a result, businesses located near the water can experience significant disruption of sales during a bloom.

Waterfront lodging and restaurants, beach vendors, marinas, and other water-related businesses are particularly vulnerable to red tide events. The severity of the economic consequences will vary with the intensity, duration, and geographic scope of the red tide.

The Numbers Don't Lie

The 2018 bloom resulted in $14.5 million being allocated for emergency funds to clean up beaches.

Last year, hotels on the Sanibel and Captiva islands in Lee County lost $8 million in revenue thanks to a 78% vacation cancellation rate between August and October. The area also lost $3.75 million in coastal property sales in 2018.

During the 2015-2016 bloom, the shellfish aquaculture industry lost $3.3 million in revenue.

In 2007, a red tide bloom resulted in $51 million in losses to the state's restaurant and hotel sectors.

During the 2005 bloom, respiratory and digestive illnesses cost Floridians upwards of $1 million.

Is every red tide this bad?

Adams: Several studies conducted by the University of Florida and Florida Sea Grant have documented the fact that red tide events generate business losses and create economic hardship for water proximate businesses and coastal communities. The magnitude of such economic losses will depend upon the severity and duration of the red tide event. How "bad" a red tide will be depends on many factors.

The blue-green blooms that impacted the Indian River Lagoon, the St. Lucie Estuary, Lake Okeechobee and the Caloosahatchee Estuary in recent years have also placed an economic burden on surrounding communities.

We know the symptoms of red tide well. We also know we can expect them in the future. In your opinion, what should be the main focus of future algae bloom-related research?

Adams: I think scarce public dollars would be better spent in the future on addressing the underlying problems that exacerbate red tide blooms, rather than repeatedly addressing the symptoms and confirming what is already known.

Although red tide is a naturally occurring phenomenon that originates offshore, ocean currents bring the bloom inshore where it feeds on excess nitrogen and phosphorus. These nutrients come from various sources along the coast including stormwater runoff, fertilizer runoff, septic tanks, and/or faulty wastewater systems.

If Florida's coastal communities are to progress toward a safe and economically viable future, Floridians must address our contribution to the problem by reducing our nutrient inputs into nearshore waters and supporting research to further understand red tide and other harmful algal bloom causes, impacts and mitigation strategies.

To learn more about the economic impacts of red tide, visit:

Economic Consequences of Harmful Algal Blooms: Literature Summary

To learn more about harmful algae blooms affecting Florida, visit:

Algae blooms affecting Florida

To get up-to-date information about red tide, visit:

Current red tide status