

FLORIDA KEYS NATIONAL MARINE SANCTUARY
Water Quality Protection Program Information-Sharing Meeting
(follow-up from March 9, 2023 meeting)

March 29, 2023

DRAFT NOTES

Steering Committee Members Present

Wade Lehmann, United States Environmental Protection Agency (EPA), Region 4 (Chair)
Kim Shugar, Florida Department of Environmental Protection (DEP) (Co-Chair)
Karen Bohnsack, Florida Keys National Marine Sanctuary (FKNMS) (Designee)
Tylan Dean, National Park Service
Christian Eggleston, Florida Keys National Wildlife Refuges Complex (Designee)
Barbara Powell, Florida Department of Economic Opportunity
Gil McRae, Florida Fish and Wildlife Conservation Commission (Designee)
Sue Heim, Key Largo Wastewater Treatment District
Andrea Leal, Florida Keys Mosquito Control District
George Garrett, City of Marathon
Shelly Krueger, Florida Sea Grant/IFAS Extension Monroe County

I. Introduction and Opening Remarks

Wade Lehmann, Ocean and Estuarine Section Chief, EPA Region 4, called the meeting to order and thanked everyone for coming. This meeting has been convened to provide the informational presentations that were unable to be accommodated during the in-person Steering Committee meeting on March 9, 2023 as a result of the Keys' water main break and early adjournment.

Steering, management, and TAC committee members in attendance are introduced and/or recognized.

Bonefish Pharmaceutical Contaminants Study

Dr. Jennifer Rehage, FIU, and Nicholas Castillo, PhD Candidate, FIU presented the results of a study to determine the occurrence of pharmaceutical contaminants in bonefish in south Florida.

There are over 5,000 pharmaceuticals that humans take to keep us healthy; hundreds of these have been detected in aquatic systems. An assessment of pharmaceutical pollution showed this is a global threat. In looking at 258 rivers across half the world's countries, only 2 had no pharmaceutical pollution. A quarter had harmful pharmaceutical levels. We have exceeded the capacity for planet to deal with these issues. In the United States, pharmaceutical pollution is also a problem; over 100 pharmaceuticals have been detected in water samples. The U.S. accounts for 5% of the population but consumes 50% of the world's production of pharmaceuticals. The average American consumes 18 prescriptions per year, which amounts to 6.4B prescriptions each year. The state of Florida ranks 3rd in the U.S. for prescriptions. The rate of production and release of pharmaceuticals into the environment has far outpaced society's capacity to assess their safety. This is a recent problem in the last 30 years; not a lot of assessment about what this means for the environment and biota. This is a new dimension of water quality and an invisible pollution (they do not alter water properties we can see).

How does this end up in coastal waters and fish? We excrete 50% of what is consumed, which goes into imperfect sewage systems that do not remove pharmaceuticals. In Florida $\frac{2}{3}$ go to septic and $\frac{1}{3}$ to sewer, but

neither system is equipped to deal with this pollution. Miami Dade County is specifically concerned about septic systems. This could be an important source of pharmaceuticals into the environment. Miami Dade also has ocean outfalls, with high dilution with currents, and deep injection wells. These inject 300M gal/day with presumption of confinement but we don't know for sure. In the Keys, we've seen high connectivity between surface and injected waters. We also have reclaimed water and small volumes may be entering the environment from this source. Wastewater is the main pathway for pharmaceuticals in fish although other sources, such as agriculture, likely contribute. As wastewater comes into contact with the environment, it provides a constant supply of pharmaceuticals entering the system. About 90% of pharmaceuticals lack toxicity data – we don't know how they function in the environment and we don't have regulations for safe levels because they are not considered a traditional pollutant. Fish and humans share about 70% of their systems, so systems targeted by drugs in humans have exposure potential for fish as well. Effects can include altered behaviors that affect survival and reproduction. Antidepressants are the best studied pharmaceuticals in terms of effects on biota - this shows increased activity, feeding, boldness, lower social ability (mating implications) and faster movement and migration rates, all of which translates to a lower likelihood of survival.

This study sought to determine if pharmaceuticals are a concern for south Florida's recreational fisheries - specifically bonefish – as their life history shows more likely exposure and contact. There are 12 species of bonefish, 3 in the Caribbean. The maximum documented lifespan is 21 years, they spawn in November-May and have a 1-month larval stage (long). Their habitat is nearshore near human populations and pollution, and their diet consists of benthic shrimp, crabs and toadfish. Reproduction, movement and juvenile habitat are not well known in south Florida. This recreational fishery is economically very important in south Florida, and leads to an economic impact of \$9B per year. One in three fishing trips in the U.S. are in Florida, and 15% of world records were caught in the state. In the Florida Keys, this fishery generates \$836M/year and is responsible for 20% of tourism dollars. Approximately 60% of 5.5M tourists are engaged in fishing in the Keys.

Over two decades, we've seen a drastic population decline in south Florida's flat's fishery. The 2010 mortality/cold water event was an issue, although there has been recent recovery in the Keys with numbers coming back. These fish are still small, not reproductive yet. This study seeks to better understand whether pharmaceuticals play a role in population declines.

Core question; Are pharmaceuticals a concern for flats fisheries? Bonefish are used as a model species, as they are representative of shallow water/seagrass habitat and the human dimension due to their economic importance. Blood samples were collected from 91 fish in Florida and 43 fish in the Caribbean.

Are pharmaceuticals a problem?

- Yes. All 134 fish across Florida and the Caribbean had at least one drug in their blood sample. In south Florida the exposure was higher, with an average of 7 drugs per fish compared to 4 in the Caribbean. This is a concern when we consider mixture effects of these drugs; this is something doctors are concerned about when prescribing medications.

Are pharmaceuticals a problem everywhere?

- This study looked at 5 regions in south Florida (upper Keys, lower Keys, Key West, Dry Tortugas and Biscayne Bay) and 3 regions in the Caribbean (Puerto Rico, Mexico/Belize border and Abaco and Grand Bahama). The study discovered that this is a problem everywhere, but with differences. In south Florida, exposure was highest in the Dry Tortugas. In the Caribbean, exposure was highest in Belize and Mexico. This shows that the concern for exposure is high in urban and remote areas. The Dry Tortugas, while influenced by tourism, is still an open seawater remote area. A total of 61 pharmaceuticals were detected in fish from Florida. Key West and Dry Tortugas have distinct assemblages of pharmaceuticals. Interestingly the Dry Tortugas is most similar to Biscayne Bay which is odd because those are the least and most urban areas, respectively. In the Caribbean, there is similarity between the 3 regions; when broken down within the Bahamas, see distinctiveness between the populations at these small scales.

- Acetaminophen (Tylenol) was looked at as it is the most common anti-inflammatory worldwide. This is 99% removed by wastewater treatment so could be an indicator of septic systems or leaky wastewater systems. This was found to be highest in Biscayne Bay and the Dry Tortugas (which does have a septic system. High in tourism also translates to high pharmaceutical exposure).

How big of a problem is this?

- The study looked at the therapeutic level (e.g., the concentration that is targeted for a human to have the desired effect of the medication). If we find $\frac{1}{3}$ of that therapeutic level in the fish, we consider the fish to be affected by the drug. This is a conservative threshold, as 10% has been shown to be a problem.
- This is a big problem in Florida. In south Florida 52% of fish had at least 1 drug above the $\frac{1}{3}$ threshold. The percentage of fish with one exceedance was 93% in the Dry Tortugas, and at a minimum, 1 in 4 fish exceeded the $\frac{1}{3}$ threshold across the regions.

How are bonefish being exposed?

- The study looked at prey (barnacles, pink shrimp, silversides, etc.), and found an average of 11.5 pharmaceuticals in each prey item (compared to 7 in fish). A total of 61 pharmaceuticals were detected in prey, and generally at high concentrations (75% had at least one exceedance of the $\frac{1}{3}$ therapeutic level).

What are they being exposed to?

- Fish were tested for 101 pharmaceuticals of 13 classes (cardiovascular, psychoactive drugs, antibiotics, antihistamines, etc.). Fish #43 had 16 drugs (8 antidepressants were found at 8-300 times the full human therapeutic level). Overall, 10 classes of pharmaceuticals were detected. Most found in Florida were cardiovascular or psychoactive drugs.
- Most commonly detected pharmaceuticals:
 - Atenolol – Prescribed for hypertension and chest pain. In fish this can reduce oxygen carried by blood, disrupt glucose production in liver, lower larval growth rates.
 - Naloxone (Narcan) – Prescribed for opioid overdose and now approved OTC. In fish this can produce anxiety-like effects, erratic movements, alter responses to harmful conditions and pain.

Conclusions:

- Exposure is widespread: Far and near populations and pollution sources.
- Concerning exposure in bonefish with physiological effects.
- High levels detected in pink shrimp = threat for all coastal fisheries.

Future work will examine relative exposure across the various channels of exposure (water vs. sediment vs. prey). This will also look at exposure over time. Is it always high level, or is there variance as a function of dry vs. wet, flow patterns and circulation patterns? Are hotspots consistent through time or is there temporal variance?

Solutions:

- Manufacturing regulations could consider environmental criteria in pharmaceutical production.
- Production of green pharmaceuticals (Sweden has a green version of pharmaceuticals).
- Upgrade wastewater treatment to include removal of pharmaceuticals (Sweden and Switzerland lead in this area using ozonation, which is cost effective).
- Overall, there is a need to rethink what we do with wastewater. It's too valuable and also damaging. Wastewater needs to become a resource, be recycled more (largest water recycling plant in the world is in Orange County). Florida can be a leader on this front.

Follow-up: The survey was expanded outside of south Florida to see if this is a statewide issue. Bonefish & Tarpon Trust funded a survey of 9 estuaries across Florida, including Jacksonville, St. Augustine, northern Indian River Lagoon, Pensacola, Apalachicola, Cedar Key, Tampa Bay, Charlotte Harbor and Florida Bay. They took 100 samples of blood and muscle from red fish and looked for 95 pharmaceuticals across 12 classes. Overall, 94% of fish sampled had at least 1 pharmaceutical in their blood, although 7 were found with zero. The

average was lower with 2.1 pharmaceuticals/fish. Seventeen drugs were detected (less than in bonefish which was ~60 drugs); same types of drugs that are concerning. The estuaries varied in exposure: Florida Bay and Indian River Lagoon were among the lowest. Tampa Bay and Apalachicola were highest (4 drugs/fish). Suspect this finding is related to population size, the percentage of the community on septic vs. other treatment. Approximately 25% of tested redfish should feel effects from the pharmaceuticals found in their system. Again, this is based on a comparison of blood levels to the human therapeutic concentration ($\frac{1}{3}$ threshold; above $\frac{1}{3}$ = likely to experience drug effects). Are we exposed by eating redfish? While some muscle samples tested positive for 11 pharmaceuticals, exposure is very low - 48,000 servings would have to be consumed to get a full dosage of drugs. There is no immediate risk, however risk over a lifetime is unknown.

Questions & Answers/Comments/Discussion:

- Chris Bergh: Could fish sampled in the Dry Tortugas pick this up somewhere else? How mobile are they?
 - This is a hypothesis they considered. Could be they were moving everywhere and we caught them in the Dry Tortugas. Could also be currents that culminate in the Dry Tortugas - could carry contaminants from elsewhere. Could also be in situ exposure from tourism in the Dry Tortugas itself. These were surprising results; they were originally looking for a control at the Dry Tortugas. Pharmaceuticals have been found in phytoplankton in the Antarctic, all of Baltic Sea waters sampled, in remote alpine creeks and rivers, etc. Most viable answer is that this is local exposure from visitors. Fish were sampled in December - a single sample event collected over a few days; very little variance was seen, unlike the samples from Key West. Samples from the Dry Tortugas were most dissimilar to Key West, even though that is the nearest population. If ocean currents were doing this, there should be similarities in the drugs. The Dry Tortugas is most similar to Biscayne Bay.
 - Additionally, acetaminophen is high in the Dry Tortugas - this is removed by wastewater treatment and is evidence of a localized, in-situ point source. Can have high exposure via high numbers of people. High numbers of people and good infrastructure could still result in high exposure, as could low numbers of people and bad infrastructure. The Yankee Freedom brings hundreds of people, in addition to sailboats, on site staff, etc. With 400-500 people per day = high exposure potential.
- Patrick Rice: Have you considered doing analysis/collections to look at concentrations in phytoplankton?
 - No, haven't thought about that. They will do a round of paired water sampling, in which they go to the same locations and to look at water, sediment and prey. Will sample every 2 months to understand temporal patterns a bit better. The first round of sampling included inshore and offshore sites (e.g., in Biscayne Bay = inside Blackpoint Marina, then outside Elliot Key). No inshore/offshore difference was detected. Hope more temporal sampling (including things that don't move) will be telling about the extent of exposure and how stable is it over time.
- Patrick Rice: Any hypothesis about why Narcan was found in such high concentrations in the Dry Tortugas? That seems like a rare pharmaceutical used for opioid overdoses; why would it be in such a remote place??
 - The Dry Tortugas samples did not have opioids (which includes the antagonist Narcan). Cardiovascular and psychoactive drugs were found there.
- Patrick Rice requested an opportunity to share this presentation with the CFK fisheries management.
 - Nick Castillo can arrange to present to the class and answer questions.
- Barbara Powell: We have had a hard time getting our hands around upgrades to septic systems in these islands. Has NPS upgraded the septic in the Tortugas? Does DEP have info on these septic systems? The Keys were also required to upgrade to AWT by December 31 2015, but getting the info on the status of that progress has been difficult.
 - They know a little from their communications with the park. Yankee Freedom is used for restrooms when at the island. They also have removable porta potties for use by visitors when the boat is not there. There is a septic system used by ~20 NPS personnel. They've been thinking about how to upgrade in the context of sea level rise and how that infrastructure may

be compromised in the future. Organic material and biosolids are removed by ozonation; that could be an effective option in the future.

- No data on whether the Dry Tortugas findings could be West Florida Shelf entrainment. What they've sampled seems to indicate a local source, more sampling may provide better clarity.
- Patrick Rice: In Panhandle close to Cedar Key, there is bivalve farming up there. Is there a concern about contamination in bivalve tissues, or a plan to sample that? Those are filter feeders that people eat.
 - Some studies have shown this to be a concern for human exposure; not necessarily in adults but levels are concerning for toddlers. No plans to follow-up on this. Did find higher levels in inverts. This is a pattern seen in literature where fish have less than inverts (their metabolism does not purge as well).

BREAK

III. Florida Bay Status Update

Tylan Dean, NPS, provided an overview of the ongoing algal bloom and current conditions within Florida Bay. *Synechococcus* blue-green algae is the dominant genus of cyanobacteria responsible for blooms in Florida Bay, and we see a shift in species concentration in bloom conditions vs. non-bloom conditions. *Synechococcus* group containing a phycoerythrin pigment (clade III) is normally dominant in the Bay during non-bloom conditions. This is adapted to high light and prevalent in shallow marine environments, and is well grazed by zooplankton. Clade VIII dominants during blooms; this grows rapidly using organic nutrients, is tolerant of lower salinities, and is chain forming with a dense mucilage (mucus like goo) that resist microzooplankton grazing. Clade VIII impacts include light attenuation with reduction in seagrass densities and O₂ production, sponge mortality (observed in 2016 and 2022), and impacts to fish and lobster populations. This also causes zooplankton community changes (e.g., reduction in predatory grazer zooplankton), and contributes to hypoxia due to high oxygen demand.

In the late 1980s, Florida Bay experienced a seagrass die off followed by a decade of algae blooms. In 2015, chlorophyll a (chl-a) concentrations, bloom conditions, and seagrass die off effects were similar to the late 1980s die offs with a lot of area across a lot of basins affected. Between 2016-2017, NPS did preliminary bloom monitoring, which included looking at chl-a by month at various locations across Florida Bay. The intensity of bloom was observed to shift over time and across space.

In 2017, Hurricane Irma potentially distributed and transported nutrient laden soils and organic matter from the die-off area around the bay. Hurricane winds defoliated most of the mangroves from Terrapin Bay to Cape Sable and deposited organic material into the system. After Irma, the park implemented a more consistent bay-wide monitoring program, which added nutrient measurements to the chl-a samples and standardized locations (77 sites monitored every other month). Also measured temperature, DO, Salinity, pH, Secchi, turbidity. Samples were also collected and sent to FWC's Harmful Algal Bloom lab for flow cytometry, pigment analysis and species identification.

Prior to Irma, monitoring was focused on the central bay, and the August 2017 data showed low chl-a. After Irma, they observed an almost immediate bloom develop that persisted through January 2018. This was observed to cross through the islands and out to the reef. By March 2018, chl-a levels subsided across the basins. Low chl-a concentrations continued through the summer, with the bloom limited to the shoreline. In July saw evidence of it starting again, and it grew more expansive across Florida Bay in Sept. 2018. Didn't see persistent high concentrations of chl-a except for a few locations in upper Florida Bay; then see seasonal dissipation by the cooler months. This was appearing as a seasonal pattern of blooms triggering late summer to early fall. In 2020 and 2021 this was less intense, but a similar pattern was observed. In 2021 - saw clearer conditions and it was hoped that the seasonal bloom would subside; didn't see high concentrations in upper basin in Sept. as seen previously.

Unfortunately, in January saw an unseasonable bloom trigger in upper basins and expand outward from there. That was a surprise; some subsidence was observed by March, but this is when we previously saw complete clearing, so a different dynamic was possibly at play. This has become more pronounced in 2022. In May, an early season bloom expanded through July and into September 2022. That was a wet period in the Everglades, so they have been considering a hypothesis for what would trigger this bloom - could it be related to freshwater inflows or something upstream? Around that time, NPS had staffing shortages that affected routine sampling; but they have been working to find remote sensing alternatives to monitor conditions. Processed satellite imagery from USF has shown good alignment in intensity and distribution with in situ cyanobacteria sampling. This is a good surrogate to track the bloom over time and how it changes without the intense sampling effort. Moving forward, field sampling is still limited, but remote sensing is being closely monitored.

NPS is working to test a hypothesis that bloom initiation is related to upstream conditions. NPS has 5 sondes deployed in central Florida Bay, where we've seen seagrass die off and algae blooms in previous years. They are starting to look at correlations between chl-a, dissolved organic matter (DOM), and salinity. Have observed patterns where chl-a would increase when salinity was decreasing, and when DOM from upstream system was increasing. They are working through this hypothesis now. Clade VIII is better suited to organic nutrients - may be from inputs from upstream system and less from remnant nutrients from the seagrass die off.

In 2017 TP, TN, TOC etc. measurements were compared to chl-a and found to correlate with similar intensity. Thus, these are probably related. Elevated nutrient levels and similar patterns were observed in 2020, but they are not always perfect. For example, May 2018 had relatively low chl-a levels, but elevated phosphorus levels.

We expect to see some continuation of the blooms. They appear to be related to Everglades seasonal hydrology - possibly from legacy marine nutrients from dead upstream mangroves affected by Hurricane Irma. To note, the blooms are harmful but not toxic. Garfield Bight is the epicenter of the blooms followed by Terrapin Bay. Elevated nutrient concentrations are on trend with the timing and locations of blooms. There is a hope that these blooms will subside at some point as we reach a new equilibrium. Currently there is an imbalance in the system; if the blooms are linked to upstream nutrient conditions, we will eventually reach a new equilibrium.

Finally, in last couple of days a new bloom has appeared in the lakes just upstream of this same general area - a Cuthbert Lake Bloom. This area has noticeably green water, but satellite imagery does show elevated chl-a concentrations in those lakes. Again, there is an imbalance at this location.

Questions & Answers/Comments/Discussion:

- Wade Lehman: During the WQPP field trip a few weeks ago Florida Bay was very clear. Southwest Florida is in a drought right now so water flows are down. As USACE begins to restore flow patterns, how might that affect this area?
 - There is potential that with freshwater flows increasing and hydrating areas, we might mobilize some of these legacy nutrients. Those could contribute to blooms. However, that would only occur until we reach a point of stability. Those freshwater releases are exactly what we need to prevent another seagrass die off in the future. This will have benefits to limit future nutrient releases from seagrass mortality. Will be an interesting dynamic along these coastal mangroves, seagrass beds, etc. Sea level rise may also affect this dynamic. NPS has a few projects to investigate these relationships further.
 - Overall, the restoration of flows will be beneficial to this system in the face of climate change and sea level rise. We need to keep freshwater coming across. This is more likely to reduce collapse of soils that would release additional nutrients. Still, we recognize this may also mobilize some nutrients and result in some intermittent blooms.

IV. Biscayne Bay Commission Update

Mollie Sinnott, FDEP, shared information about ongoing water quality efforts in Biscayne Bay. Governor Desantis created the Biscayne Bay Commission in June 2021 to protect Biscayne Bay resources. The legislation enabled coordinated action to address issues, with goals to develop and track a strategic plan, create a financial plan to fund priorities, and provide a forum for exchange. The commission meets four times per year. Outputs include a semiannual report (generated to summarize meetings and update project tracker), project tracker (updated by commission and member agencies), and a financial plan (to identify potential funding sources from agencies). DEP, SFWMD, FWC, Florida Inland Navigation District (FIND), the Miami-Dade Commission, and League of Cities, among others, all have representatives on the commission.

The goals of the Biscayne Bay Commission are to: Consolidate existing plans, programs and proposals into a coordinated strategic plan; prepare a consolidated financial plan using the projected financial resources available from the different jurisdictional agencies; reduce duplication of efforts; and maximize coordination. The commission helps identify funding sources for these actions and highlight funding needs up the chain. They also provide technical assistance and support to implement strategic plans, liaise with DOI and the MDC watershed advisory board, and act as a clearinghouse for information/public engagement.

Future meetings: April 26th, July 12th, October 25th. Action items: create strategic plan for Biscayne Bay, learn about projects implemented from the Biscayne Bay Water Quality Improvement Grant, continue updating the project tracker for the next semi-annual report. More information is available online: [Biscayne Bay Commission | Florida Department of Environmental Protection](#).

Questions & Answers/Comments/Discussion:

- None.

Meeting Wrap-Up and Adjourn

- Wade Lehmann thanked everyone for participating in the meeting, and noted that presentations not covered today that were initially planned for the March 2023 meeting will be rescheduled during the next full Steering Committee meeting.