DRUM *and* CROAKER

A Highly Irregular Journal for the Public Aquarist

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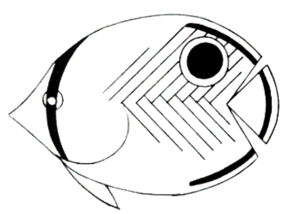

Cover Photo: Megan Rusin
Interior Gyotaku: Bruce Koike, Little Pond Nature Prints, https://www.brucekoike.com/
Interior Line Art: Craig Phillips, D&C Archives

Letter from the Editor – January 2025
THE REGIONAL AQUATICS WORKSHOP – "IT'S OFFICIAL"

Pete Mohan

If you are reading this outside of North America, you may not be familiar with the Regional Aquatics Workshop, better known as RAW. It's an annual meeting for public aquarium professionals that began 35 years ago as a tiny group from the USA state of Ohio and its neighbors. The original attendance of a dozen or so aquarium folks has gradually ballooned into a 400-plus horde, and the "region" has expanded to routinely include representatives from much of North America, with friends often joining us from other parts of the globe.

It was pointed out by Paul Clarkson, our newest RAW Advisory Committee chair, that our "organization" didn't really exist as more than an idea. Individual hosts put their stamp on each meeting with varying levels of input from the RAWAC, which is composed of former hosts with relevant experience. While previous iterations of the RAWAC had discussed forming a non-profit, Paul followed through, leading the group that finally crafted formal bylaws and incorporated RAW as a non-profit in early 2024. The RAWAC provided input, and others who already manage non-profits, such as Jennie Jansen (also a 2025 host), were valuable contributors. The initial directors of the "non-profit corporation" are Paul (President), Becky Elsworth (Treasurer) and myself (Secretary). Ohio will be RAW's home base, and it's appropriate that Becky and our legal advisor have established a home address in the Columbus area. Why? The idea that became RAW originated in a food prep room at the Columbus Zoo with managers from their aquarium (Doug Warmolts), Toledo Zoo (Jay Hemdal), Belle Isle Aquarium (Doug Sweet), and SeaWorld Ohio (me) present.

The biggest kudos and high-fives must go to Paul, who pushed this effort to completion through an organized and thoughtful process, and Becky, who shepherded the legal and financial paperwork. When I was the original RAWAC chair, I wrote some guidelines that served as a substitute for bylaws for decades. Therefore, my current role is largely to provide some historical perspective, and I have the white hair and beard to prove it.

The above directors have completed the incorporation process. Elections for the initial board of directors and committee chairs will happen soon. Becky has opened a bank account and Paul hired a web designer. The new website just launched (see below). We're tossing around ideas for a logo that will be unique to RAW, Inc. Don't expect much else to change on the surface in shorter term. The help we already provide will be improved, streamlined and accountable to the board.

I'm looking forward to seeing many of you all at "B'more RAW" at the National Aquarium, Baltimore, MD, USA. As always, the abstracts from the conference will appear in Drum and Croaker. You'll find the 2024 abstracts in this issue!

https://www.regionalaquaticsworkshop.org/
(The old website address, https://rawconference.org/ will direct you to the new site, and https://rawconference.org/wordpress/ is now invalid.)

DRUM & CROAKER 50* YEARS AGO: A RETROSPECTIVE

Steven L. Bailey

(From 1976 Vol.16 #1 issue)

**With no 1975 issue published, this gaze into the Drum & Croaker rearview mirror will select the first of the (2) issues of D&C published in 1976 (March).*

This year's column will offer a slightly different approach versus the traditional "Rick Segedi style" for this issue's retrospective column. The aquarists and aquarium directors of 1975 were resourceful and industrious types, with some of them staying in the public aquarium profession for their entire careers, others not, but transitioned to other natural sciences callings where they amassed impressive bodies of work. Two of those D&C Vol. 16 #1 issues authors are recognized in this installment for their life-long aquatics careers and their contributions to environmental education.

Miami Seaquarium's Leatherback Turtle
Patricia F. Foster, Aquarist, Miami Seaquarium

This is an engaging account of early pioneering husbandry work on *Dermochelys coriacea,* the leatherback sea turtle, the most difficult of sea turtle species to maintain in a controlled environment.

Still a nearly unexhibitable species, this work by the Seaquarium (in collaboration with the Florida Department of Natural Resources) demonstrated substantive progress over the course of 8 years of effort. Astoundingly, the account details a hatchling specimen reaching 17months of age and a weight of 51lbs.

The evolving project in 1975 concentrated on diet, behavior, and tank enclosure design parameters. A number of these husbandry aspects (to this author's knowledge) have changed very little despite the passage of 50 years. Amongst those factors mentioned are:

- tank design – circular geometry with foam & nylon padding.
- diet/nutrition – repeated trials led to a focus on the Mangrove upside-down jelly *Cassiopeia xamachana* with vitamin-injection supplementation.
- behavior – includes notes on repetitive behaviors e.g. wall rubbing and its requisite abrasions.
- wound treatments - potassium permanganate and violet gentian.

Interestingly, Aquarist Pat Foster went on to marry a fellow Seaquarium husbandry staffer Patrick "Bucko" Turley and earn her PhD. She served many years with USAID overseas organizing and implementing a variety of environmental health, fisheries, and forestry projects, as well as work as an international biodiversity specialist. She continues to travel, engage in environmental advocacy, and write extensively as a naturalist in Northeast Florida. Here are links to a few of her columns:

Pat's Wildways: Snorkeling - Fernandina Observer
Pat's Wildways: Otter Introductions - Fernandina Observer
Pat's Wildways: Crooked River State Park - Fernandina Observer

Pat was contacted to share that her leatherback sea turtle submission was having particular attention drawn to it.   She was quite delighted to hear of it being resurfaced!

Seaquarium Aquarist Pat Foster with leatherback *D. coriacea* hatchlings c.1975
Photo credit: Pat Foster-Turley

{1976} NOTICE *(of changes for Drum & Croaker going forward)*
William P. Braker, Director, John G. Shedd Aquarium.

With Vol.16 #1, and with the following message, the Shedd Aquarium team led by Director W.P. Braker passed the D&C torch to John H. Prescott, Director, New England Aquarium for continuation of D&C's documentation of, impact and influence on the public aquarium industry.

> *With this issue the John G. Shedd Aquarium will turn over the responsibility for editing, publishing and distributing to the New England Aquarium. John Prescott has agreed to do the honors for a few years.*
>
> *We are proud to have had a part in the publishing history of this unique, elite and sacred journal. Kim Marggraf, Editor of Drum and Croaker, and my Secretary, has left Shedd Aquarium for other pursuits. She deserves our thanks for the countless hours she spent typing, assembling, and mailing these words of wisdom.*
> *{from} Kim Marggraf. "Adios Amigos"*

Bill Braker is still going strong at 98 years of youth, and was just mentioned at our periodic Sunday breakfast rendezvous by Capt. John Rothchild, retired Coral Reef II collecting boat captain of 34years.

Mr. William P. Braker is a name very familiar to many of us long-serving "aquarium-lifers." His contributions have been immense, including a leadership role in convincing existing public aquaria to join the public zoo organization that has become AZA. His strong and influential guidance initiated field conservation projects, pioneered collecting expeditions involving aquarium supporters and donors' participation, mentored many future aquarium leaders, and cultivated collaboration amoungst an influential group of national and international aquarium directors, to mention just a few accomplishments. His legacy is considerable and he is, for many, the preeminent architect of institutional excellence.

As an aquarium director who started in the trenches – "a tank man," as Mr. Braker describes an entry-level husbandry position – he fully understood the nuances and considerable invisible considerations and subtle details of operating a public aquarium. As a native Chicagoan, he was delighted to be asked by Shedd Aquarium Director Walter Chute (formerly of the South Boston Aquarium) to assume the Assistant Director position and learn by doing, an anecdote that Mr. Braker has shared with many over the years.

Our industry has changed significantly since its inception in the 1850s. Mr. William P. Braker has been a witness to and creator responsible for much of the last 50 years of its evolution.

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Shedd Director William P. Braker in flight with collecting trip specimens c.1960s.
Photo credit: zooaquariumvideoarchive.org

NOVUS AQUAS (NEW WATERS)

Barrett L. Christie, enteroctopusdofleini@yahoo.com

Once upon a midnight dreary, while I pondered, drunk, eyes bleary - came a rapping at my office door. A ghost appeared, an apparition, a dreadful spectre on a mission, intent upon restoring imagination to our tanks without intent to bore. Startled by the stillness broken, and seeing a zoologist once outspoken, I asked, pleaded, to know perchance why he has come to my door.

Suddenly he started toward me, I began to see this devil more closely, and in a flash he jumped up on a hickory stump, and said "boy, let me tell you what".

Alarmed at this spirit before me, and confused as to how a stump had appeared in my office, I asked who he was, and what he wanted from me, for I had no fiddle playing abilities of which to speak. As I got a closer look at his face, I realized 'twas not a demon, nor an ogre, or devil as I had surmised before. He was strangely familiar, though I could not say as I have ever met the man. I began to calm as I realized this mustachioed spirit was not intent on doing any harm, he said I could call him 'W'. Then the spirit demanded of me an answer to his question: "How is it", he asked, "that you are trying to buy a jaguar shark for eleventy-thousand dollars, when you don't even have a proper exhibit for bluegill?"

"Bluegill!" I replied, "What would a common backyard species like *Lepomis macrochirus* possibly do for my aquarium?"

Surprised, W. exclaimed "You only *think* you are doing something for your aquarium, when you have lost sight of your mission, which ought to be thinking of what you can do for the average visitor to your aquarium. All your mission statements contain some permutation of the charge to *inspire*, after all! You really think that spending that much money on a species that only another biologist will truly appreciate is a better way of connecting with your visitors than displaying a fascinating creature that is endemic to North America, and moreover, quite tasty when battered and fried?"

A bit taken aback by this challenge to my curatorial judgment, I responded that the acquisition of a jaguar shark, *Squalicorax zissoui*, was well supported by our institutional collection plan (which we wrote with intent to purchase a jaguar shark), and moreover was key to our goals of sustainability and conservation, as the animals would be part of the new jaguar shark SSP, a coalition of institutions who had similarly written their collection plans to indulge their fascination with the species.

Footnote: Adapted shamelessly from the classic 1973 article "How to exhibit a bullfrog: a bed-time story for zoo men" by William G. Conway (W.); with profound apologies to Conway, Edgar Allen Poe, Wes Anderson, Charles Dickens, and Charlie Daniels.

The original Conway article is a humorous and wonderful call to action for imagination in animal exhibitry from the age of sterile concrete zoo enclosures, and is well worth a read by all, a reprinted copy can be found at this link: https://zoolex.org/media/uploads/2018/07/30/conway_how_to_exhibit_a_bullfrog.pdf

“Conservation!” W. roared, “nothing makes me angrier than the tenuous argument that your desire to bring this animal into your collection is for conservation! Do you even know *how* to breed them? And how do you expect to do so with only one animal?” he paused, and further remarked “all too often you use the façade of sustainability, or conservation as a flimsy justification for acquiring a species you find fascinating. Why can’t you just admit your *learned* curiosity drew you towards this exotic species, rather than the prospect of possible breeding or loftier goals?”

I began to retort with a comment regarding the marvels of artificial insemination, cryopreservation, and other population management tools, but W. interjected “And I can’t help but notice you’ve only defended your decisions to acquire this bedazzled *wondershark,* and said nothing of your abject failure to provide a proper exhibit for bluegill!”

Being quite off-balance in the conversation, I pointed out that that such a simple and ubiquitous pond fish as a bluegill just didn’t have the power to catalyze wonder in the aquarium guest, no one is left in awe of the LBJs (little brown jobs) so common to native freshwater exhibits. He raised an eyebrow skeptically “…and besides,” I said, “we do have a few as an accessory species in the largemouth bass tank”

“Accessory species!” He roared, “that’s exactly the problem, you consider this marvel of ichthyological evolution to be just an accessory to the main event! A remarkable fish such as the bluegill need not play second fiddle to a *ditch pickle*! You throw a few bluegill in a larger exhibit just to *fill it in*, and ignore the capacity the bluegill has for education, recreation, and *excitement*!”

Still confused, and skeptical myself that a bluegill could ever have the same impact as some of the primary species we had on display, I conceded that as a biologist I could certainly appreciate the bluegill, though I just did not feel that they were a compelling enough species to warrant an exhibit unto themselves. At this point W, incredulous, said “An exhibit? Hell, you could make an entire aquarium themed around the bluegill and done well enough to spark inspiration in as many of your visitors as your highfalutin’ *sparkle-shark*!”

And then, he said we would need to consult with three of his colleagues. “You mean the ghosts of Christmas past, present and future?”, I asked, to which he replied “Ha! No, not hardly, we reserve those for tech billionaires, dictators, despots, and health insurance executives. We will need to confer with their functional analogs in biology – the ghost of natural history past, ecology present, and adaptation future.”

In a flash, we found ourselves transported through space and time, standing in a large enclosed greenhouse with towering tropical palms and ferns, a path winding through ponds and rainforest showing the Eocene period when sunfishes arose. Bright colorful macaws and other parrots are perched over some exhibits, an interpreter tells us that the psittaciform birds also arose during this time period and were originally closer to their dinosaur cousins in their carnivorous nature than their modern contemporaries that adorn the shoulders of pirates and Jimmy Buffett resorts.

A projection behind one of the pools brimming with colorful sunfish displays a hologram of a two-horned rhinocerous, *Arsinotherium*, and the signage explains that the earliest large mammals arose in this time period, predated by fishes by about 500 million years. The dense vegetation is also interpreted by an animation, showing how these ancient wetlands created oil deposits today. As we continue down the trail the dense jungle air gives way to a minty floral perfume and I see we are in a dense grove of *Eucalyptus*, another plant that arose on earth with the sunfishes. In the dense *Eucalyptus* plants, we see an enormous anaconda slide delicately into the pool, with dozens of crappie and redbreasted sunfish. My delicate curatorial sensibilities were insulted by this, and I asked why on earth one would display *Eunectes* with an assortment of sunfishes and not with the myriad of South American fishes that would be geographically appropriate. From beside W. the ghost of natural history past piped in "remember, you need not be constrained by either time or place in exhibitry, in this exhibit we ignore place to explore time, specifically the era where sunfish arose on the earth…coincidentally the time when python diversity was at its peak!"

I conceded this was an interesting angle, but still could not help but feel unease at geographically disparate species displayed together. The ghost continued "the story you tell need not be linear, but must above all, be compelling. And what is more compelling and likely to grab the attention of a young visitor than a giant snake! That's how you get them to appreciate the bluegill!"

I could see the rationale, but my thinking had been so biased towards biogeography that I didn't appreciate how all these exhibits were telling the story of a species, I noticed W. and the ghost heading towards a doorway and followed suit. We stepped into a dark room, and I was relieved to be back in air conditioning, beautiful as the last exhibit was. As my eyes adjusted, I saw W. and the mysterious ghost, next to a large sandy bottom tank in the center of the room, flanked by large exhibits on each wall. Approaching the central exhibit, it was a beautiful recreation of a rolling sand hill as one might see between reefs, with a thriving colony of jawfishes. The industrious little fishes scurried to and fro, hither and thither, moving sand, moving more sand, occasionally squabbling with a neighbor who was also moving sand. It was a fascinating exhibit to behold, yet when I asked why bluegill had been abandoned in favor of a more colorful saltwater species a new ghost appeared and laughed incredulously. "Your ichthyology professor would be ashamed!" he said, "think of the *phylogeny*, these are some of the closest evolutionary relatives of the Centrarchidae!"

Realizing that this was the ghost of adaptation future I began to realize that from the frame of reference of the bluegill, these large exhibits were telling the story of speciation. And in this story, the throughline was the humble bluegill. The charismatic and industrious jawfishes speciated in coral seas worldwide and looking up at the large acrylic panels flanking the gallery I realized these told a similar story. One was a huge Atlantic Ocean exhibit, with hundreds of hulking striped bass, with bluefish, red drum, and other species well known to anglers. The graphics talked about how these relatives of the humble bluegill represented the largest animal migration on earth and shared a common ancestor with the white basses in freshwater, and yes, our friend the bluegill.

The other large tank had a beautiful tall display of bull kelp from the west coast, bathed in rays of interspersed ethereal sunlight, and a wide array of rockfishes, kelp basses, and a few ginormous *Stereolepis* sea basses. The graphics showed how the sea basses and the scorpionfishes all shared a common ancestor with bluegills, and I had to admit the photo of a juvenile *Stereolepis* even bore more than a passing resemblance to the bluegill we all know so well.

As we passed to the next gallery we walked past beautiful coral displays from the far-flung Pacific, each showing how their denizens were kin to that backyard wonder so recognizable to us. We entered the final gallery, and I saw a third ghost had joined W.'s entourage. "Ghost of ecology present, I presume?" I asked.

"Why yes of course" he responded, "take a look at these displays, you should find the theme a bit more *conventional* to your limited way of thinking geographically about aquarium exhibits"

I saw a dark wall with more than thirty jewel tanks in varying sizes, the largest holding a single crappie or bass, the smaller ones containing beautiful examples of pygmy sunfishes with brilliant hues of azure. I realized this wall contained all the North American endemic sunfishes in one place, from the diminutive bluespotted sunfishes bearing iridescent blue spots, to the rock bass with ruby red eyes, and pumpkinseeds and longears, every bit as brilliant as the most beautiful exotic cichlids coveted by hobbyists.

I had to marvel at this impressive display of diversity, but as we walked to the end, I saw a sprawling immersive freshwater lagoon full of plants and fishes commonly found amongst bluegill, gars, catfishes, turtles, bullfrogs, and of course, hundreds and hundreds of bluegill building and tending nests in the substrate, and darting in and out of wood and plants. "This shows the aquarium guest a look at the species they may know, but in their world that is still just a bit alien to us, despite being right in our backyards"

We saw movies showing the bluegill building its nest through a spring breeding season, and graphics explaining how we were losing freshwater biodiversity at an alarming rate as waters warmed and invasives displaced natives. I had to admit, this progression of exhibits all had every bit of appeal as the biggest and best public aquaria I had seen, and all with the common frame of reference of the lowly bluegill.

W. spoke, seeing the realization in my eyes "you must give your visitors a novel intellectual reference point" he paused, watching my reaction "the species they know is connected to an ecosystem that they perhaps understand a little less, which in turn is connected to species and ecosystems and diversity expanding out ever further around the world that they can scarcely imagine!"

And I realized he was right, we seek to inspire our visitors, to spark in them a bit of the fascination that drives us as biologists. He continued "Bluegill are but a single example, but one I am particularly partial to, it could be any common species, a turtle, or maybe even a bullfrog, but starting from a common frame of reference makes everything more relatable."

I realized an aquarium collection is like an all-you-can-eat buffet, the visitor can take as much, or as little as they want from it, but to maximize your impact you must have a little something for everyone. The bluegill may not spark that child-like curiosity in them, but their relatives might, as might the role in the ecosystem which supports the species they love to eat, or to catch, or even the charismatic species they find so damned *cute*. You don't need a huge animal, or an impossibly rare species to spark curiosity and fascination, you can do it with any species, presented well enough. As it was incredibly late, and I had been sipping bourbon even *before* these wild hallucinations, I suddenly recalled the Robert Hunter lyric, sang by Jerry Garcia: "Once in a while you get shown the light, in the strangest of places if you look at it right." …a fitting analogy to this newfound realization.

But before I could share this thought, W. had vanished into the æther amid a cloud of mist, and I was back in my home office. All that remained was my tattered copy of Spotte's book on bluegill sitting atop the mysterious hickory stump. As I pondered how the hell I was going to remove a hardwood stump from inside the house, I took to heart the message that no species is too small, too common, or too plain to be the centerpiece of an aquarium exhibit. Every species has an angle that is fascinating and compelling, it is up to us to ensure other people see that.

Another Footnote: For those who want to take a deep dive into bluegill, (and who wouldn't?) an excellent reference is the monograph by Stephen Spotte. A more captivating treatise on a single fish species one would be hard pressed to find…well, except maybe the book on candiru by the same author, but I digress. Reference: Spotte, S. 2007. Bluegills: Biology and Behavior. American Fisheries Society Press. 214p.

Bluegill Sunfish, Bruce Koike

COLLECTION AND HUSBANDRY OF TWO ENIGMATIC MARINE INVERTEBRATES OF THE SALISH SEA: BASKET STARS, *Gorgonocephalus eucnemis,* AND FEATHER STARS, *Florometra serratissima.*

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Abstract

The diversity of marine invertebrate life found in the Eastern Pacific is vast and breathtaking for any diver who has the opportunity to experience these cold waters. A large portion of aquariums across North America barely tap into the complexity of life found in the waters of the Pacific Northwest. Institutionally this gap in diversity can range from factors such as accessibility, space, availability, cost of maintenance, and knowledge of care. Two of these truly unique marine invertebrates found within the Salish Sea, whose care in captive aquaria has significantly progressed in the last decade, are feather stars, *Florometra serratissima* (AH Clark, 1907), and basket stars, *Gorgonocephalus eucnemis* (Müller & Troschel, 1842). These species are both found in deep, rocky, high-current environments; all of which are difficult or near impossible for the general public to view in person. By streamlining collection techniques, essential water quality parameters, dietary needs, flow preferences, and preventative maintenance, these extraordinary cold-water species could be more commonly displayed in aquaria. Expanding animal care skills and management knowledge within the industry will help to enhance the overall welfare of these animals. These species have been collected and cared for at the Point Defiance Zoo and Aquarium with varying levels of success over the last decade, and it is important to learn from both our successes as well as failures. This knowledge and experience will help to progress care and expand the abilities of other facilities to include some of these unique invertebrates in their collections.

Introduction

The aquarium industry has made tremendous leaps of progress in the care of our animals over the last century. One of the main hurdles in our industry remains the transfer of knowledge. This knowledge of husbandry and collection techniques can be lost when staff turnover, move to another aquarium, or leave the industry completely. It is crucial for this information to be retained in order to continue to provide the best, consistent care for the animals in our collections, and to advance the industry forward. This information can be shared during conferences or passed down through generations by mentoring new staff. Although one of the best ways to retain this information is through publications and transcribing new methods and discoveries.

Cold-water marine fish and invertebrates found in the Eastern Pacific Ocean encompass a large majority of marine life found in North American waters. Yet fewer institutions exhibit the diversity of life found in these temperate seas bordering North America. Reasons for this lack of diversity can include cost of acquisition and care. Typically, it is easier and more cost effective to heat water than to maintain a lower temperature in which many of these organisms require. Institutional knowledge to care for some of these complex invertebrates is limited as well, with only a few institutions exhibiting other Eastern Pacific specific organisms such as the Orange Sea

Pen, *Ptilosarcus gurneyi* (Grey, 1860). This can make training new staff or troubleshooting issues difficult when trying to bring in a new species, further pushing the need for transparency between institutions. Without open communication and transparency, gate keeping of this knowledge can slow down and inhibit growth within our industry. Another major limiting factor with increasing Eastern Pacific fish and invertebrate displays comes from a shortage of collectors in the region and cost of acquisition for these animals. Many of these invertebrates can be found in high densities in the wild, which makes recreating realistic displays costly without the ability or knowledge to breed these animals in house. A cost-effective method is to collect these animals within one's own institution, and have direct control of the collection, care, and transportation of these animals. Collection trips give staff the opportunity to experience the ecosystem first-hand in order to create displays that better interpret the ecosystem and potentially make changes to preconceived husbandry techniques based on in-field observations. With all of these challenges in mind, there are two species of cold-water marine invertebrates, which are not commonly seen in aquariums, that we would like to discuss in terms of collection, care, and display.

Both the feather star, *F. serritissima,* and basket star, *G. eucnemis,* reside in the Phylum Echinodermata and are found all along the Pacific Coast of North America from Alaska down to Baja California at depths as deep as 6,000ft (Hendler et al., 1995; Rosenberg et al., 2005). These species are found in deeper depths and in rocky high current areas, making them uncommon for many recreational divers to encounter. Care for both of these species has been limited in aquaria with mixed success based on the institution and the staff at the time of care. Recently more success has progressed care for both of these species particularly the basket star, *G. eucnemis,* is being seen in more institutions around the Pacific Northwest. The Point Defiance Zoo and Aquarium (PDZA) has kept basket stars in their collection with varying success over the last decade. These animals are either collected in house from specific dive sites or donated from nearby research institutions when they are trawled up during research excursions. One particular individual has been in our care for 3 years with no signs of decline. The Alaska SeaLife Center has kept this species successfully for decades and most notably maintaining the same individual throughout this time (personal comment). Recently PDZA added feather stars to our collection, bringing them in during the summer of 2023. We have had no mortalities within this group. These two species have been successfully cohabitating in the same display for 18 months. We want to document our operating procedures and struggles so other institutions can consider adding these invertebrates to their collections.

Feather Star (*Florometra serritissima)*

Biology

Feather stars, *F. serritissima,* are a species of crinoid in the echinoderm phylum. They have pentaradial symmetry with each limb diverging into two arms, giving the impression of a total of 10 arms. Each arm has pinnules extending from the arm that capture food by suspension feeding (Pruzynski, 2021). They then carry food down the ambulacral grove via podia to the mouth (Macurda jr, 1970). The mouth and anus are separate on the dorsal surface of the organism in a central disk like region called the "calyx" (Figure 1) (Pruzynski, 2021). On the ventral surface the larval form would have a stalk, which is reduced in the juvenile and adult form (Comeau et. al., 2017). The organism holds onto the substrate with 20-30 cirri - hook like appendages (Pruzynski, 2021). This species locomotes by crawling short distances as well as swimming greater distances (Stevenson et. al., 2022).

Figure 1. A close-up view of the calyx of *Florometra serritissima.* Note the location of both the mouth at the center of the central disc and the anus separate from the mouth. The pentaradial symmetry can also be seen on the central disc as the paired arms meet down the ambulacral groove with podia present. Photo: Megan Rusin.

Collection

This species is found primarily from Alaska through Washington, although specimens have been recorded as far south as northern Mexico (Pruzynski, 2021). This species is found at a depth of around 80 feet on rocky boulders, but has been recorded as deep as 1100m (Baumiller, 2013). Our institution has not observed this species within United States waters and therefore had to outsource our collection to a Canadian based collector. Ken Wong was able to source this species out of the northern Salish Sea where he collected and shipped 5 individuals to PDZA in July of 2023.

Husbandry

We have found the feather stars to prefer moderate consistent flow. If the flow is too high crinoids are known to seek refuge in crevices (Macurda, 1970). We have observed that if a feather star does not find a suitable location in the tank providing the correct flow, their delicate arms can break off in small segments. Their display tank is set up with a large, epoxied boulder pile (Figure 2) in the center of bubble tank with the tank's only two returns angled directly at the front of the rock. The feather stars position themselves directly in front of the flow to maximize suspension feeding, and this keeps the organisms within view of the public. In the wild feather stars feed on a diet composing of foraminiferas, larvae, algae, diatoms, small crustaceans, radiolarians, & organic detritus (Macurda, 1970). In order to mimic the wide range of food available to filter feeders ex-situ, a "shot gun approach" is used to feed these individuals as their diet rotates throughout the week. A wide variety is offered including krill, roe, macroalgae, preformulated gel diets, various fishes/invertebrates blended during preparation and pre-prepared microalgae, engineered powdered reef foods, aquaLife® CALA-fin, and oyster eggs/ovarian tissues served without modification. The liquid diet is administered to the feather stars via a turkey baster ~6 inches from the individuals multiple times a day. The flow is reduced during feedings to maximize contact time with the stars. Due to low lighting on the exhibit to simulate depth, minimal scrubbing is required. Depending on how the food item settles out in the water, a turkey baster may be needed to blow off the rock pile to prevent a detritus film. Although the stars do not travel to the substrate, it is vacuumed regularly to prevent biofouling.

These organisms have been handled out of the water without damage or loss, but minimal handling to reduce stress is recommended. Since this species is highly motile, they will try to swim away when placed back in water. With coaxing they can be guided to the desired location for placement. Individuals will slowly crawl around until ideal conditions are found for each individual. We have not observed intraspecific or interspecific tangling when placed in close proximity to other feather stars or basket stars. They have not shown to outcompete each other, making a mixed display possible.

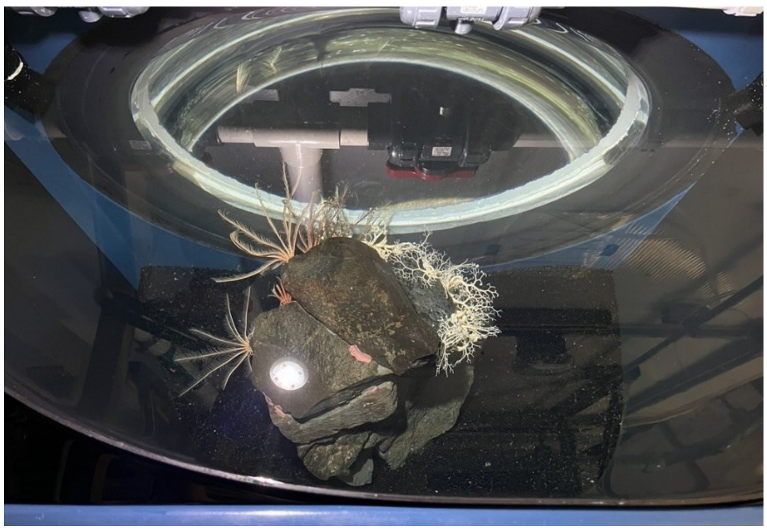

Figure 2. An above view of the exhibit at PDZA showing both the feather stars, *Florometra serritissima,* and the basket stars, *Gorgonocephalus eucnemis,* on display together. The rock pile is the only structure in the exhibit, and both returns in the top left and right of the photo are angled towards the front of the rock pile.

Challenges

In our experience the feather star has posed to be an easier animal to maintain compared to the basket star. Our only difficulty was experiencing extreme arm loss on the smallest individual during the final days of an observational quarantine. This was resolved by providing a more adequate environment on display in regard to flow and biofouling. There the individual regrew arms within a few months. Feather stars have the ability to regrow arms and the rate at which is multifactorial. Arm loss is common with 80% of observed wild organisms missing some portion of an arm (Mladenov, 1981). This species regenerates lost arms at a higher rate than other feather stars that cannot locomote via swimming (Stevenson et. al., 2022). We occasionally notice a broken arm but, in all cases, thus far it begins to regrow.

Basket Star (*Gorgonocephalus eucnemis*)

Biology

Basket stars, *G. eucnemis,* are a species of brittle star in the echinoderm phylum. They have pentaradial symmetry with each limb diverging dichotomously into smaller and smaller subdivisions. The basket star is a suspension feeder that perches in an elevated position, using 2-3 arms to hold onto the substrate or elevate the mouth while up to the rest of the remaining arms are unfurled to snare food particles (Emson et. a., 1991). The arms contain small hooks and ambulacral spines that catch onto prey when the star it unfurled in a basket-like position. When a large particle of food is ensnared by an arm, the arm is coiled towards the mouth. When prey becomes trapped by the small hooks & actively coiling arms, a mucus is secreted that immobilizes the food item. The arms then bring the food to the mouth which is on the underside of the body. The mouth has a comb-like structure that removes the food particles from the arms (Patent, 1970) (Figure 3). They do not have a separate anus & any undigested fragments are expelled through the mouth. Basket stars have a tight relationship with cold-water corals, specifically sea strawberries in Puget Sound (Neves, 2020; Patent, 1970). Embryos are ingested by soft coral & will develop in the polyps, feeding there until they are large enough to leave & capture food on their own (Patent, 1970).

Figure 3. A ventral view of a basket star, *Gorgonocephalus eucnemis,* clearly showing the pentaradial symmetry analogous to other sea stars. The mouth is also clearly visible with the comb-like structure for removing food particles ensnared in the arms.

Collection

This species has been brought in to PDZA on five separate occasions since 2022. Three of these instances occurred as donations from a local university. The university comes across these individuals during deep-water trawling course along the San Juan Channel. These organisms are held in a flow through system for a few days, weeks, or months until the proper paperwork is obtained and a transport arranged. The first two individuals were picked up in February 2022. One of the larger basket stars, which was already in poor condition prior to transport, died three days after arrival at PDZA. Two additional individuals were donated in April of 2022 after a shorter holding period. Both of these stars were in great condition upon arrival. Finally, four more basket stars were donated from the same university in May of 2024. All eight of these individuals were collected and brought in through the same deep-water trawl methods. They resided in university classroom wet tables on an open system until being transferred to PDZA. Occasional supplemental feeding was provided by university staff while waiting for permitting for transportation. PDZA staff provided transportation in a 20-gallon cooler. No air was added during the transportation to reduce the risk of air entrapment in the central disc. A PVC frame was developed with plastic mesh attached to the frame to provide structure for the basket stars to attach to during transport (Figure 4). This reduced any movement or rubbing of the stars in the cooler and provided great stability during any unforeseen jostling during transport.

Figure 4. Four basket stars, *Gorgonocephalus eucnemis,* ready for transportation in a 20-gallon cooler attached to a PVC frame with mesh. This allows the stars to firmly grip a rigid structure to reduce rubbing during transport.

On two separate dive trips in September of 2023 and July of 2024 two divers collected basket stars while diving between 75 and 90 feet deep between Cape Flattery and Neah Bay on the northwest corner of the Olympic Peninsula in Washington state. At the time of collection these stars were found in high abundance. Once located they were gently removed from the rocks that they were attached to, placed in a plastic bag, and secured with a rubber band until transferred to a cooler on the boat. Removal of the basket stars from the rocks could be difficult (Figure 5) without damaging any of the arms, so a hammer a chisel is recommended to help break up the rock rather than try to pry to remove the many arms. These collected stars were then stored again in 20-gallon coolers and immediately transported the four-hour drive back to the aquarium.

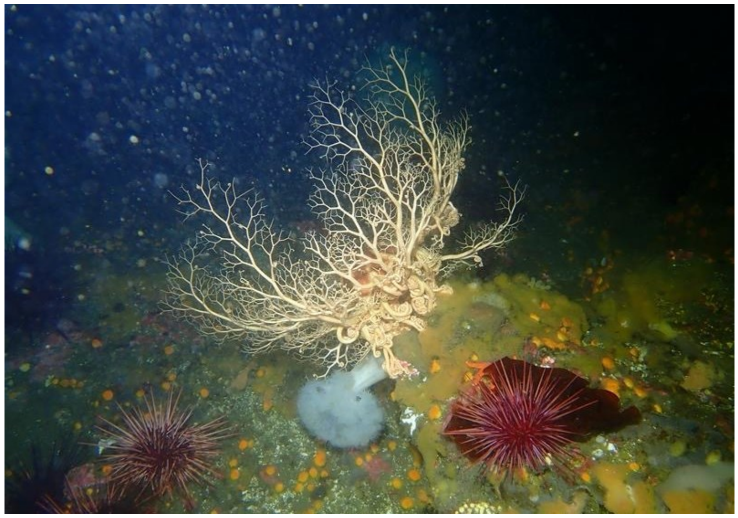

Figure 5. A wild basket star, *Gorgonocephalus eucnemis,* prior to collection just outside of Cape Flattery, WA around a depth of 85 ft. Many of the arms are up and exposed to catch any potential food, while the remainder of the arms are gripping the rockwork making removal and collection a bit tedious. Photo: Mikiko Williams.

Husbandry

Our husbandry for this species is almost identical to the feather stars. We have found that they also prefer moderate consistent flow in their exhibit throughout the day. Flow varies slightly and is decreased during feedings in order to increase retention time between the food and the individual. The flow is increased by the end of the day to help flush out the system and keep it clean. Since the basket stars cohabitate with the feather stars, they also reside on a large, epoxied boulder pile (Figure 2). The basket stars have shown to prefer being near direct flow, but not directly in it. Using this knowledge one can control where the basket star chooses to settle by setting up the flow accordingly. The basket stars feed by perching in an elevated position and extending those arms in a net-like fashion perpendicular to the current (Patent, 1970). When their arms are outstretched the basket stars ensnare small crustaceans, jellyfish, chaetognaths, embryos, and detritus that comes within reach, but may also feed on organisms found on the substrate (Patent, 1970). The same "shot gun approach" is used for feeding the basket stars to mimic their wide range of wild diet with the same preparation of food as the feather star as noted above.

These organisms have been handled out of the water without damage or loss, but minimal handling to reduce stress is recommended. In order to move a basket star from one enclosure to another, care must be taken to gently but swiftly remove the basket star from whatever it is attached. If possible, it may be easier to transfer the rock or pipe to which it is currently attached, and move that to the new enclosure until the basket star begins to move on its own. If the individual must be removed from a larger object, slowly apply lift on the basket star and "tickle" the attached arms as an applied irritant to encourage the arms to move and let go of its attachment.

Challenges

In both of our experiences directly caring for this species over the last 3 years, we have encountered several challenges. These challenges first manifest themselves through a shift in the static behavior of the basket stars. In our experience once the basket star has found a suitable location in the exhibit, there is very little movement around the exhibit, other than opening up when food is presented. If conditions are no longer deemed suitable, the basket star will move around the exhibit, most likely in search of more suitable conditions. For example, we have noticed the basket star retreating to the bottom of the exhibit in times of warmer temperatures, potentially attempting to seek colder waters. If an imbalance in conditions isn't quickly recognized by staff, a basket star will usually begin dropping sections of their arms (Figure 6). This arm loss presents itself analogous to sea star wasting disease where we see arms dropping and tissue degradation that leads to a sudden death of the individual (Hewson et al., 2019). Hemolymph and tissue cultures have been sampled in the past, sometimes resulting in positive *Staphylococcus* sp. and *Pseudomonas* sp. infections. Like sea star wasting disease, antibiotics, such as TMP-S (trimethoprim sulfa) baths, have not shown any benefit to stopping the eventual death of the star, but may slow down the process. The best form of treatment we have found is making adjustments to water quality as soon as the moving behavior is noted in basket stars. These stars are collected in areas of very cold and full-strength salinity water, closer to the mouth of the Pacific Ocean. They are not found further into Puget Sound where salinity is typically lower, and water temperatures are higher. We have found the upper limit of their captive temperature range to be 48°F; although they can tolerate slightly warmer temperatures for short periods of time (e.g. during transport, LSS emergencies). PDZA is an open system and typically pulls in 29ppt filtered sea water from Puget Sound. Similar to the temperature quandary the basket stars can live at this lower salinity, but we acknowledge it is pushing their range of what is preferred. We have noticed if any of these parameters fluctuate, such as the temperature increasing above 52°F or the salinity dropping below 27ppt, the basket stars begin to move around their enclosures. Keeping the system as cold and salty as our life support can handle is the best prevention. We have run ICP analysis of our collection dive site & found no other significant difference in water quality parameters.

If a basket star has begun to drop arms, we have two treatment options that have shown some promise in stopping or reversing arm loss. Mimicking the work from the Oregon Coast Aquarium in 2023 (Rudek, 2023), a 10ppm dose of Ziegler® Rescue™ Probiotic has shown to help slow down or reduce the signs of stress and limit arm loss. Another treatment that has successfully saved one of our basket stars exhibiting arm loss is the use of hyperbaric treatment in combination with probiotic dosing. In 2019 PDZA built a hyperbaric chamber off the design and schematics done by Joe Welsh at the Monterey Bay Aquarium (Welsh, 2012). This chamber has been mainly used for treatment of teleosts, but we hypothesized this may also help better mimic the conditions that basket stars are more adapted to at depth. A single individual that was dropping arms was placed in the hyperbaric chamber for 3 weeks. After the arm loss had subsided the pressure was slowly reduced. The individual was then moved to a separate system in a water table behind the scenes for close observation. Almost 6 months later this individual is still alive, and new growth is seen from the arms that were dropped.

Acknowledgements

Our time and efforts to collect and troubleshoot displaying these species was generously supported by the Point Defiance Zoo and Aquarium. We would like to thank the PDZA cold water aquarium team both past and present for helping to support us to build our exhibits up to these levels to display these challenging species. We would also like to acknowledge the late Dr. Roland Anderson, whose work and publications such as <u>Aquarium Husbandry of Pacific Northwest Marine Invertebrates</u> has served as guidance and inspiration all throughout this process. Finally, we would like to acknowledge MacKenna Hainey and her initial work with caring for basket stars, and all of the feedback as we were working to bring this species back into our collection.

Figure 6. A basket star, *Gorgonocephalus eucnemis,* in severe stages of arm loss. The figure on the left shows an individual during hyperbaric treatment after the arm loss had subsided. On the right is the same individual six months later showing new growth from the base of the arms that were previously dropped.

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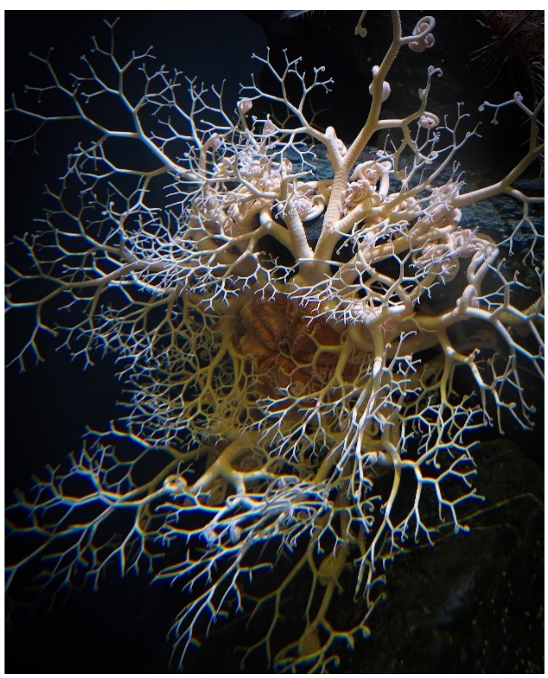

HEAVY METALS AND ANTIBIOTICS: SOLVING ISSUES OF DECAY IN *Chrysaora plocamia*

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Introduction

In early 2022, Wonders of Wildlife started construction on a 6,000-gallon stretch kreisel, 16.5 feet tall, 20 feet long, and 18 inches deep (Figure 1). To ensure the long-term success of the new system and the four existing gallery exhibits, the jelly team was expanded from two aquarists, who split their time between jellies and fish exhibits, to a dedicated four-person jelly and live food team. Two rooms previously used for ambassador animals were redone to accommodate a new live food area and expand the aquarium's jelly culture capabilities. Four grow out rack systems with five pseudokreisels each, two water tables with small pseudokreisels, two nine-foot stretch pseudokreisels, and two six-foot pseudokreisels were added to the original two small jelly culture systems.

The new exhibit would be stocked with *Chrysaora plocamia*, the South America sea nettle because of their fast growth rate, size, coloration, and ease of culturing and care.

C. plocamia usually grow between 50 to 60 centimeters in diameter and have an oral arm length between two to three meters, so a large exhibit would highlight their size (Mianzan et al., 2014). Based on previous experience, they can grow from an ephyra to about 15.5 centimeters in diameter in 15 weeks with twice daily feeds of enriched 48-hour old brine artemia, and each polyp can produce more than 20 ephyra, so keeping a large exhibit stocked is sustainable.

We received multiple shipments and donations of *C. plocamia* from two different sources to fully stock the new exhibit and hopefully develop a culture of our own. One source donated nettles that developed dark orange bells and stripes with light orange oral arms and happened to be all female, while we purchased more from another source that developed white oral arms and white bells with orange stripes and were all male. The two populations reproduced, and the resulting polyps produce medusae with a variation of colors (Figure 2). The lighter colored medusae are more commonly found off the coasts of Chile and Argentina, while the darker color variations are more commonly seen off the coast of Peru (Mianzan et al., 2014).

Figure 1. Newly constructed stretch kreisel

Figure 2. Color variation in *C. plocamia*

First Signs of Rapid Decay

We received our first batch, a total of 515 donated *Chrysaora plocamia* that were one to three inches in bell diameter, on November 2, 2022. They were kept between a temperature of 58 to 60 degrees Fahrenheit, a salinity of 30 to 35 ppt, and a pH of approximately 8.0. They were fed 48-hour old brine shrimp enriched with live *Nannochloropsis*, Shellfish 1800®, and DHA Selco®. The systems the nettles were housed in were not cycled when they were first added, but water quality was monitored daily, and appropriate water changes were performed when ammonia levels and other water quality parameters rose above the acceptable threshold.

The *C. plocamia* grew rapidly, behaved normally, and appeared healthy until two months after receiving them. The jelly team found several nettles with erosion on their oral arms that would either cause an entire oral arm to fall off in one piece at the base of the bell or cause segments of the oral arm to detach while the erosion progressed up the arm until the entire manubrium would fall out (Figure 3A). Occasionally, erosion would also be found in a small place on the edge of the bell and grow toward the center of the jelly (Figure 3B). The decay progressed quickly, impacting multiple but not all systems with jellies from the same source. The first observation of oral arm loss occurred on January 5, 2023. By January 13, 2023, the first jellies were euthanized due to poor quality of life as a result of the decay. One hundred twenty-seven of the original 515 nettles died or were euthanized in the two months following the first signs of the decay.

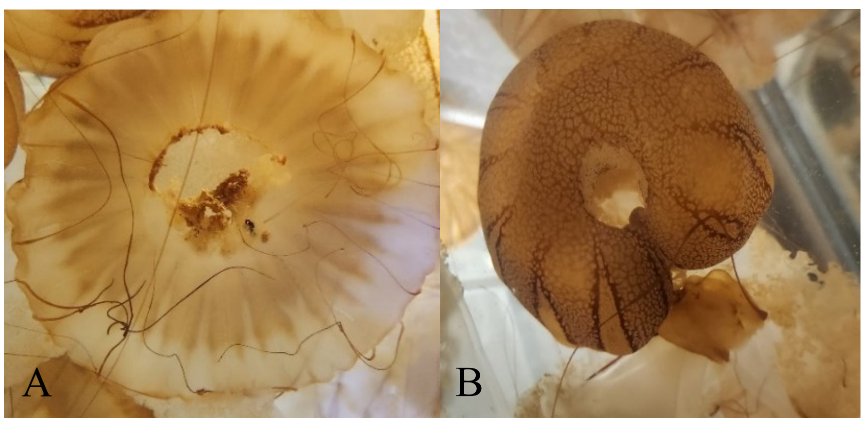

Figure 3. A) Oral arms and the manubrium of a *C. plocamia* have decayed leaving only a bell and tentacles. The jelly still pulsed but could no longer eat. B) Erosion started along the margin of the bell of a *C. plocamia* and progressed toward the center giving the jelly a pinched appearance with pieces of the bell hanging off the nettle

Treatment of Decay

Samples of the decay were examined under the microscope by the jelly and vet teams but nothing of significance was identified. The jelly team started with a conservative approach to remediate or slow down the decay by analyzing current husbandry methods, increasing water changes and water quality testing on affected systems, checking the function of the life support of each system, analyzing feeds and nutrition, and putting all the affected systems on a strict quarantine. The life support systems of the new culture systems were not finished when the jellies were first added, so UV sterilizers and protein skimmers were plumbed into each system to reduce the concentration of any parasites, bacteria, or other pests. Decaying oral arms were manually removed above the decay line in an attempt to slow down the progression. Each of these methods failed.

On January 18, 2023, the team then tried a dip with Revive® (Two Little Fishies, Inc.), which is normally used in-house prophylactically to remove any external pests when wild caught jellies are received. All of the jellies in a grow out rack system were given a one-to-two-minute bath in a five-gallon bucket filled with four gallons of cold reverse osmosis saltwater (ROSW) and 80 milliliters of Revive®, which is half the recommended dosage used to dip corals. It was difficult to move the jellies because of their decay-related fragility, but they all made it through the bath. The bath slowed down the effects and kept the jellies alive longer than those that were not given a bath, but was not a permanent solution. A scrape of an affected nettle was sent out for an aerobic bacterial culture and susceptibility test on January 20, 2023, and came back with *Vibrio* sp. Because of the number of animals involved, the potential to increase quality of life, and the uncertainty of when the new large stretch kreisel would open, the jelly team in collaboration with the vet team and leadership decided to treat the jellies with an antibiotic.

Not much information has been published about the use of antibiotics on jellyfish. Treatment with 20 ppm tetracycline baths for two hours over a course of five days has been tried with mixed results (Association of Zoos and Aquariums, Aquatic Invertebrate Taxon Advisory Group, 2021). Some people reported success while others reported they had success initially, but the jellies then senesced or died (AZA AITAG, 2021). One aquarium reported treatment with oxytetracycline and enrofloxacin baths for 6 hours every 48 hours for three days at a concentration of 2 ppm was successful (AZA AITAG, 2021). We decided to use oxytetracycline because it is a broad-spectrum antibiotic commonly used in aquaculture to treat infections caused by gram positive and negative bacteria such as *Aeromonas*, *Pseudomonas*, and *Vibrio* (Leal et al., 2019; Lu et al., 2021).

We had difficulty acquiring the drug, so treatment was delayed until March 30, 2023. There were two holding systems that needed to be treated at that time, but since the effects of the antibiotics on the jellies were unknown, we started treating one system, observed the effects, and then began treatment on the second system on April 3, 2023, after no detrimental changes to appearance or behavior were observed. Each system was dosed with 40 ppm oxytetracycline every 48 hours with a 25% water change between each dose. The UV sterilizers and protein skimmers were turned off for the duration of each treatment and water quality was closely monitored to make sure the biological cycle was not entirely inhibited.

The first system was treated with five doses, while the second one was treated with three to compare outcomes. Normally, we would treat the jellies in a bath separate from the system but due to the fragility of the jellies from the decay and the number of jellies needing treatment, this was not a viable option. A low dose of the antibiotic was used to hopefully reduce its effects on the nitrifying bacteria and water quality, and because jellies have a simplistic physiology more open to the environment allowing a greater availability of the antibiotics when compared to fish.

Results

After treatment with three and five doses of oxytetracycline, the nettles stopped decaying and began to heal. The decay slowed down within the first two days after the first dose, in about a week the decay had ceased, and by two weeks after the first dose, they were regrowing oral arms, and their bells were healing (Figure 4A and 4B). Before the treatment, any jelly showing signs of decay would die or need to be euthanized in a few days. Observed side effects of the treatment included reduced feeding, slowed pulsing rate, and thinning of the bells that made them more susceptible to damage. After treatment, if the jellies rubbed on the side of the tanks or screens, their bells developed a wrinkly or bubbly appearance (Figure 5). The thinning of the bells was less prominent when they were only treated with three doses versus five doses and tended to heal better. Pulsing rates returned to normal at the cessation of treatment. We would lose a few jellies after treatments that were likely too far gone when treatments began but the deaths from decay stopped. This type of decay appeared in two more systems that year, affecting jellies we purchased from a US supplier and the original donated jellies. We treated the jellies with five and three doses, respectively, with similar results.

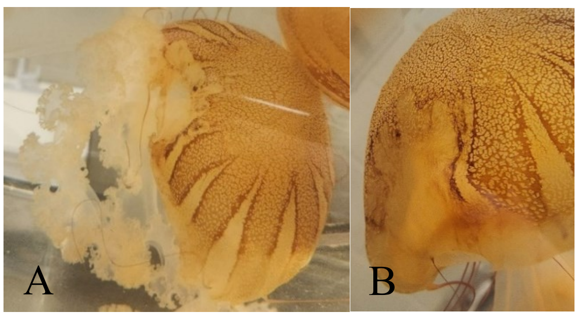

Figure 4. A) Hole in bell of *C. plocamia* medusa due to decay. B) Hole in same *C. plocamia* healed after three doses of 40 ppm oxytetracycline hydrochloride.

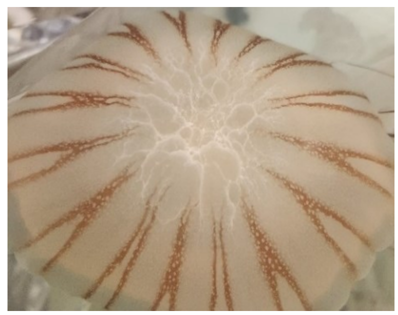

Figure 5. Thinning bell of *C. plocamia* after treatment and rubbing against the side its tank

Figure 6. Color of saltwater after five doses of oxytetracycline

One of the drawbacks to treating the entire system instead of using separate baths is the effect of the antibiotic on the color of the water. It initially turns the water yellow, but with additional doses and degradation of the antibiotic, the water turns red/amber. The degradation rate of oxytetracycline increases with increasing salinity, pH, and light exposure, so in a full salinity jelly system it broke down quickly and turned the water bright red (Saraswathy et al., 2021) (Figure 6). It was removed with frequent, large water changes with cold ROSW matched to the system parameters and well rinsed carbon in pantyhose placed in the skimmer boxes. After the water appeared clear, the UV and skimmer were turned back on. The UV caused any remaining drug not seen with naked eye to turn the water red again, which had to be removed with more water changes.

Preparing to Stock the New Exhibit

The new stretch kreisel was completed and filled with saltwater by the end of November 2023. Before jellies were added, the team wanted to test the flow patterns and flow rates of the system. Ninety nitrile gloves tied off and partially filled with water from the system and 300 ping pong balls with holes drilled into them were added to the exhibit. The gloves were used to loosely mimic a jelly to see where they may get stuck or rub against the side of the system, and the ping pong balls were used to better visualize overall flow patterns (Figure 7). The flow is manipulated by 11 spray bars and an upwelling plate that are controlled by 10 flow valves, so testing was essential to learn the quirks of the system and make adjustments before jellies were added to prevent as much damage as possible and see how flows can be manipulated to move jellies into desired positions. The ping pong balls and gloves were in the system for two weeks before 117

Chrysaora plocamia were added in small batches over a two-week period starting on January 3, 2024 (Figure 8).

Figure 7. New exhibit during flow testing with gloves and ping pong balls

Figure 8. Exhibit fully stocked with 117 *C. plocamia* with tentacles and oral arms fully extended

Rapid Decline of Entire Population

The first signs of issues occurred nine days after the first jelly was added when one nettle developed a perfectly shaped square hole in its bell and had its oral arms contracted (Figure 9A). The nettles quickly stopped pulsing, stopped eating, and shrunk significantly in size. Their bells deteriorated, their tentacles disappeared, and their oral arms fell off in chunks (Figure 9B). Three weeks after the first hole in the nettle was discovered, only two nettles from the entire population were still pulsing and by five weeks after, the system was empty (Figure 10).

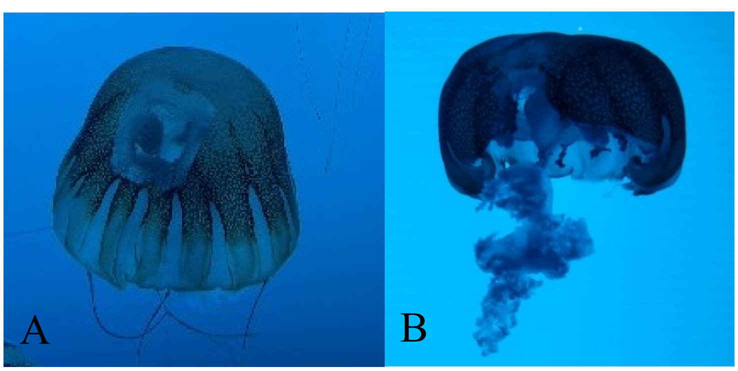

Figure 9. A) *C. plocamia* presented with a square shaped hole in its bell, doming of the bell, and contraction of its oral arms. B) *C.* plocamia showing signs of rapid deterioration one week after being added to the new exhibit.

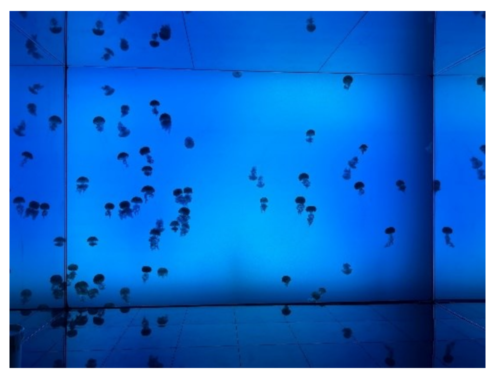

Figure 10. Entire population of nettles showing signs of rapid deterioration

Testing

As with the first decay event, we analyzed our husbandry practices, increased the frequency of water changes and backwashes to four times per week from two, added more frequent bulkier feeds such as mysis, attempted target feeding, and tested all water quality parameters we could in house. The system was cycled, there was no chlorine, there was no copper, and pH, salinity, and temperature were all normal. We sent water samples to ICP Analysis to have our water tested via inductively coupled plasma mass spectrophotometry (ICP – MS) for heavy metals. All levels came back within an acceptable range except zinc, which was at 57.859 ppb. Current knowledge and experience show that jellies start seeing detrimental effects from zinc at 4.5 ppb (AZA AITAG, *Under Review*). We had sent previous samples out for testing during construction and before jellies were added to the exhibit with no abnormal results found. All life support equipment was new and double checked for metal parts, and the entire system was inspected for contamination from water dripping into it or items dropped in it to no avail.

To determine the source of the zinc, the jelly team set up six, five-gallon buckets full of four gallons of reverse osmosis saltwater that we use for all the jelly systems. Each bucket was filled with a single type of object that had come in contact with the system, so one was filled with pairs of nitrile gloves, one with ping pong balls, and three with the different metal jacks used to support the acrylic window (Figure 11). Each time the system is drained, eight jacks have to first be set up along the edge of the front acrylic window to keep it from shifting as water is removed or added. As soon as the system is full of saltwater, divers get in to remove the jacks to prevent contamination of the water. The final bucket was used as a control and only filled with reverse osmosis saltwater made using Instant Ocean Reef Crystals, the salt brand used throughout the entire aquarium. The buckets sat for a week in a back of house area maintained at a temperature similar to the exhibit water before a water sample from each was sent for analysis. For a comparison, we also sent off samples from a system filled with the same species as the new exhibit that had been running and cycled for more than six months, a recently turned over system, the water in our brine culture full of hatched eggs from INVE enriched with DHA Selco® and live *Isochrysis* algae, and from the non-chlorinated city water line used to top off the new exhibit a few times. Samples of systems that had been cycled and running for a time and recently bleached and restarted were taken to establish what levels of zinc the *Chrysaora plocamia* could tolerate, while showing no health or behavioral issues, and if zinc accumulates in a system over time. The live algae were fertilized with Fritz Aquatics Pro F/2 algae Food part A and B.

Figure 11. Five-gallon buckets filled with objects used on exhibit after it was filled with ROSW and before the jellies were added. From left to right: large jack with orange protective coating, nitrile gloves, small jack, large jack with coating removed, ping pong balls.

Results

It was speculated that the jacks would be the source of the zinc, because they were made of metal, rust in the water, and leave debris behind as seen in Figure 11. The results for the small jack came back inconclusive due to an error, but both large jacks came back with high levels of zinc and iron (Figure 12). The levels of iron from the jacks and lack of iron found in the exhibit water excluded them as the source of the zinc. The water from the 48-hour old brine, the ping pong balls, the non-chlorinated water line that is run thru carbon and used to top off the system, and the control bucket of reverse osmosis saltwater each had less than 12 ppb of zinc, while the bucket filled with the nitrile gloves had a concentration of 298 ppb zinc (Figure 13). The second highest concentration of zinc came from the brine culture at 11.2 ppb, but it was easily ruled out as even a contributing factor because all the jellies in each system at the aquarium were fed the same food and did not show signs of deterioration. The powder free blue nitrile gloves from Covetrus® that we used to test flow rates and patterns before adding the jellies leached enough zinc into the water to cause the loss of the entire population of nettles on display.

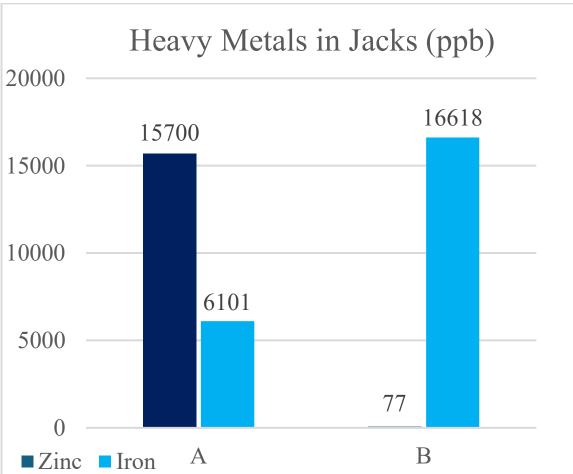

Figure 12. Levels of zinc and iron leached into a five gallon bucket of ROSW after a week from two sets of jacks used in the new exhibit

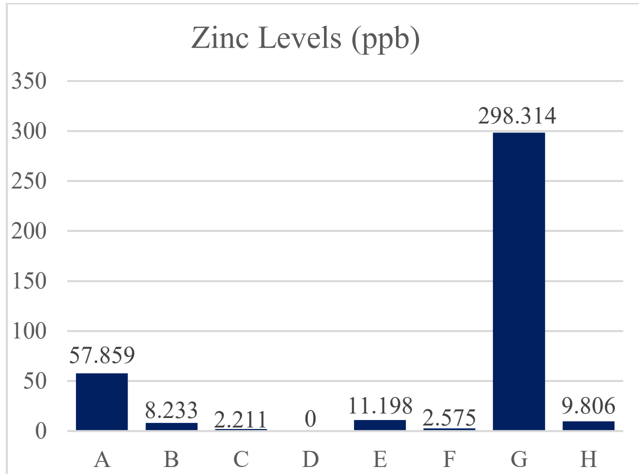

Figure 13. A: Concentration of zinc in water sources or leaching from objects soaked in a five-gallon bucket of ROSW for a week. A: new exhibit - initial sample, B: established cycled system, C: newly turned over system, D: non-chlorinated water line, E: 48-hour old, enriched brine shrimp water, F: reverse osmosis saltwater, G: nitrile gloves, H: ping pong balls

Remediation and Implications

Zinc is an essential micronutrient to the biological processes of marine organisms, especially phytoplankton, so its presence in the water is needed and expected but at a level of 58 ppb, it is toxic to jellies (Jakuba et al., 2012). Concentrations of zinc in natural seawater are generally around 0.5 ppb, but they tend to decrease with increasing distance from the shore and tend to increase with increasing depth (B. Christie, personal communication, January 29, 2024; Neff, 2002). It is toxic at different levels for different species. At a concentration between 119 and 175 ppb zinc, *Crassostrea gigas* and *Mytilus edulis* embryos start to develop abnormally, and in one study, at 10 ppb zinc, fertilization rates of *Acropora tenius* decreased by 21% (Neff, 2002; Freitas and Espósito, 2023). Based on our testing of long-established systems holding *C. plocamia*, this species can withstand zinc concentrations up to at least 8.2 ppb, but their upper tolerance level still needs to be researched.

Immediately after the ICP – MS results on the new exhibit came in, a subset of 15 nettles was removed from the new exhibit and placed in a clean system. The younger jellies in the cohort showed signs of improvement compared to the older jellies. They began pulsing, eating, and regrowing tentacles, while the older and larger nettles continued to decay. If the jellies are removed from a system with suspected heavy metal contamination, they may be able to recover. Their long-term survivability after such an event needs further research.

Disposable gloves made of nitrile, latex, and vinyl can all leach zinc after incubation and short contact, while latex gloves have been proven to leave behind zinc on tissue samples with a single touch (Humann-Ziehank et al., 2021). Vinyl gloves leach 10 to 100 times less trace elements like zinc, manganese, cobalt, nickel, and other metals that can be detrimental to aquatic animals especially invertebrates or contaminate labware than neoprene, latex, and nitrile gloves (Garçon et al., 2017). The zinc and other elements are additives in the manufacturing process and not a coating that can be easily removed or rinsed off, and they are present in common well-known brands such as Ansell, Medline, and Kimberley-Clark (Garçon et al., 2017). The aquarium still uses the same brand and type of gloves, but they are no longer used for flow testing where they are in contact with the water for lengthy periods of time. The jelly team no longer uses them when working with non-flow through polyp cultures where the volume of water is small and can easily be contaminated.

To make the exhibit habitable by jellies again, life support staff attempted to remove the zinc from the water by plumbing in a carbon filter. It was unsuccessful and only reduced levels to 32.801 ppb zinc, so the entire system was drained and rinsed with freshwater. The bioballs and the media in the sand filter was replaced, and every corner of the sump was scrubbed. Unfortunately, when the tank is drained, the jacks must be put in to prevent the acrylic window from shifting. Not wanting to risk contaminating the system again even though they did not cause the lethal dose of zinc, a new technique to place the jacks was adopted. Before going into the water, each jack would be placed in two large plastic shipping bags that reduce the amount of contact the jacks had with the exhibit water. The bags would be wrapped around the jacks and tied shut after the jacks were tightened into place (Figure 14). Once the system was refilled with ROSW, the jacks were immediately removed ensuring any water in the bags was not spilled into the tank. Two water samples were sent to ICP Analysis to test for heavy metal toxicity via mass spectrophotometry, one immediately after the system was refilled with ROSW and the jacks were removed and one after the system had been running for two weeks and getting water changes. Zinc was detected at a concentration of 9.219 and 5.472 ppb, respectively. The final result was below the threshold the jelly team discovered the *C. plocamia* can tolerate, so we proceeded with stocking the system again, and it has been running with jellies successfully since July 19, 2024.

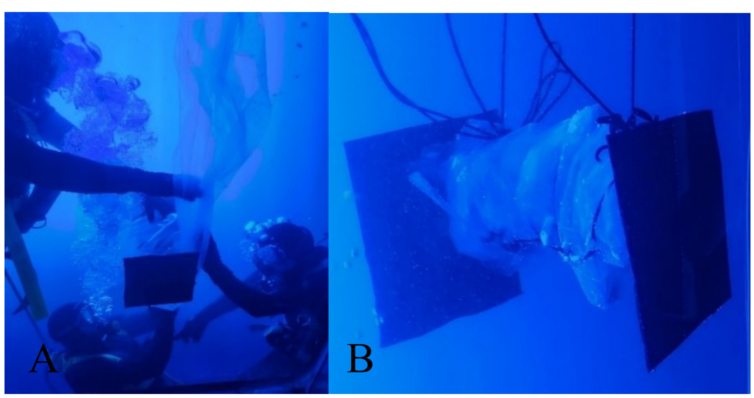

Figure 14. A) Divers placing jacks in bags to prevent high amounts of metal leaching into the exhibit water. B) Jack fully enclosed in two plastic shipping bags and tied off with paracord.

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SERENDIPITOUS CULTURING OF *Nereocystis luetkeana* AND OTHER KELP

Chris Emmet, Senior Life Support Systems Aquarist jemmet@ucsd.edu

Birch Aquarium at Scripps Institution of Oceanography, 2300 Expedition Way, La Jolla, CA, USA

Background:

Birch Aquarium at Scripps Institution of Oceanography at UC San Diego is located in La Jolla, near San Diego, California. Bull kelp's range is generally acknowledged to end around Point Conception, approximately 250 miles up the California coast. Specimens occasionally wash up on Southern California beaches, but there are no established populations this far south. Furthermore, sea temperatures off La Jolla often exceed the generally accepted range for *Nereocystis*, up to 59°F (15°C)[Figure 1].

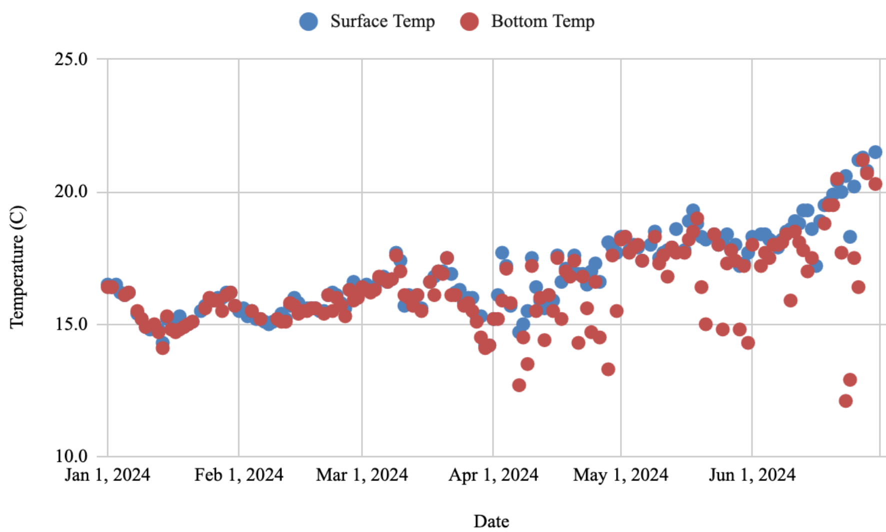

Figure 1. Ocean surface & 5m depth temperatures for the first half of 2024 near seawater intake.

Birch Aquarium is a semi-open facility and receives seawater pumped in from the nearby Pacific Ocean. The system filters incoming water through a 20µm drum filter screen, sand filters, and several settling basins before it arrives at the aquarium. The tank in which the kelp grew (Northwest Reserve 1) is part of the Pacific Northwest system, where temperatures are maintained between, 41°F to 45°F (5°C to 7.2°C)[Figure 2]. The tank measures 60" x 30" x 24" (152cm x 76cm x 61 cm) inside and is filled to 19" (48cm), giving ~150 gallons (567L) of volume (Pentair model #FT160W2). We have not observed bull kelp or any other macro brown algae in any other tank on the shared water system.

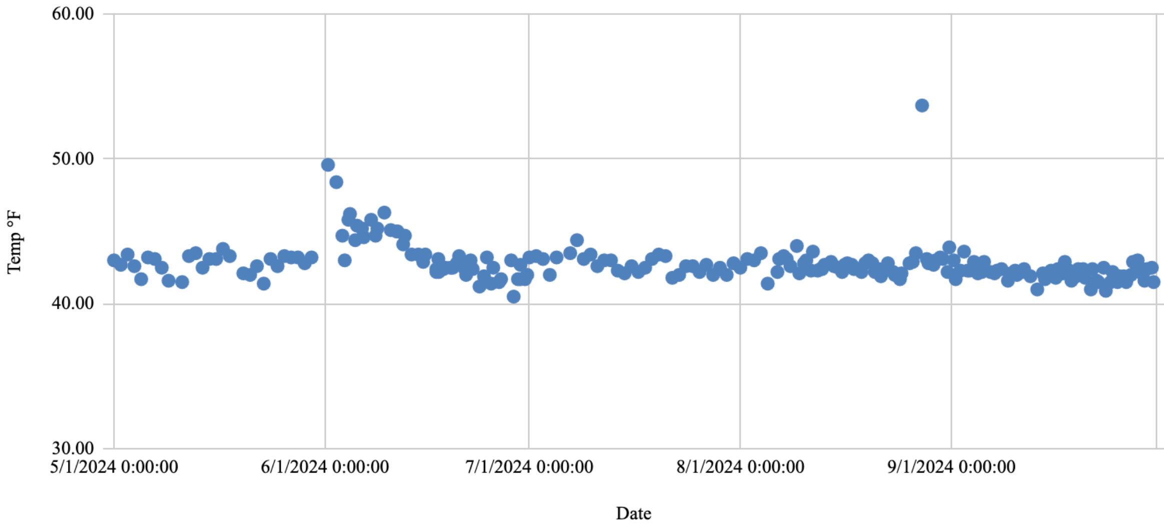

Figure 2. Water Temperature in NWR-1 from July through September 2024.

Given the geography, ocean temperature, and filtration, it seems unlikely that a zoospore would have gotten sucked into the intake, and just so happened to have landed in the one tank hospitable to development.

How then, did *Nereocystis* end up in NWR-1?

On May 14, 2024 we received a shipment of invertebrates from Monterey Abalone Company, including several Giant Green Anemone (*Anthopleura xanthogrammica*) specimens. To try to retain their natural color, a 32-watt GE Seeds & Greens LED bulb was installed 30" (76 cm) above the trough, operating on a 12/12 light cycle. Additionally, a Tunze® Turbelle® Stream 6105 Controllable powerhead was added to improve circulation within the tank. An Apogee® Instruments MQ-200 PAR meter measured values of 77 $\mu mol \cdot m^{-2} \cdot s^{-1}$ at the surface and 25 $\mu mol \cdot m^{-2} \cdot s^{-1}$ at the bottom of the tank. It is assumed there were hitchhiking kelp spores or gametes in the shipment water, and some made it into the tank with the accessed animals.

On June 4, 2024, small kelp blades grew among the usual hair algae, but they went largely unnoticed. Despite the presence of grazers like Gumboot Chiton (*Cryptochiton stelleri*) and Red Abalone (*Haliotis rufescens*), the kelplings remained uneaten.

Houston, We Have Kelp:

By early July, the largest kelps developed pneumatocysts and the split pattern of the blades resembled *Nereocystis*, versus local species such as Elk Kelp (*Pelagophycus porra*)[Figure 3].

Figure 3. Early stages of pneumatocyst growth & blade splitting, July 09, 2024.

By late July, confirmation revealed that the two largest plants were *Nereocystis* and were growing rapidly. An additional grow light was added to ensure the entire trough was illuminated. Names were assigned based on morphology, with Curly-Q having an exceptionally long and twisting stipe, while Zip-Tie had a detached pneumatocyst resecured to the stipe with a zip-tie [Figure 4]. Despite kelp often having issues once detached from its stipe, Zip-Tie lived for about a month and a half and its blades more than doubled in length after its reattachment. Measurements taken during early August indicated blade growth of up to 7.1cm per day, averaging 3.2cm [Figure 5]. Due to the unique nature of each stipe, the stipes were not measured. No significant change in pneumatocyst growth during this period was recorded. The rapidly growing kelps soon outgrew the measuring tape and became unfeasible to measure due to length and fragility. Unfortunately, the kelp soon outgrew the depth of the tank, causing the pneumatocysts to float and remain half submerged. After about three months of life, the kelp desiccated and split open, while its long blades were caught and mangled by the powerhead [Figure 6].

Figure 4. Fully recognizable *Nereocystis* individuals (L, Zip-tie, R Curly-Q), August 03, 2024.

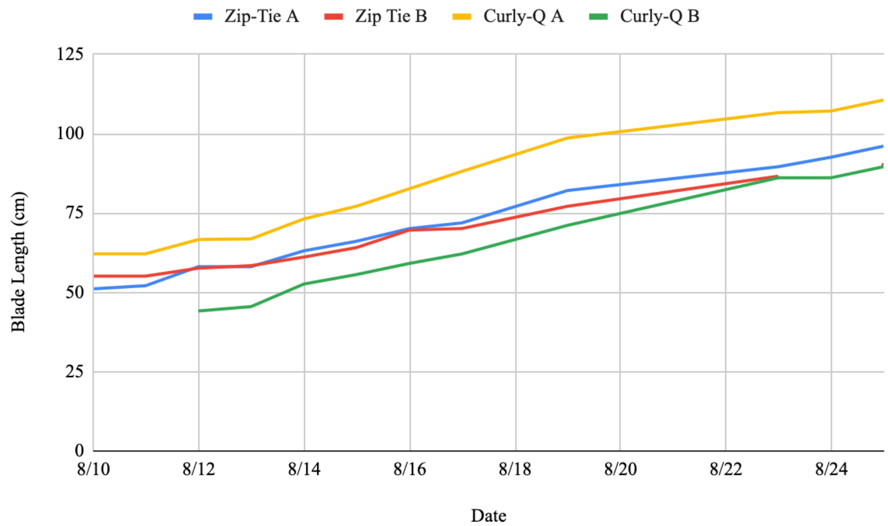

Figure 5. Growth of longest blades of two kelp plants

Figure 6. Zip-Tie at "death." Curly-Q with a desiccated pneumatocyst is visible at right, August 24, 2024.

Aftermath:

By late August, much of the first cohort of kelp began to die off due to issues with the pneumatocysts cracking after desiccation. However, new plant growth was almost exponential, with most of the illuminated walls of the tub covered in new stipes [Figure 7]. During July and August, a second and third cohort began growing and appeared to contain *Macrocystis pyrifera* [Figure 8], among other unidentified species [Figure 9].

Figure 7. Undifferentiated kelp sprouts densely growing from the wall, August 24, 2024.

Figure 8. *Macrocystis* growing from the wall of the trough, August 17, 2024.

Figure 9. Unidentified Kelp Species with branching stipe & multiple pneumatocysts, August 24, 2024.

Due to large-scale construction, the Pacific Northwest system was drained and the animals moved to other holding tanks. Unfortunately, there was not adequate room for the kelp in the holding area, so the surviving kelps were transplanted onto small stones and transferred to the 70,000 gallon (250,000L) open-air Giant Kelp Forest. This tank is on a different system than NWR-1, and typically holds at 60°F, (15.6°C), but varies depending on ambient temperature, sunlight, and ocean temperature, unlike the fairly constant temperature in NWR-1. Over three days the kelp was acclimated to the new system's temperature before being transplanted on September 20. As of the first week of December 2024, none of the transplanted Bull Kelp has survived, but several Giant Kelps have persisted and are now nearly 10 ft (3.05m) in length [Figure 10].

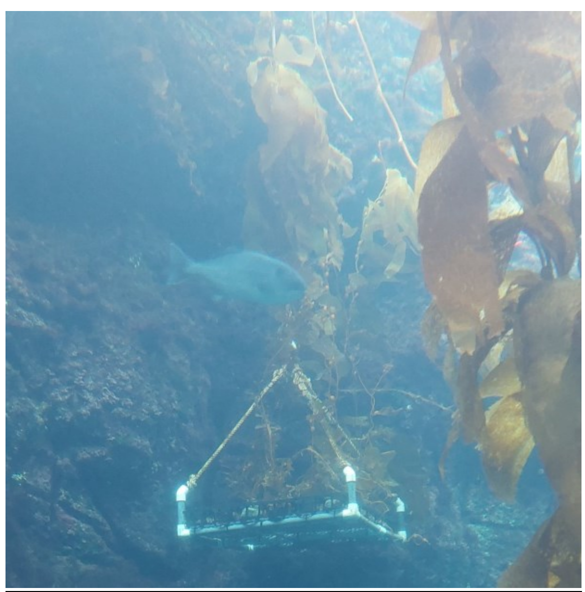

Figure 10. Surviving Giant Kelp in Giant Kelp Forest tank

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I would like to thank Gale Bruell, Kailey Kraus, and Bob Shein for their care & tending to the baby kelp garden. As well as Alex Feltes, Cari Paulenich, Jenn Nero and Fernando Nosratpour for their assistance in proofreading & reviewing.

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Yelloweye Rockfish juvenile, Bruce Koike

BMORE ·2025· RAW
NATIONAL AQUARIUM
BALTIMORE, MARYLAND

https://www.regionalaquaticsworkshop.org/product-page/baltimore-md

Dates: April 23rd-26th 2025, hosted by the National Aquarium, Baltimore, MD USA.

Hotel/conference center: Renaissance Baltimore Harborplace Hotel.

- 202 E Pratt St, Baltimore, MD 21202.
- Less than 2 blocks from the National Aquarium.
- Booking is live on the RAW website for the discounted rate.
    - Room block rates: $189/night + taxes and fees (17.5% as of Dec 2024)
    - Block dates: April 21 check-in through April 27 check-out. (This rate will be honored 3 nights pre- and post-block dates, pending availability).
    - Book your lodging here: https://book.passkey.com/go/RAW2025

    *If you wish to make your reservations by phone, please call 1(877) 212-5752
- Parking is $36/day.

Schedule:

- AZA TAG steering committee members will be meeting pre-conference on Tuesday April 22.
- RAW conference sessions will run April 23-26.
- Evening event at the National Aquarium is on April 24.
- The RAW business meeting (voting for 2027 venue) will be on April 25.
- Sponsor table setup and breakdown will occur on April 22 and 26.

Getting here:

- BWI Airport: 10 miles from the aquarium and conference center/hotel.
    - Lightrail service (above ground commuter rail) runs from BWI Airport to Baltimore's Convention Center. From there the hotel is about a 0.5 mile walk or 3 stops on the free Charm City Circulator (Orange line).
    - Uber/Lyft/ride share options.
    - Rental car services.
- Amtrack/Train: 2 miles from Baltimore-Penn Station to conference hotel
    - Rideshare (Uber/Lyft) recommended from the station.
    - Or 8 stops from the station on the free Charm City Circulator (Purple line).

- Other Major Regional Airports (all 3 can be searched using airport code WAS):
  If driving from these, expect an extremely long transit time to Baltimore during rush hours (6–9:30 AM and 3:30–6:30 PM). Public transportation via subways and Amtrak exists, but involves multiple transfers.
    - Ronald Reagan Washington National Airport (DCA, ~43 miles to venue).
    - Dulles International Airport (IAD, ~59 miles to venue).

Registration:

- Registration is live on the RAW website: www.regionalaquaticsworkshop.org.
- $225 until 3/19/25, 11:59pm ET
- $250 after 3/19/2025
    - Includes breakfasts, lunches, breaks, and the Aquarium evening Event
- Guest registration for Aquarium evening event only:
    - Ages 21+: $75 + transaction fees.
    - Ages 5-20: $60 + transaction fees.

Questions about B'MORE RAW? Email us at: raw2025@aqua.org

Tiger Rockfish, Bruce Koike

ABSTRACTS from "TacomRAW," 2024
The Regional Aquatics Workshop, May 4-9.
Point Defiance Zoo and Aquarium, Tacoma, WA. USA.

Sunday, May 5th
AZA TAG Meetings

FFTAG Steering Committee Meeting
George Brandy et al.

AITAG Steering Committee Meeting
Brian Nelson et al.

MFTAG Steering Committee Meeting
Paula Carlson et al.

Monday, May 6th
Session 1: Mental Well-being

Talks recorded by:
AnimalProfessional.com

RAW Welcome

The Balancing Act: Combating Mental Fatigue in the Animal Care Profession.

Jami Asher, Caitlin Marsh and Mina Grant
jami.asher@gmail.com (417)669-6166
Mississippi Aquarium

Recently, it has become apparent that between stagnant wages, short staffing, and a greater focus on personal mental health, this is no longer the once sought-after profession it once was. With the addition of furloughs, institutions closing due to Covid, and the rise of work-from-home jobs, these existing issues have become exasperated, leading to a rise of professionals leaving the field, and a decrease of those entering the field.

When working in a field that can be mentally and emotionally taxing, it is imperative to learn tactics to set boundaries to maintain a healthy work-life balance. At Mississippi Aquarium, our team employs various strategies at work and home that have been proven to work for us. With our curator's support, we set firm boundaries regarding work-related communication at home and help check in with each other after emotionally demanding days. We also agree to focus on enriching our personal lives to help off-set the mental load of this field through a variety of methods.

While institutions might implement many of these tactics, it is also important for employees to be aware of when these strategies are not enough and reassess. You owe it to yourself to be aware and advocate for yourself just as much, if not more, than you advocate for the animals you care for.

Taking Care of Those Who Take Care of Animals

Brooke Zurita
bcarlson@moodygardens.org
Moody Gardens

The industry has made great strides in the areas of Animal Welfare and Animal Wellbeing. The Association of Zoos and Aquariums have increased the industry standards in these areas drastically in recent years, but what about the welfare and wellbeing of the staff? Our facility has tried to address where we feel we have been lacking, and these are our results.

First, we needed to identify the issues our facility was facing internally. To do this, we created a culture survey that was sent to every one of our staff members in our aquarium husbandry team. The survey was 15 statements that staff rated as either "Never true", "Sometimes true", or "Always true". After each statement, there was space provided for anyone to elaborate on their answer if they chose to. I took all the results and rated the different statements to see where our strengths and weakness were as a leadership team. Once we identified the primary issues from the culture survey, we put different policies and procedures into place to address the staff's concerns.

Roughly 6 months after the first survey, we sent it out once more to see if we were moving in the right direction. The results were surprising. We had raised almost all our scores for every one of the statements. This has encouraged us to make sure we are finding more ways to make sure our staff is heard and feel listened to, including a Focus Group of staff to send us suggestions and feedback.

Animal Care Manual for Employee Well-Being

Megan Paider
Megan.Paider@PDZA.org
Point Defiance Zoo and Aquarium

The most overlooked yet greatest asset for any organization is staff. Staff are responsible for innovation, implementing change, shaping morale, cultivating culture, and advancing the field of public aquariums and animal conservation. But are we contributing to a positive quality of life for our staff and peers? How can we improve?

Highlighting employee well-being within teams can improve individuals' well-being and group dynamics. The presentation's objective aims to break down employee well-being in the Animal Care Manual format while incorporating supporting data from peer-reviewed journal articles and data collected through digital surveys of convenience sampling of 123 zoo and aquarium staff in 2023. The ACM will minimally include psychological safety, intra-organizational trust, voice behaviors, mental wellness, sense of purpose at work, organizational commitment types, accountability, autonomy, professional enrichment, camaraderie, and self-care. This presentation will include an introduction to the topics listed above, the relationship between the subjects and well-being, reflective questions for attendees, and additional resources. As awareness improves around employee well-being, our staff and peers can thrive as they continue to support the mission of public aquariums and animal conservation.

The Development and Implantation of an Animal Department Multi-Level Committee and How It Relates to the Assistance in Mental Health and Employee Welfare.

Ryanne Sullivan
John Ball Zoo

Starting in March 2022 the John Ball Zoo developed and implemented a Keeper Liaison Group in order to facilitate communication between different areas of the animal department. This communal effort between all the different teams within the animal department along with our General Curator helped to address issues that included but is not limited to communication streamlining, clarification of updates and Mental Health and Employee welfare. When addressing our departmental Mental Health and Employee Welfare we developed a survey that addressed burnout and staff welfare. This presentation will go over how the meeting began its implementation process, the individuals involved, topics covered, the surveys implemented, and the conclusions that were made from the results.

Resources for Employee Retention and Mental Wellbeing

Jennie D. Janssen[1] and Meghan Holst[2]
[1]president@miazs.org , [2] executivedirector@miazs.org
Minorities in Aquarium & Zoo Science

The mission of Minorities in Aquarium & Zoo Science (MIAZS) is to advance aquarium and zoo science by diversifying the professionals and perspectives within it. This requires not only bringing in new people and perspectives, but also supporting and retaining the variety of people and perspectives that are already here. To support individual professionals, MIAZS has created a community of professionals and aspiring professionals, networking and professional advancement resources, and provides centralized access to all of these plus existing resources for mental health, allyship, career development, financial assistance and more. These resources can be used to create and support work environments and cultures where minorities and non-minorities feel supported and inspired. Since launching in 2021, MIAZS has grown to over 150 members that identify as racial or ethnic minorities, and in that time, has provided financial support to 26 MIAZS members for conference attendance or some other professional development opportunity. Opportunities such as these can bolster mental wellbeing for employees, in addition to growing professional knowledge, skills, and networks, and can therefore also be a boon to supporting employee retention. Reviewing where and how to access all these resources for both managers and employees, attendees will also learn how they can contribute to this ever-growing repository.

Session 2: Institutional Knowledge

Sponsor Presentation:
121 Animal Handling

Cross Training for a United Animal Care Staff

Alyssa Daily
OdySea Aquarium

Within the public aquarium industry there is a common divide between animal training staff and the aquarist staff. The effort required to care for such different species is specialized, resulting an animal care staff that do not have a clear understanding of how the other teams operate daily. At OdySea Aquarium a program was put forth to provide staff from both departments with the opportunity to shadow teams from the other department in an effort to gain exposure and understanding with the goal of a more united animal care team.

Without hesitation there was an incredible interest in participating in this program from OdySea's animal care staff. On a voluntary basis, members from the aquarist team were exchanged with members of the animal training team for four hours at a time. For example, otter keepers were trained on how to maintain seahorse exhibits while jellyfish aquarists were educated on training basics with sea lions. This shadowing opportunity was provided over a few months and over fifteen staff members participated.

A survey following the shadowing opportunity revealed that there was an increased appreciation for the other teams' efforts and a more well-rounded understanding of animal care operations as a whole, leading to improved team morale and a more cohesive work environment. While the divide between animal trainers and aquarists has been long lived in the public aquarium industry, efforts like this break down the walls that have existed for so long.

Keeping Up with The Kraken: Releasing Phase 2 of the Kraken Curriculum

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The Kraken Curriculum is an online, self-directed professional development resource, created and updated from new and existing content on AnimalProfessional.com with links to supplemental materials. It is curated by topic to lead individuals or groups through industry knowledge on animal husbandry, life support systems, water quality, veterinary care, collection planning, and more. The Kraken continues to be a cost-effective professional development program, specifically focused on continuing education for the public aquarium community, while highlighting recent advances in the science of aquatic husbandry. Since launching in 2021, the Kraken has been a resource available to managers to build an in-house professional development program, and a tool for aquarists and keepers to drive their own professional development. A total of 12,930 minutes have been completed by 56 active users to date, representing 215 hours of professional development (equivalent to 5.4 RAWs). With each new conference, pertinent material is curated to augment the existing curriculum and create new topics. A second phase is being launched with even more content including syngnathid fishes, larval fish culture, behavior and training, project management, and more. Organizing existing content in this way allows for learning to occur from a breadth of perspectives, while also allowing industry knowledge gaps to be identified and filled through future presentations.

AZA Animal Welfare Committee Update and Listening Session

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The AZA Animal Welfare Committee (AWC) is embarking on a new strategic plan in 2024 that will shape the AWC's goals and initiatives for the next several years. An important aim of the new strategic plan will be to incorporate more initiatives specifically related to aquatic husbandry in addition to other taxa that have been considered understudied.

Within the past few years, the AWC has been collecting data and feedback that has highlighted the need for increased emphasis on welfare science and the welfare assessment process within certain taxa like aquatic species. The AWC is committed to improving the guidance and resources available for such species but knows that will require insight, direction, and assistance from the aquatic animal experts in the zoo and aquarium industry. This will ensure that the initiatives that AWC champions will be meaningful and useful.

The AWC proposes hosting a session at RAW to provide an update from the AWC and hold a listening session to gain valuable insight from the aquatics community. The update will cover the new strategic plan that is currently being developed by the AWC and the goals it will be hoping to address. For the listening session, a series of questions will be presented to the audience that they will be able to provide their opinion on through a web-based platform in real-time as we progress through the questions. The audience will also be able to ask questions and provide feedback to the AWC through a Q&A style portion.

Sponsor Presentation:
Piscine Energetics

Session 3: AZA TAG Reporting Sessions

AITAG Update

Sponsor Presentation:
TJP

FFTAG Update

MFTAG Update

Tuesday, May 7th
Session 4: Research and Collaboration, Part 1

Sponsor Presentation:
Fritz Aquatics

Florida Coral Rescue: Evolving to Build the Reef's Future

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In 2018, at the invitation of the State of Florida and the Federal Government, the Association of Zoos and Aquariums mounted a first of its kind multi-species rescue to preserve critical coral diversity of the Florida Reef Tract, also known as Florida's Coral Reef. The rescue of thousands of corals was made possible by the collaboration of the Florida Fish and Wildlife Conservation Commission, NOAA Fisheries, the Fish and Wildlife Foundation of Florida, and AZA accredited facilities across United States and in 2024, that effort will be 5 years old.

Mobilizing facilities and coral care specialists to provide homes for thousands of corals removed from the reef as part of a planned relocation effort, was only the beginning. The initial effort is the foundation for what has become a game changer for coral reef restoration efforts in the United States and beyond. The national network of coral care facilities has prioritized advancing coral science with an eye on long term banking of coral populations, fortifying collaborative approaches to reef conservation, building capacity to meet current and future environmental disturbance response, and creating a production pipeline to send offspring of rescued corals back to the reef in planned restoration efforts.

The Florida coral rescue effort is evolving to build the reef's future. Much of the work being planned and executed requires the skills sets, resources and professional experience of AZA accredited facilities and animal care teams. Looking forward, collaboration will remain our foundation and significant stewardship impact our outcome.

Disturbances on Florida's Coral Reef and Plans for Recovery

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Florida's Coral Reef (FCR) has been experiencing a lethal disease since 2014. Stony Coral Tissue Loss Disease (SCTLD) has resulted in the mortality of millions of corals from >20 species, including reef building and endangered species. The FCR experienced another catastrophic disturbance due to record setting elevated seawater temperatures starting in July 2023. The excessively hot temperatures caused rapid mortality directly by heat shock, and mass bleaching due to prolonged exposure to temperatures >30 C. The highest bleaching related mortalities were observed in Acroporids, which resulted in their disappearance from several iconic reefs. This presentation will include results from post-bleaching surveys, led by Florida Fish and Wildlife Conservation Commission (FWC), to assess the impacts of the 2023 bleaching event.

FWC works closely with the Association of Zoos and Aquariums (AZA) on the Florida Reef Tract Rescue Project (FRTRP). Many facilities are focusing on induced spawning, sexual propagation, and rearing juvenile corals, to understand husbandry techniques to optimize the production of offspring for restoration. FWC received 464 sexually derived offspring from The Florida Aquarium, and outplanted them in 2022. The project tested if predator deterrents and acclimating corals to native conditions via in situ nurseries before outplanting them would reduce the amount of early fish predation. Acclimated corals that received predator exclusion devices did have the highest survival after two years. Many of these corals fared well during the 2023 bleaching event. Results from studies like these will improve outplanting strategies and benefit the broader restoration of FCR. The SCTLD outbreak and 2023 bleaching event illustrate why the FRTRP is a necessary and critical strategy in the mitigation of coral population decline and the restoration of reef building coral species.

Developing a Propagation Strategy for Restoring Florida's Coral Reef Using Rescued Corals from Stony Coral Tissue Loss Disease

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Florida's Coral Reef (FCR) is experiencing an unprecedented disease outbreak described as stony coral tissue loss disease (SCTLD). First reported near Miami in 2014, SCTLD has since spread throughout the entire reef tract including the Dry Tortugas resulting in the mortality of millions of colonies from >20 coral species, including primary reef builders and species listed under the Endangered Species Act. A multi-agency Coral Rescue Team (CRT) was developed to design and implement a coral collection plan for SCTLD-susceptible species, preserve genetic diversity of Rescue corals in land-based holding,) scale-up propagation, and plan for the restoration and introduction of Rescue coral offspring to the wild. Since 2018, the CRT has collected over 2500 corals across 20 different species which are being held at 24 long-term housing facilities, labs, and organizations across 13 US states including many Association of Zoos and Aquariums (AZA) accredited facilities for care. Propagation of these corals is now the main focus in these land-based facilities to create sexual offspring which will eventually be outplanted in hopes of restoring the coral populations of FCR. The "Propagation Strategy " was established to take the Rescue Project from holding broodstock through the steps of propagation in preparation for outplanting and restoration. The Propagation Strategy encompasses four primary components, the genetic management and breeding plan, in-water infrastructure plan, land-based infrastructure plan, and transfer plan. Initial efforts are focused on land-based capacity building and scaled-up propagation. The development of the "Propagation Strategy" is essential for scaling up activities and maximizing current and potential resources necessary for restoring corals lost to SCTLD.

Corals Across Countries: Uniting Research for Reef Restoration

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Within the California Academy of Sciences, you'll find both the Steinhart Aquarium and the Institute for Biodiversity Science and Sustainability, which serves as the Academy's research division. Since 2018, biologists and researchers from these two divisions have been collaborating to study ex situ coral sexual reproduction. This partnership, now known as the Coral Regeneration Lab (CoRL), has resulted in publications on the genetic variations of corals spawned in human care, as well as successful Acropora spawning over the past five years.

Following the awarding of a Coral Research and Development Accelerator Platform (CORDAP) grant last year, this collaboration expanded to include the Roatan Marine Park (RMP). This non-profit organization, located on the island of Roatan, Honduras, is dedicated to conserving their marine and coastal ecosystems. Roatan, like many other areas of the Caribbean, has witnessed a decline in their reefs over the last several years due to issues like stony coral tissue loss disease and rising ocean temperatures.

With the CORDAP grant funding, RMP and CoRL plan to establish Honduras' first coral-rearing laboratory. Additionally, we will continue research in San Francisco, focusing on optimal coral larval rearing techniques. The goal being to equip the RMP with best practices for coral rearing, to support their efforts in restoring the Mesoamerican Barrier Reef.

Safe Shark & Ray:
Collaborative Work to Support Elasmobranch Research and Conservation

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SAFE Shark and Ray works with zoos, aquariums, and global conservation partners to support ex situ research and best practices, work collaboratively with in situ research to advance conservation, and to effectively inform and engage our audiences in actions and behavior change to save sharks and rays.

The **Best Practices in Handling and Welfare Project** will share updates on progress towards a tool that will help align best practices approaches to elasmobranch handling in situ and ex situ. Listening sessions with international partners and subject matter experts held in 2023 were important to defining and refining the shape of project. The input from those sessions and their influence on the project's progress will be shared.

The **Elasmobranch Blood Project** will be presented to invite husbandry teams to participate in this important project working to create blood reference intervals for elasmobranchs to better assess the health, welfare, and wellbeing of animals in our care.

Assessing the sustainability of the seafood products we procure for animal feed is a priority for SAFE Shark and Ray. We will share preliminary data from the **Sustainable Feed Project** and invite participation and introduce project tools to begin looking at their own purchases for sustainability.

Lastly, we will share data and results from a formal evaluation on **shark conservation messaging** in zoos and aquariums to help all of us to speak effectively and consistently with "one voice" when sharing information about elasmobranchs with our audiences.

Connecting Through the Chondrocensus

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In an effort to facilitate collaboration between public aquaria that care for chondrichthyans and between these stakeholders and researchers, the ChondroCensus was born officially as the International Census of Chondrichthyans in Human Care under the umbrella of the AZA SAFE Shark and Ray program. As the 2nd generation iteration of what had been the International Elasmobranch Census under the purview of the American Elasmobranch Society (AES), the ChondroCensus has representatives that co-chair the AES Captive Elasmobranch Census Committee and provide a report at the annual business meeting. However, the ChondroCensus is much more than a collection of information for various parties to contribute to and access. Much like the upcoming AES Symposium "Contributions of Aquariums to Elasmobranch Research", the ChondroCensus also provides a platform of common interest, creating avenues for individual connection, and opportunities to increase collaboration within and between areas of expertise. As the ChondroCensus has expanded, so too has the leadership team. And there are added opportunities for individuals to assist in coordinating the flow of information, while building their personal networks and advancing the goals of the SAFE Shark and Ray program: to **S**ave these **A**nimals **F**rom **E**xtinction by enabling evidence-based support for conservation action, supporting science-based shark conservation communication, and creating opportunities for partners to provide direct, impactful, and collaborative support for the conservation of these taxa.

Restoration Aquaculture: A Vital Collaborative Tool for Pinto Abalone Recovery in the Salish Sea

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Building diverse partnerships is essential for successful species conservation and recovery efforts. Partners outside of the aquarium community, including resource management agencies, universities, tribes, and NGOs, provide important conduits into local communities, expertise on threatened *in situ* marine and aquatic populations, and broad perspectives on implementing recovery programs. The aquarium industry is poised to assist with these recovery efforts because of their expertise in husbandry and life support systems, their respected role in education and outreach, as well as the unique skillsets they can provide, such as field diving.

Pinto abalone, *Haliotis kamtschatkana*, are the only abalone species found in Washington waters and are important ecosystem engineers in kelp forests by grazing rocky reef substrate clean for the settlement of other invertebrates and algae. Having declined by 97% in state waters between 1992 and 2017, pinto abalone are listed as endangered in Washington state. The Seattle Aquarium contributes to recovery efforts led by Puget Sound Restoration Fund and Washington Department of Fish & Wildlife through captive rearing, field surveys, and outplanting to augment this depleted population.

Session 5: Research and Collaboration, Part 2

Sponsor Presentation:
McRoberts Sales

Collaborative Aquarium Research: A Global Approach

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The role of aquariums in the 21st century is evolving. Ensuring their future will require a global collaborative research approach. This presentation proposes ways for aquariums to adapt to their changing role and suggests tools to help make the transition successful. It introduces ideas for creating sustainable collections and ways to help save species from extinction by aligning collection plans with species conservation needs. It will also explore how collaborative research can increase aquarium community impact and provide data to change public perception. The results show that a collaborative network is necessary for aquariums to adapt and thrive in the future.

What Does Progress Look Like? Development of *In Situ* and *Ex Situ* Research Programs to Inform Husbandry Practices and Conservation Outcomes

Gregory J. Barord, PhD
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Conservation Biologist, Save the Nautilus

The question of whether the chicken or the egg came first (the egg did) is something that we grapple with in our personal lives, within our facilities, or out at sea conducting field work. The whole idea rests on the type of feedback system in place. Is fieldwork informing husbandry practices? Are husbandry practices informing field work? Is husbandry and/or fieldwork informing conservation initiatives? Regardless of the answers, perhaps the more pressing questions revolve around the type of evidence used and how the information is shared at each step. Here, I present a model framework for developing a feedback system that incorporates all stakeholders more efficiently, drawing on previous examples of partnerships and collaborations as well as a literature review of the topic.

Case Studies in Marine Animals Handling,
With an Emphasis on Specimens Under Human Care

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Handling of animals under human care requires specialized equipment and a professional attitude. Some species living in zoological facilities around the world may pose life threatening abilities to their human care takers, and the methods use to handle them must take into consideration their life history, biology and behaviour, thus ensuring neither party - animal and/or human - are harmed in any way. Handling is a necessity, during veterinarian procedures, during collection from the wild, during moves between exhibits, or even during inter-institutional transports, such as breeding loans.

I present to you a case study of large, marine animal handling, with an emphasis on reducing collection and movement induced stress with the use of industry led, practical equipment solutions that have animal welfare at their core and can supplement positive reinforcement behavioural training protocols. In addition, a brief introduction to concepts aimed at enhancing visitor-exhibit interaction with reference to recognised benefits.

That Time I Made High Schoolers Pretend to Like Jellyfish for Two Years

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Using volunteer labor, outreach relationships, or community partnerships to achieve institutional goals is a common practice among aquariums and zoos, perhaps even more so for smaller institutions or staffs. Many of these programs focus on using volunteers for regular, routine tasks or planned volunteer workdays for large scale maintenance projects, but within these partnerships also exists the opportunity for research projects. The Tennessee Aquarium recently utilized an existing educational outreach partnership to meet the needs of a proposed research project for an aquarist. Working with a high school teacher and two of her students, the aquarist was able to plan, test, complete, and publish a study on the effect of ocean acidification on upside down jellyfish. The teacher helped to train the students in research methods and oversee part of the project, while the students served as lab assistants, gathering a majority of the data. The research team was also able to get assistance from a statistics professor at the local university and add them as an additional author on the paper, bringing in a second community partner to the project. The results of the study were accepted and published by a peer-reviewed journal, to the benefit of all participants of the project.

A Unique Partnership

Rebecca Leitner
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The Aquarium at Moody Gardens

Meeting after meeting you discuss the "problem", the best solution is "cost-prohibitive", your operation remains unchanged, and you continue with the "status quo". This scenario plays out daily in facilities across the country, leaving staff with two choices. The first option is to fall into the complacency of routine and repeat this seemingly endless cycle. The second option is to forge a path towards the best solution through creative partnerships.

Moody Gardens staff arrived at this same crossroads when addressing the challenges of weighing elasmobranchs without creating added stress. Factors such as facility design, space limitations, handler safety, animal safety, and physics demanded custom fabrication of a portable weigh station that could withstand a harsh salt environment, safely and gently lift and weigh animals, and be deployed and recovered by minimal staff. Rather than choosing option one and throwing in the towel, Moody Gardens turned to the community and partnered with the students on the entrepreneurial tract at Ball High School.

The unique partnership that began with the welding students quickly grew to include students in the engineering tracts. In doing so, we were able to effectively and affordably address animal care issues, and students from Ball High were not only able to showcase their skills for the community, but it showed them that their skills were applicable in the zoological industry, both opening doors and expanding horizons for future generations of students to come.

Session 6: Innovation, Part 1

Sponsor Presentation:
Asahi America

Hyperbaric Therapy to Treat Presumed Gas Supersaturation in a Zebra Shark (*Stegostoma tigrinum*)

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In June of 2022, a 31.3 kg, 6-year-old female zebra shark (*Stegostoma tigrinum*) was diagnosed with probable gas supersaturation following the failure of a de-gassing tower at PDZA's Aquatic Animal Care facility. The zebra shark was exhibiting the following clinical signs – increased opercular rate and effort with occasional opercular pauses. Blotcheye soldierfish in the same system experienced mortality secondary to gas supersaturation while other species were unaffected.

Recompression therapy as a treatment modality was investigated given PDZA's success treating gas supersaturation in rockfish and tropical teleost fish, however, the size of the shark made utilization of the on-site recompression chamber not an option. A local equine rehabilitation facility was contacted and collaborated on successful treatment of the shark.

While a definitive diagnosis was unable to be determined for this shark, the zebra shark and an epaulette shark from the same system successfully underwent hyperbaric treatment at the equine facility. Factors to consider when performing similar treatments include transit time, temperature moderation, water quality, and animal welfare. The use of hyperbaric therapy for aquatic animal care is continuing to evolve and has potential to improve outcomes for managing gas supersaturation in aquatic animals.

Acknowledgements: The authors would like to thank Melissa Ledford from the Pegasus Training & Rehabilitation in Redmond, WA for their collaboration and assistance with treating this animal.

Addressing Symptoms of Head and Lateral Line Erosion in *Paracanthurus hepatus* with Recurring Naltrexone Treatments

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Head and Lateral Line Erosion (HLLE) is a commonly occurring syndrome among fish in human care. While maintaining optimal environmental and nutritional conditions can minimize occurrences and severity of HLLE, some cases persist. Although prevention is always the goal, there are circumstances where HLLE occurs. In a study of six Palette Surgeonfish presenting with HLLE, monthly administration of topical 0.4% Naltrexone paste resulted in reduction of lesion coverage.

The surgeonfish that participated in this study reside in a 3,100-gallon exhibit at Great Lakes Aquarium. Five of the palette surgeonfish have been in the exhibit for ten years, and the remaining individual has been in the exhibit for three years. The severity of HLLE seen in the original 5 surgeonfish at the onset of the study ranged from mild to moderate, with individuals experiencing between 2.6% and 17.5% depigmentation of the head. The individual that was added to the exhibit later presented with severe HLLE, with 54.1% depigmentation of the head.

Four treatments of Naltrexone were administered over the course of four months, with photographs taken and analyzed each month. All test subjects showed at least slight improvement, with four of the six showing significant reduction in depigmentation of the head. Naltrexone should be considered as a treatment option for HLLE when prevention is not possible.

Updates on Monogene Assessment and Treatment in Aquarium-housed Eagle Rays

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Morbidity and mortality of *Aetobatus* species due to the *Decacotyle* monogene have continued to be an issue in aquaria and often remain undiagnosed until postmortem evaluation. With few successes at eradication of the parasite, what steps can be followed to minimize negative impacts to life expectancy of the species? Early detection and treatment are fundamental to successful monogene mitigation of eagle rays under human care. Visualization of the monogenes on the gills via endoscopy, followed by quantification of the parasite after a bath treatment, such as praziquantel, are current methods for antemortem determination of the *Decacotyle* load. Praziquantel has been a mainstay for treatments but with heavy loads less responsive to treatments, an alternate was needed. Levamisole was used and provided a promising adjunct to monogene management.

Sodium Bicarbonate and its Effects on Chloroquine Phosphate Treatments in Aquaria

Alyssa Daily
OdySea Aquarium

The compound chloroquine phosphate is regularly used as a treatment for *Cryptocaryon*, *Uronema*, and many other parasites that are persistent pests in public aquaria. At OdySea Aquarium this treatment was depended on regularly to eradicate disease from both wild caught and aquacultured animals, however we experienced erratic test results and unreliability with this treatment option.

After analyzing our water quality throughout these treatments, one trend was seen correlating dosing buffer (sodium bicarbonate) and a significant decrease in our readable chloroquine in the system. An experiment was conducted with various concentrations of chloroquine and buffer to test if there was a reaction between the two compounds in a closed environment. The results of this experiment indicated that the sodium bicarbonate buffer did not directly affect the readable chloroquine levels, however additional hypotheses for indirect effects can be made using this data.

The results of this experiment, while unexpected, are largely beneficial to both hobbyists and those in public aquaria. The knowledge that there is not a direct effect on chloroquine levels from buffers allows for clearer decision making for medical treatments and water quality management for animals in human care.

Manipulating Omnivory to Navigate Nutrition and Study Survivability in Bonnethead Sharks (*Sphyrna tiburo*) During Critical Rearing Stages

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Bonnethead Sharks (*Sphyrna tiburo*) are a commonly housed elasmobranch species in aquariums, however despite their popularity, best practices for care and rearing remain ambiguous at best. After recent publications exploring the diet and nutritional absorption of seagrass for *in-situ* bonnetheads (Leigh et al, 2018 & 2021), we explored the incorporation of vegetative matter in bonnethead sharks under *ex-situ* care during the first 288 days of their lives. Beginning in February 2020 and again in September of 2022, a total of 15 bonnetheads were born at Shedd Aquarium spanning 2 litters of same sire and different dams. The 2020 litter, with a 100% survival rate to 1 year old or more, was fed a diet containing alfalfa hay pellets to replicate observed omnivory and handled every two weeks for morphometrics and blood analysis. The 2022 littler was handled similarly but split into two groups, with one group not receiving the alfalfa pellets to explore the effects of dietary vegetative matter on survivability, growth, and blood parameters. All feeds were recorded and of the 9 bonnethead sharks born in 2022, 6 survived the whole study period. A larger sample size and further study on husbandry, genetics, nutrient absorption, and litter sizes is needed to form more reliable conclusions. Based on our data, animals given an omnivorous diet had steeper growth curves but similar blood parameters to those receiving only seafood, but additional variables such as litter and parentage also affected these results.

Session 7: Innovation, Part 2

Sponsor Presentation:
Cairns Marine

Evaluating Black Soldier Fly Larva Meal as a Sustainable Alternative to Fish Meal in Aquarium Diets

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Black soldier fly larva (BSFL) meal is a sustainable, high protein alterative feed ingredient that may lessen our reliance on fish meal for zoo and aquarium diets. To evaluate the efficacy of BSFL meal as a fish meal alternative, we conducted a trio of crossover experiments to test palatability, growth, and overall health of tropical teleost species fed commercially produced (Mazuri, EnviroFlight) complete gel diets containing BSFL meal compared to a control. Body weight and fork length were collected as markers of growth performance.

Study 1 - 40 sailfin snappers (*Symphorichthys spilurus*) were fed a control or experimental diet containing 50% replacement of fish meal with BSFL meal over two 8-week periods. Fish were fed a diet of 33% gel and 67% mixed frozen seafood.

Study 2 – BSFL meal replaced 100% of fish meal. Test diet was fed to 400 smallmouth grunts (*Haemulon chrysargyreum*) over two 8-week trial periods. Diets included 50% gel and 50% mixed frozen seafood.

Study 3 – BSFL meal in carnivorous complete gel diet, 100% replacement of fish meal. Fed 120 smallmouth grunts (*Haemulon chrysargyreum*) over two 12-week trial periods. Diets included 50% gel and 50% mixed seafood.

Across all experiments, fish showed no significant difference in growth performance between treatments and experimental diets were well consumed. With this success incorporation of BSFL meal as an alternative to fish meal, insect protein can potentially decrease our use of fish meal to feed aquarium fishes.

Implementing a Multi-Faceted Behavioral Approach to Mitigate Undesirable Behavior in a Cowtail Stingray (*Pastinachus sephen*)

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After introducing a cowtail ray (*Pastinachus sephen*) into the 5.7-million-gallon Main Environment at Disney's The Seas, aquarists discovered that the social, behavioral, and husbandry requirements of this ray exceeded those of other species. Shortly after release, the adult ray, Larry, began exhibiting heightened, aggressive interactions of chasing and biting towards contra-specifics. These interactions escalated with time and were creating disruption to feeding opportunities to the entirety of the elasmobranch collection, disturbing daily husbandry routines, causing animal injuries that required medical intervention, and contributing to increased aquarist frustration.

To address Larry's undesirable behavior, the husbandry team created a multi-fold plan that tackled the issue from a short-term behavioral, long-term behavioral, and physiological perspective. Through strategic implementation of this combination strategy, aquarists were committed to producing a holistic animal management plan that encouraged not only a sustainable change in Larry's chronic chasing and biting behavior, but also a welfare plan that he and his contra-specifics benefitted from for the long haul.

By creating a data tracking tool to measure the frequency and intensity of Larry's interactions, the team used evidence-based research to see how his aggression was trending over time and assessed the success of the behavioral modification techniques being utilized. Through consistent implementation of the multi-faceted strategy, regular data interpretation, and collaborative work amongst partnering teams, not only did Larry's interactions substantially decline, but numerous unexpected animal welfare wins were achieved within the Main Environment that continue to positively influence the way its inhabitants are cared for today.

Behavioral Husbandry through Operant Conditioning of Teleost Species to Reduce Stress and Increase Welfare

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In 2023, the Aquatics Department at Cameron Park Zoo improved the welfare and safety of two species of teleost to facilitate husbandry. First, aquarists reduced the stress related to capturing and containing Red Lionfish (Pterois volitans) to allow a diver to enter their exhibit. Historically, lionfish were caught in a net and placed in a plastic bin to reduce the risk of diver envenomation. This led to stress responses from the fish and required at least thirty minutes of staff time to catch the animals. When Cameron Park Zoo acquired 0.0.3 Red Lionfish in 2023, staff trained them to voluntarily enter a howdy, which reduced stress responses from the lionfish and decreased the amount of staff time needed prior to dive maintenance.

Next, aquarists wanted to increase successful food acquisition of 0.0.1 Snowflake eel (Echidna nebulosa) in a mixed species habitat. The eel was previously trained to eat from a feeding stick, but triggerfish in the habitat often stole most of the diet before the eel could eat. The snowflake eel has a history of jumping out of the tank during feeding, which had the potential to injure the animal. Through operant conditioning, the eel was trained to swim into a mesh tube at the water's surface, where tankmates could not reach its diet. The top of the tube is covered in mesh, preventing the eel from jumping out of the water during feeding. This training has made feeding less stressful and safer for both the eel and the trainers.

The Successful Birth of Smalltooth Sawfish in a Closed Aquarium System

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SeaWorld Orlando

Sawfish are a charismatic genus that are a crowd favorite among aquarium guests. However, reproductive events in this critically endangered genus in human care are very rare. In July of 2023, SeaWorld Orlando became the second aquarium in the world to have a successful birthing event for any sawfish species. To the best of our knowledge, it was the first time a sawfish pregnancy has been documented in an indoor closed system.

Over the last 8 years several improvements have been made to the Shark Encounter habitat that houses SeaWorld Orlando's 1.1 smalltooth sawfish. This included updates to the LSS and lighting. There were also changes in the husbandry program such as an increase in temperature and a reduction in light pollution during dark hours in the building. The improvements of the habitat combined with some changes in the husbandry program likely contributed to this exceptional pregnancy.

The involvement of an experienced veterinarian was critical in detecting the pregnancy and executing a plan for a safe and successful birth. The pregnancy was initially detected, and then further monitored, by ultrasound. The pregnant female sawfish was safely relocated to a holding area behind the scenes prior to the birth with the help of IV anesthesia. The isolated female gave birth to 3 live pups in the early morning hours of July 11, 2023. At the time of this submission, all 3 pups are growing well and thriving.

Reproductive Husbandry of *Mobula hypostoma*

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The Georgia Aquarium has exhibited *Mobula hypostoma* for 14 years. The institutions lengthy history with this species has allowed a better understanding of their care and reproduction. Through the 19 individuals that have been in the collection over the years, their growth rates were monitored, which helped to develop a fundamental diet and feeding system that allows the population to thrive. In 2017 behavioral trends were noticed in 8 individuals that affected their feeding behaviors as the population began to mature. In addition to this, the first of seven mobulid courtship and mating behaviors were observed. During this time, data was collected on the initiation, endurance, evasion, and pre-copulatory positioning behaviors. Observations were unsuccessful for the copulation stages of mating however, data collection was successful on pregnancy, and birthing events. There are still questions to be answered about *Mobula hypostoma* reproduction including how long the gestation period is, do they need more space for birthing process, and will the males continue to fight for dominance without females being present.

Wednesday, May 8th

Session 8: Invertebrates, Part 1

Sponsor Presentation:
Gulf Specimens Marine Laboratory

Coral Restoration in the Florida Keys: Lessons Learned from the 2023 "Heat Event"

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The Florida Keys experienced an unprecedented heatwave in the summer of 2023 with seawater temperatures reaching some of the highest on record. This prolonged hot water event had a significant impact on the remaining live naturally occurring corals throughout the Keys, as well as the tens of thousands of corals that had been out planted onto reefs throughout the Florida

Keys. In-situ coral nurseries throughout the Florida Keys were also heavily impacted by the unprecedented heat, causing nursery practitioners to scramble to find ways to save the corals in their care.

Reef Renewal USA reacted to this emergency with a swift, novel, multiprong approach that saved thousands of corals from near certain death. Corals from offshore nurseries in the middle and lower keys were brought to shore and stored in a repurposed, temperature-controlled tanks owned and managed by Dynasty Marine, and a subset of corals at the upper Keys nursery were moved to deep water nursery where cooler water and lower light levels protected them from the extreme heat. Most corals at the upper Keys nursery were left in place to challenge them with conditions expected in the decades to come.

Lessons learned from all three treatments will be discussed, along with Reef Renewal USA's plan for addressing future extreme weather events.

This Coral Parasite May Be Eating Your Corals and You Would Never Ever Know It

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The never-ending saga of diseases and parasites has presented itself in a unique way here at the Long Island Aquarium. A small white amphipod was discovered after the hard reboot of the 20,000-gallon reef habitat here. The damage done by this amphipod presents itself as STN, RTN, a bacterial sloughing of tissue or just one of those "yeah, that's just what corals do sometimes" episodes.

Identifying and securing this amphipod is critical so proper diagnosis and treatment can be applied to effectively deal with this bug known as "THEM"

Spawning and Rearing *Diadema antillarum* for Coral Restoration

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Florida's coral reefs have undergone a phase shift from hard coral cover to a macroalgae-dominated state. Among the various reasons why is the disappearance of a keystone herbivore, *Diadema antillarum.* This urchin species experienced a Caribbean-wide die-off in 1983-4, after which natural populations have not fully recovered. Algal overgrowth currently threatens natural coral recruitment and survival. Therefore, restoration efforts would benefit from *Diadema* aquaculture to augment wild populations. A partnership between the Florida Aquarium and the

University of Florida that began in 2018 aimed to refine rearing techniques for this species. Combined husbandry and research expertise resulted in the development of novel culture methods and generation of thousands of captive-reared *Diadema* to support coral restoration. Temperature induced spawning provided a reliable and non-invasive way to obtain gametes. Rearing of larvae over 40-plus days in 40-L pseudo-kriesels connected to a 1,800-L recirculating system allowed for replicated experimentation at production-relevant scales. Multiple studies revealed improved growth and survival from diverse live microalgae diets containing *Rhodomonas* sp. and *Chaetoceros muelleri* and the presence of specific settlement cues. Together, this collaboration has resulted in the most successful *Diadema* culture efforts to date and enabled investigation of restocking aspects. This process has been hyper-focused on an extremely challenging species, but has proven to be successful with other urchin species such as *Lytechinus variegatus*, *Tripnuestes ventricosus,* and *Eucidaris tribuloides.* These methods are vital for restoring functional herbivory to Florida's coral reefs and could otherwise be pivotal in invertebrate larval culture.

Too Much of a Good Thing *Might* Be Okay?

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For many years live coral aquariums were operated under the assumption that low levels of nitrogen (N) and phosphorus (P) were necessary for success. Nevertheless, both public and private aquarists have long shown that levels of N and P, many orders of magnitude above NSW values, still produced thriving coral communities.

The Steinhart Aquarium has operated a 800 m^3 (212,000 USG) live coral habitat for 16 years and has experienced three periods of significant coral loss: March 2014, January 2020 and May/June 2023. Using nitrate and phosphate values from 2013-2024, we found that N:P molar ratios exceeding 200 appeared to correlate with these episodes, while values below 200 correlated with recovery.

Our hypothesis is that when phosphorus levels become too low in the presence of high nitrogen values, some corals may become phosphorus limited resulting in fading color, reduced or lack of growth, tissue recession, and increased frequency of disease and ciliate infections. However, not all corals react negatively e.g. some *Acropora* sp. grow while others don't. While corals may appear healthy, the scientific literature has shown that high nutrient levels can result in lower skeletal densities as high nutrients promote rapid tissue growth requiring the skeleton to grow faster, creating a less dense skeleton. This has yet to be explored in our system.

While our understanding of the role of dissolved nutrients in coral health in aquaria is still limited, we feel the examination of N:P ratios may be useful when troubleshooting coral issues.

Exploring the Enigmatic: Redefining Mysteries in Aquarium Husbandry of the Salish Sea's Intriguing Marine Invertebrates

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Companion Article in this Issue of Drum and Croaker!

The diversity of invertebrate marine life found in the Eastern Pacific is vast and breathtaking for any diver who has the opportunity to experience these waters. A large portion of aquariums across North America barely tap into the complexity of life found in the Pacific Northwest. Institutionally this gap in diversity can range from factors such as accessibility, spaces availability, cost of maintenance, and knowledge of care. Four truly unique marine invertebrates found within Puget sound, whose care in captive aquaria has progressed in the last decade, consist of the Giant Sea Pen, *Ptilosarcus gurneyi,* Willemoe's White Sea Pen, *Balticina willemoesi,* Feather Star, *Florometra serratissima,* and the Basket Star, *Gorgonocephalus eucnemis.* These species are all found in individually distinct and diverse habitats, all of which are difficult or near impossible for the general public to view in person. By streamlining collection techniques, necessary water quality parameters, dietary needs, flow preferences, and preventative maintenance, these extraordinary cold-water species could be more commonly displayed in aquaria, expanding animal care skills and management knowledge within the industry will help to enhance the overall welfare of these animal. These species have been collected and cared for at the Point Defiance Zoo and Aquarium with varying levels of success over the years, and it is important to learn from both successes as well as failures. This knowledge and experience will help to progress the care of these species, and expand the ability of other facilities to include some of these unique invertebrates in their collection.

Culturing the Warty Sea Cucumber (*Apostichopus parvimensis*): Proof that even animals with "warts" can be cute

Ellen Umeda
Monterey Bay Aquarium

The Monterey Bay Aquarium displays warty sea cucumbers, *Apostichopus parvimensis*, as an accessory species in many exhibits highlighting the marine habitats of Monterey Bay. Although warty sea cucumbers can be collected locally via SCUBA diving, culturing reduces collection pressures on wild populations and provides an opportunity to study larval development. The Monterey Bay Aquarium spawned seven adult warty sea cucumbers on March 28, 2021, using heat shock. The warty sea cucumbers developed through several planktonic larval stages, which we documented through routine photos every few days. After 28 days post hatch, the larvae started to metamorphose and settle on the benthos. The settled warty sea cucumbers continued to grow and developed the coloration and features seen in adults. Currently, 15-20 warty sea cucumber juveniles remain, ranging from 2-8 cm in length. This was the Monterey Bay Aquarium's first attempt at spawning warty sea cucumbers and future spawning attempts would aim to improve culture protocols and survivorship of larvae post settlement.

Tiny Giants: Raising Giant Pacific Octopus

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Despite their popularity in public aquariums, the early life history of giant Pacific octopus *(Enteroctopus dofleini*) is relatively unknown. Only one record of captive breeding, by Snyder at the Seattle Aquarium, is widely available. Furthermore, neither the delicate planktonic paralarvae nor newly settled juveniles are easily observed in the wild.

Aquarium specimens are typically collected as juveniles weighing several pounds. The Port Townsend Marine Science Center (PTMSC) had the opportunity to collect and raise two well-developed giant Pacific octopus paralarvae. The first was collected in June 2020 and released in January 2023 after producing a spermatophore. The second was collected in June 2022 and will be released upon maturation.

At the time of collection, both specimens had a mantle length of approximately one centimeter and clung to surfaces with occasional bouts of swimming freely, but were not yet fully settled. They were initially fed a combination of frozen krill pacifica and live plankton. As they grew, a more varied diet was introduced, including shrimp, clams, scallops, crabs, and herring (frozen). Photographs, videos and weights document their growth and development, giving a glimpse at a rarely-observed phase of their lives. This experience can inform future attempts at rearing *E. dofleini* in captivity and further our understanding of this iconic animal.

Session 9: Invertebrates, Part 2

Sponsor Presentation:
Abyzz

Charismatic Mesofauna:
Culturing and Exhibiting the Common Siphonophore *Nanomia bijuga*.

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Siphonophores, colonial hydrozoan jellies capable of free-swimming, have been relatively scarce in public aquarium displays due to their delicate nature and the challenges associated with obtaining wild specimens. *Nanomia bijuga*, a siphonophore in Monterey Bay that is prevalent at approximately 300 meters depth, engages in vertical migration to the surface during nighttime and is an important part of the mesopelagic ecosystem. Collection efforts of wild *N. bijuga*, involve the use of remotely operated vehicles during the day and dip-netting from the surface at night. To sustain a display of deep-sea siphonophores for the "Into the Deep/En lo Profundo" exhibition at the Monterey Bay Aquarium, adults were spawned using diffusion tubes, and larvae were reared to adulthood. Husbandry requirements vary across life stages, so variables were isolated to determine optimal water parameters and diets for planulae, siphonulae and fully formed adults.

Trials and Tribulations: Raising and Displaying *Chrysaora plocamia*

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Companion Article in this Issue of Drum and Croaker!

While opening a new 6,000 gallon stretch kreisel, we received 515 one to two inch cultured *Chrysaora plocamia* via donation and purchased another 200 cultured *C. plocamia* from a US supplier. Through several husbandry successes and current and past challenges, the Wonders of Wildlife jelly team learned a significant amount about raising this number of *C. plocamia* while dealing with constant setbacks in opening the new system. We successfully treated a decaying event that killed many jellies in a short time using 40 ppm oxytetracycline for three to five days, and we are continuing to investigate treatments and research why this species is prone to sudden and rapid decay.

Our greatest success was being able to identify male and female jellies and successfully establish a culture so we have a consistent supply to stock our large exhibit. Interestingly, the male and female medusa that produced the polyps had different color variations with the females being more orange and the males being whiter. The young medusa produced from the polyps are showing a mix in their parents' coloration. We learned an incredible amount about this species including their rapid growth rate, their sensitivity to being transported, and their preferred nutrition. In less than three months, they grow from an ephyra to a medusa four inches in diameter. Unlike most nettles, these do not eat moon jellies, so we successfully housed them together. We hope to encourage a larger discussion about jellyfish treatments, welfare, and solving the mysteries of *Chrysaora plocamia*.

"FOR SALE – Mottled Christmas Painting"
A Successful Rearing of the Painted Anemone, *Urticina crassicornis*

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The successful rearing of the vibrantly striated painted anemone, *Urticina crassicornis*, demonstrates an efficient and sufficient method for the rearing of a temperate anemone species in public aquariums. Gametes were collected during two spontaneous spawning events and after refining fertilization and husbandry methods utilizing minimal resources, the development of planula larvae, settlement, and growth significantly increased from 25 individuals to over 340. The methods developed offer a cost-effective and sustainable means for aquariums and academic institutions to acquire and maintain specimens for display or study.

Culturing *Pachycerianthus fimbriatus*

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There is not much in published literature about the reproduction of the cerianthid anemone, *Pachycerianthus fimbriatus*. The goal of this project was to document the spawning and settlement triggers for *P. fimbriatus*, thereby expanding the knowledge base of husbandry and reproduction of sessile invertebrates. Larval planulae were collected opportunistically after a spawning event on exhibit. Post-fertilization developmental stages of the planulae were documented via stereomicroscopy. Nearing the time of larval settlement, various substrates were offered to identify preferences. A UV light with a yellow filter was used to see the fluorescence of newly settled larvae. There appears to be a preference of substrate over no substrate as well as a preference for medium sized sand grain. Maturation time to reach adult size or become sexually mature is still unknown and may be the bottleneck in culturing the species. The next trial seeks to determine what induces *P. fimbriatus* spawning. As in the initial trial, planula development stages are documented. Based on these initial results, *P. fimbriatus*, makes a great sustainable exhibit animal to represent Pacific sandy seafloor habitat.

Intensive Aquaculture of *Sepia bandensis*

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Cuttlefish have had successful multigenerational culture for decades in both public aquaria and research facilities. Although many species have been cultured successfully, rarely are they in large numbers or through established methods in a husbandry protocol. The Axel lab maintains a consistent population of ~250 *Sepia bandensis* at all times and at all life stages with a structured culturing and housing strategy that is also applicable to other cuttlefish and bobtail species with minor alterations. These methods have been used on other species such as *Metasepia pfefferi, Sepia officinalis,* and *Sepioloidea lineolata* in combination with *S. bandensis* to raise over 3,000+ individuals to sexual maturity. The purpose of this talk is to establish a baseline for culturing strategies of *S. bandensis* that other institutions can follow to ensure high fecundity in their cultures and keep them stable to prevent removing specimens from the wild or having gaps in public exhibition in aquaria.

Stirring The Pot: A Novel Method for Rearing Marine Invertebrates

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Rearing invertebrate species in public aquaria offers a variety of benefits to captive and wild populations. It minimizes collection pressures on wild animals, offers incredible staff development opportunities, and can unlock mysteries of a particular animal's natural history to further our fundamental understanding of a species' biology.

In 2022, Steinhart Aquarium at The California Academy of Sciences began to take a more active role in invertebrate rearing to take advantage of these opportunities. Several methods for rearing invertebrate larvae were investigated to combat the challenges of limited space and resources. After trialing previously described methods for invertebrate rearing, as well as multiple novel approaches, a method utilizing simple off-the-shelf items that require minimal spatial and financial needs was found to be most efficacious; an automatic pot-stirrer paired with simple glass jars and silicon spatulas.

Various species of echinoderms, gastropods, and crustaceans have been reared using a simple, modular culture setup. Continuing studies of dietary needs and best spawning practices are ongoing. The results of this work have allowed Steinhart Aquarium to rear numerous invertebrates for exhibit and co-culture clean-up crews critical to advancing the rearing of corals from in-house spawning events and conservation initiatives.

Healing Sea Star Illness and Injury Through Environmental Management and Immune Support

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Managing sea star illness and injury in any setting has always been a challenge, since the causative factors are not always able to be determined. At the Oregon Coast Aquarium, the focus shifted from triage response for specific symptoms to the control of an overall environmental perspective within the animal and surrounding the animal. The treatment utilizes temperature control, invertebrate probiotics, sea water buffers and nutrient additives, hormone cue control, enhanced water flow, and an iodine-based solution. With this, the exact causative agent of the animals' decline whether it be viral, bacterial, parasitic, fungal, injuries, or general stressors such as pH or temperature does not matter because all possible issues are addressed and corrected within the same protocol. This combination of factors allows the sea star to properly utilize its own immune system to focus on healing instead of expending excessive energy combatting other possible stressors. The stars are carefully monitored for behavioral signs that indicate healing status, and the treatment elements are adjusted according to the identified positive or negative behaviors. Since there is no use of any antibiotics or medications, this method allows treated individuals to remain candidates for wild release after recovery. This research has led to a dramatic increase in recovery rates of treated sea stars across 8 cold water species (including sunflower sea stars) for all causative factors.

RAW Business Meeting

Sponsor Presentation:
Dynasty Marine Associates

RAW Organizational Update
Choosing the Venue for 2026
Remembrance of Colleagues

Thursday, May 9th

Session 10: The Art of Display

Sponsor Presentation:
Aquatic Equipment & Design

Creating an Inspiring Displays Toolkit

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SEA LIFE North America

With more than 55 aquariums globally, the SEA LIFE Aquarium Group (owned by Merlin Entertainments LLC) has created an Inspiring Displays Toolkit to provide our displays teams with practical examples of how to get the best out of our exhibits. SEA LIFE is known for immersive theming designs, with the creative teams for our new aquariums often thinking out of the box, with LEGO elements or local connections such as our newest City under the Sea theme in New Jersey. Unfortunately, not all of our exhibits are able to have a facelift on a regular basis. Our toolkit starts with the basics and highlights key principles of exhibit design around lighting, theming, water movement, collection planning, interpretation and storytelling to create amazing discoveries to inspire our guests. Understanding that budget, time and resource are often limited and can result in displays becoming tired over time, this Inspiring Displays Toolkit is designed to arm you with new ideas, providing a live and interactive platform for sharing information, innovative ideas, best practice examples, masterclasses and photo galleries from around the world. We would like to share what we've created with the aquarium community and discuss how we can collaborate moving forward to share 'The Art of Displays.'

Exhibits Design and Fabrication

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This presentation explores cutting-edge strategies in exhibits design and fabrication tailored specifically for professional aquariums. We delve into advanced technologies, sustainable materials, and immersive storytelling techniques that enhance visitor engagement while prioritizing the well-being of aquatic inhabitants. Join us to discover how these innovations redefine the aquarium experience, balancing education, conservation, and entertainment in a harmonious aquatic showcase.

From The Banks of The Licking River, To the Deep-Sea Trenches of Japan: Exhibit Design & Remodeling

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Redesigning and remodeling exhibits are an inevitable factor in the aquarium and zoo industry. Renovations are multifaceted and provide an opportunity to improve not only aesthetics, but also the life support and animal welfare which are vitally important for long-term success. These can benefit the guest experience, provide staff development and utilize limited space, time and available funds. In 2019, Newport Aquarium remodeled a system to house local fishes & Eastern hellbenders to highlight the importance of local conservation. Local exhibits provide the opportunity for low-cost animal acquisitions through sustainable collection while also providing team-building and improving staff morale. Newport Aquarium has also recently renovated a large cylindrical tank into an exhibit housing various deep-sea species found within the 'ring of fire' region across the Pacific. By using creative exhibit design elements, we were able to tie the gallery's geographical theming together and showcase more obscure species & habitats that guests would otherwise never witness. Without having a large production team, both of these remodels were largely conceptualized and competed in house. This demonstrates the immense value of utilizing ideas and skill sets from staff at all levels.

Don't Drain the Pool!

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This presentation will explore how the Monterey Bay Aquarium and Animal Exhibits and Design recently collaborated to safely remove and replace roughly one-third (2200 ft^2) of the artificial rockwork from within their 350,000-gallon Kelp Forest. The exhibit remained open to the public throughout the entire process.

A few decades ago, there were some technological advances that allowed single exhibits at public aquariums to become much larger in size. Many of these "Flagship" exhibits are now turning twenty-five or thirty years old which is also the generally expected lifespan of decorative concrete in seawater. Delamination, cracking, and spalling of concrete theming leads to exposed structural components in the exhibit and is common in these larger tanks. Many facilities find themselves in the dilemma of how to rehabilitate larger aquariums. The practicality of catching and housing the fish, the consequences of removing the weight of millions of gallons water from within the walls and from behind the windows, life support, or that exhibit is an integral part of the life support for the entire facility all make emptying the exhibit impossible. Aquariums are then stuck with an unsightly, and more importantly, unsafe exhibit for animals and for animal care staff to maintain.

Animal Exhibits and Design is a zoo and aquarium exhibit design and fabrication company has developed a series of innovative water/ animal-safe techniques that allow them to remove and replace, or just resurface, rockwork theming underwater. With specialized tools, augmented filtration, water quality monitoring and proprietary materials and methods, AED has successfully completed large-scale projects.

Acrylic Products, Usage & Maintenance:
Keeping your Acrylic Healthy

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The recent events surrounding the AquaDom in Berlin has the attention of many – ranging from acrylic industry manufacturers to those who regularly work with acrylic in aquariums, zoos and for exhibit purposes. The demand for increasingly grand and immersive underwater and habitat-oriented experiences has brought acrylic into a much larger spotlight. With tremendous advances in the field of acrylic manufacturing, the opportunity is prime to make efforts in educating the industry.

These expectations create the need for high quality throughout the life cycle of acrylic products. The industry needs product that is going to perform LONG-TERM – to accomplish that it is critical to focus on the following areas: up-front design/engineering, manufacturing and installation processes, review and training on proper acrylic maintenance, repair and care, frequency of inspections, what in-house repairs can be made versus those requiring outsourcing and focusing on long-term performance of acrylic installations. Additionally, refurbishment of existing acrylic and some unique uses of acrylic for exhibit purposes will be discussed.

Increased knowledge and understanding of what to look for in all aspects of acrylic and its life cycle will help increase the value and performance of your acrylic panels.

Session 11: Husbandry of Aquatic Plants

Sponsor Presentation:
Species 360

MBA's Kelp Forest Exhibit – From Holey to Holdfasts

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In 2020, an 800-pound piece of Monterey Bay Aquarium's iconic Kelp Forest Exhibit rockwork fell to the bottom of the 28-foot-deep exhibit. The 39-year-old exhibit's decorative rockwork wall required extensive repairs that resulted in a third of the wall being replaced over three years by a contracted commercial diving company. Upon completion, aquarists were tasked with re-establishing the diverse algae species the exhibit is known for across the new wall. Although algae would naturally recruit, to achieve optimum results, multiple techniques were used. We transplanted *Macrocystis pyrifera* holdfasts, collected and seeded cystocarpic red algae from tidepooling, and planted *Phyllospadix* in newly created planter boxes. Additional Abyzz pumps were also installed at key points in the exhibit, to further improve water motion and assist with algal growth. A combination of new and old techniques, and cultivating particular species in specific areas, resulted in the new wall blending into the exhibit within three months. The brown algae is thick, the red algae is diverse, and the flowering underwater plants are thriving one year later, with reproductive seeds being observed in the fall months.

How To Grow a Forest in a Fishbowl: Culturing Bull Kelp for Display

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Aquarium of the Pacific,

In 2022 Aquarium of the Pacific was invited to participate in an exciting research collaboration with the University of Wisconsin-Milwaukee focused on preserving genetic diversity of kelp to help facilitate future restoration projects. In recent years, kelp have been under pressure from many stressors including climate change, pollution, sedimentation, and direct damage from vessels and construction. Kelp populations recede and recover in a cyclical fashion based on weather patterns, but pressures from extreme warm weather events and over-predation have had an accumulative effect, preventing kelp forests from recovering since 2014. Researchers have taken advantage of kelp's unique bi-phase life cycle to create a "seed bank" to preserve genetic material from *Macrocystis pyrifera* (Giant Kelp) and *Nereocystis luetkeana* (Bull Kelp) in the form of gametophytes. These gametophytes can be kept in stasis for years by regulating temperature and light conditions. In the event that wild kelp populations suffer catastrophic loss of genetic diversity, these gametophytes could be used to produce new kelp for restoration efforts. Maintaining a copy of the gametophyte bank has allowed Aquarium of the Pacific the unique opportunity to cultivate lab grown kelp. Cultivating kelp allows AOP to display bull kelp, which we are not permitted to collect, to help drive conservation messaging about bull kelp as well as the intersection of other cold water conservation initiatives in which AOP participates.

Developing Methods for Growing Bull Kelp (*Nereocycstis luetkeana*) at the Point Defiance Zoo and Aquarium

Wesley Hull[1], Chad Widmer[2], and Joshua Fishbein[1]
[1] Washington Department of Natural Resources
[2] Point Defiance Zoo, and Aquarium

Bull kelp (*Nereocycsits Luetkeana*), a species of floating kelp in Washington State, provides essential ecosystem services to nearshore coastal marine systems. Unfortunately, the distribution and extent of bull kelp within sub-basins of the Salish Sea have declined, with decreases in abundance persisting over decades. Natural stressors such as temperature, eutrophication, and sedimentation have contributed to their decline, but their effects have been exacerbated through human activities. Further, continued declines are expected due to the emerging and continued effects of climate change. To ensure that bull kelp is not lost from our nearshore environments we need effective ways of acquiring and growing sporophytes that can be used to restore natural populations, understand population level responses to specific stressors, and showcase and interpret the importance of bull kelp to the public. Together, the Washington Department of Natural Resource's Aquatic Assessment and Monitoring Team (AAMT) and the Pacific Seas Aquarium staff began building and testing methods for cultivating bull kelp at the Point defiance Zoo and Aquarium. Through the creation of a semi-closed system mimicking natural conditions, the use of tumble aquaculture, and sporulation techniques the AAMT and aquarium staff successfully grew roughly 60 sporophytes from spores to an average total length of 1.4 meters and produced sori that were used to cultivate the next generation of sporophytes. The results of this project provide a methodological foundation for how aquariums may contribute to knowledge and efforts to restore bull kelp and for showcasing live individuals that can be interpreted to the public.

How Seagrass Can Save The World, A Blueprint in Setting Up a Successful Conservation Project

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With 100-million-dollar NOAA resiliency grants floating around and other government funding available to address sea level rise, ocean acidification, temperature rise, serve weather patterns. How does one go about setting up a conservation program to solve these issues. Could the answer be as simple as a plant? It eats nutrients, protects shore from erosion, sequester carbon among other things. Sea grass might just be the answer.

These are the steps into making this a successful conservation project. From planning, to stakeholders, government support, legislative support, permitting, to actual set up, monitoring and follow up. This is a quick outline for future planners and program directors to follow when setting up a conservation or restoration project for your zoo or aquarium. And yes, seagrass will save the world.

Sponsor Presentation:
The Aquarium Vet

Session 12: RAW Variety Pack, Part 1

Sponsor Presentation:
Hayward Flow Control

First Day of School:
A Systematic Approach to Introducing Aquaculture Fish into a Multispecies Exhibit

Amy Jo Li
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Aquacultured fish are typically reared in sterile, single species tanks. As the industry moves to more aquacultured species, the naivety of these individuals can present unique challenges when introducing them into large multi-species exhibits, such as the Sea's 5.7-million-gallon main environment. Through collaborative efforts with the quarantine aquarists, as well as implementing a multi-stage release program, the Sea's team has achieved success in integrating numerous aquacultured species on display. These species continue to thrive in their environment and these techniques have helped improve the welfare of both aquaculture and wild-caught species released into this exhibit.

Jellies on Ice! or
How to Keep Your Animals from Overheating in the Ice Apocalypse

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Moody Gardens

This presentation will discuss the unique husbandry practices that we employed during 2021’s Winter Storm Uri which left us without running water and electricity for about 5 days.

This presentation will cover the topics of Aquarium Innovation and Invertebrate Husbandry by focusing primarily on our response to the needs of our Pacific Sea Nettles (*Chrysaora fuscescens*), a cold-water jellyfish species that needs an average exhibit temperature of 55ºF/13ºC as well as constant water flow.

During Winter Storm Uri, Galveston Island experienced rolling blackouts and an eventual water shut off due to the freezing temperatures. While Moody Gardens is familiar with having to work through power outages due to tropical storms, being without running water was a new challenge for the majority of the staff. The “Cold Water Loop” is what keeps our cold water exhibits cool and relies on the city’s fresh water supply. Since we had power for the majority of the storm our systems were functionally fine, but were too warm for the animals. This led us to moving our Nettles out of their exhibit into several 5-gallon buckets in a not-so-well insulated hallway that had an ambient temperature that matched their natural environment.

Overall, this experience gave our staff a crash course in being quick on our feet in response to (un)natural disasters, how to think outside of the box to meet our animals' husbandry needs, and how to be resourceful in a situation where even the most basic resources are scarce.

Flip and Roll; Bonnets on the Move

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John G. Shedd Aquarium

Transporting sharks within aquariums can be a challenge, especially when dealing with ram ventilators, a sensitive aquarium species like the Bonnethead shark (*Sphyrna tiburo*), and longer distances. Historically at Shedd, when bonnetheads needed to move it has been a process of anesthetizing, pushing them to a transport while ventilating, if at all, and hoping for a quick recovery. Results of this method would involve higher lactate levels associated with stress, multiple injuries, long recovery time requiring aquarist exertion while waking the animal up, and a non-zero mortality rate.

At one point, Shedd had 11 bonnetheads across 3 systems with a large remodel on the horizon requiring a lot of impending moves. We decided to simplify and streamline a way to move all these sharks around safely and easily. Most of the bonnetheads we have worked with since birth using tonic immobility (TI) regularly and discovered just how well they can handle it, so we decided to find a way to use TI while moving them longer distances. We found that having an aquarist sit in a transport, holding the shark in TI, while a flow bar attached to the front of the transport, connected to a battery powered pump, worked as a hands-free ventilator decreasing stress, mortality, and eliminating recovery time. With this method of a portable ventilation system, we were able to quickly move all 11 sharks to another system or a truck for further transportation without the associated issues with other modes of transport mentioned above.

Nutritional Considerations for Support Feeding of Elasmobranchs

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Elasmobranchs can become inappetent stemming from a variety of health and environmental factors. Under human care, supplemental nutrition is often provided to support the animals' nutritional health, typically through gavage feeding of a gruel diet.

Caloric requirements of sharks and rays depend on variety of factors including species, life stage, and activity level. Daily caloric targets should be based on an individual's typical energy consumption levels. In cases of high caloric demand, multiple daily feedings may be essential to meet intake targets without exceeding stomach capacity or passage rate. Two percent of body weight can be used as an initial dose, and may be paired with ultrasound imaging to monitor stomach fill and avoid over feeding. Stomach capacity can be increased with repeated tubing, increasing volume delivered per tubing and thereby minimizing handling frequency. Collecting frequent body weights during handling is vital for tracking progress to determine success of the assist feeding program. Monitoring fecal quality is also important in assessing how gruel is being digested. Floating oily fecals could indicate poor fat digestion or excessive dietary fat levels, poorly digested fecals could indicate over feeding or rapid transit time.

In conclusion, elasmobranchs in negative energy balance require comprehensive nutritional support. Proper techniques for delivery, formulation, and assessment will drive best possible outcomes for our animals.

Got Crypt? Who Doesn't!

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SEA LIFE Orlando Aquarium

SEA LIFE Orlando has a unique system in which many small exhibits as well as all three large exhibits are filtered by one Life Support System. This allows for a uniquely large gallery with exhibits placed around the aquarium. However, this can also mean challenges with parasites like Cryptocaryon within those exhibits. The purpose of this talk is to provide insight into how SEA LIFE Orlando has managed Cryptocaryon outbreaks on exhibits that can only be isolated temporarily. We would like to share different techniques we have learned to manage Cryptocaryon outbreaks and best practices for introducing new animals into water with historical Cryptocaryon presence. After many years of handling outbreaks and introductions in this unique system type we have found that combining medication, changing light schedules, cleaning routines, managing secondary infections, and close observations can create a successful introduction and long term management for fish within this type of system.

Session 13: RAW Variety Pack, Part 2

Sponsor Presentation:
U.S. Mysids

Use of a Customized 3-D Printed Harness for Buoyancy Control in a Green Sea Turtle (*Chelonia mydas*)

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Mystic Aquarium, Adia, Inc, New Balance Athletics, Inc.

In 2008, the Mystic Aquarium was selected as the permanent home for Charlotte, an estimated 3-year-old male green sea turtle (*Chelonia mydas*) that was deemed non-releasable. Charlotte had sustained a severe boat strike injury that resulted in positive buoyancy in the caudal half of its body and limited mobility in its posterior flippers. Since arrival, multiple buoyancy correcting measures have been implemented with the intended result of aiding Charlotte in obtaining neutral buoyancy. These efforts include weights epoxied onto the carapace and various neoprene, non-customized harnesses, all with varied success. Thus, the goal became to develop a customized 3-D printable harness with removable weights. For this purpose, Mystic Aquarium partnered with Adia Inc. (a regional 3-D printing company) and New Balance Athletics Inc. to create a strong, flexible, and adjustable 3-D printed harness for Charlotte.

After two years of design trials, Charlotte has successfully adjusted to the harness through desensitization training. Weights have been incrementally added to the harness over time, eventually allowing him to reach neutral buoyancy. Other positive outcomes have been noted such as increased movement in Charlotte's posterior flippers while wearing the harness. Major feeding session improvements have been recorded as Charlotte's training scores have gone from the lowest possible score to the highest. This successful project and unique collaboration between a local startup and a global corporation has allowed Mystic Aquarium to build new partnerships and explore additional opportunities, and we hope this can serve as inspiration for other public aquariums.

Are We Sure It's Ready? Modeling Animal Nitrogen Excretion for Effective Biological Filter Cycling

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Living exhibits operates outdoor seasonal elasmobranch touch exhibits at institutions throughout the country. This involves draining the exhibits for the winter and restarting them in the spring. Cycling the biological filter is one of the most important steps in preparing exhibits for animals. Daily ammonia production for each exhibit was estimated based on the amount of food introduced. Biological filters were cycled using increasing doses of ammonium chloride until the full estimated daily ammonia production was nitrified in 24 hours. We will review the results of biological filter conditioning and water quality after animal additions of seven exhibits.

Supersaturation in Aquariums: Stop Bombing This Interview Question

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Companion Article in this Issue of Drum and Croaker!

Total Gas Supersaturation is one of the more poorly understood phenomena in the public aquarium environments. Despite it being a common interview question, a simple explanation is difficult to come by. Indeed, the subject does not appear in the Kraken curriculum on AnimalProfessional.com and is not well addressed by beginner aquarium literature or online content. This talk aims to demystify the subject for aquarists specifically by defining total gas pressure and differentiating it from total dissolved oxygen. Additionally, it will explain the ways in which it poses health risks like Gas Bubble Disease, discuss how to measure it with modern equipment, and prescribe what to do in a supersaturation emergency. The goal is to create a clear, short, and understandable way for aquarists to understand this topic and be able to confidently navigate this issue in their home institutions.

DEVELOPING A MOBULID BODY CONDITION SCORING TOOL

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A critical tool when monitoring the welfare of an animal is body condition scoring. Annual physicals will provide a more comprehensive and in depth look at the animal's overall health; however, monitoring the body condition, food intake/calories consumed, and behavior, will also help to assess the health of an animal. Taxa like *Mobula sp.* can exhibit rapid changes in body condition due to multiple factors including a fast metabolism, mating behaviors, injury, or changes in their social hierarchy.

With more aquariums expanding their focus on animal welfare, there is a need to have body condition scoring tools for multiple genera of elasmobranchs. Body condition scoring on elasmobranchs has been established by Perry and Sawyna 2023 using a bronze whaler shark (*Carcharhinus brachyuru*) as a model and Kamerman et al. 2017 using spotted eagle rays (*Aetobatus narinari)* as a model. As more aquariums begin to exhibit Mobulid species, having a body scoring tool specifically for this genus is important due to morphological differences from other pelagic and benthic rays.

In body condition scoring of Mobulids, there are three features that are looked at: the dorsal coelomic surface, ventral coelomic surface, and pectoral girdle (Figures 1a, b). To conduct the body condition score, both the rear and lateral views are observed. Scores are ranked on a scale of "1-5". "1" illustrates an emaciated individual, "2" represents an under-conditioned individual, "3" is optimal body condition, "4" illustrates an over-conditioned individual, and "5" constitutes an obese individual. Some *Mobula* species may go through normal fasting periods and others may experience frequent social hierarchy changes, injuries etc.; therefore, most aquariums should target a score of "4" instead of a "3" to ensure that the animals have a cushion to support them during fasting periods.

Body condition scoring in Mobulids is usually more fluid than in other elasmobranchs due to their planktonic diet and multiple feeds a day. Once the animals miss a few feeds, it is important to regularly monitor the body condition until normal feeding behavior resumes. Having an unbiased method to conduct quick body condition scoring between routine physicals can help increase the longevity of these species in aquaria.

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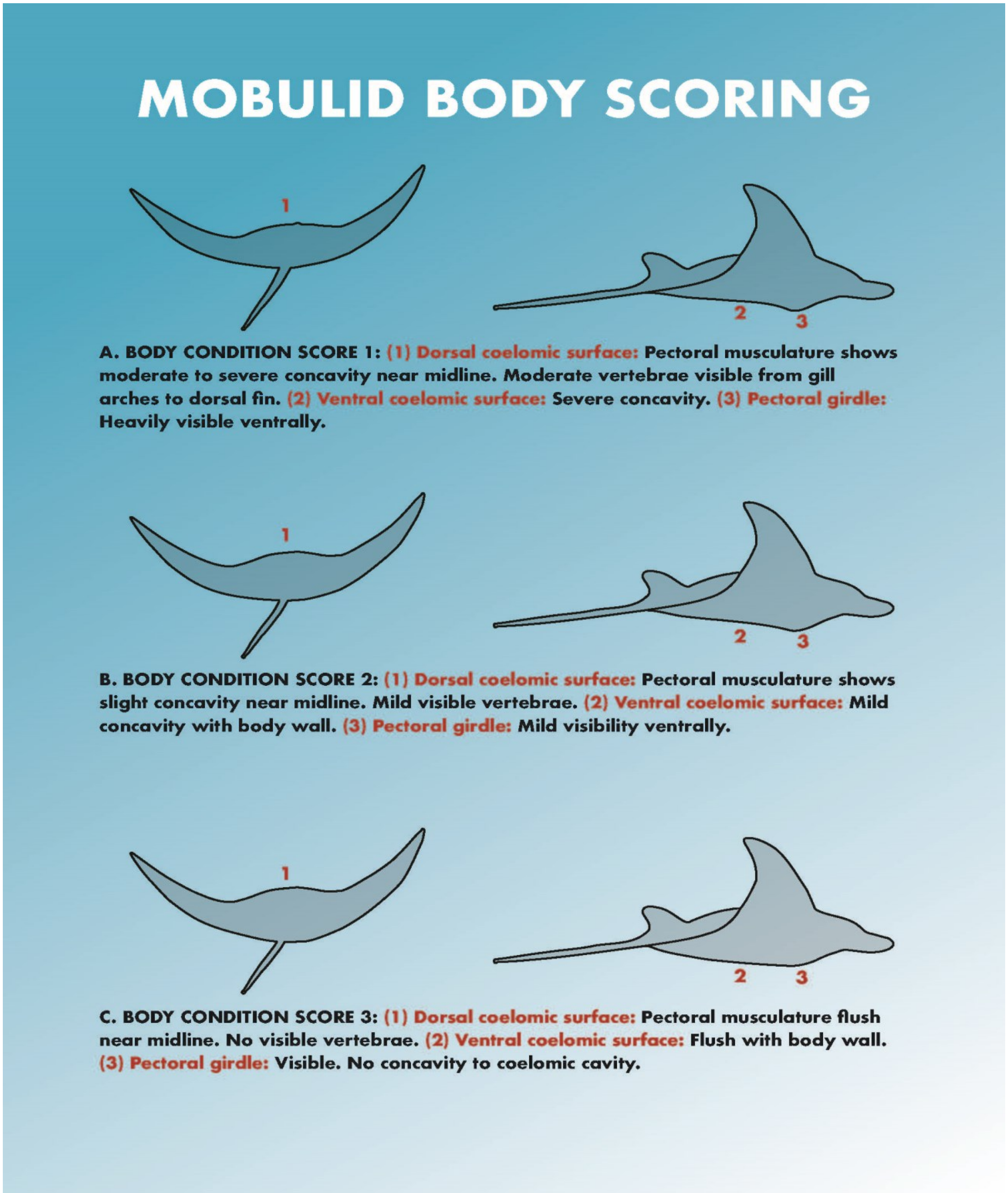

Figure 1a. Mobulid Body Condition Scoring utilizes a manta illustration to show body proportions and key anatomical features viewed from the rear and laterally. Scores 1 through 3 shown.

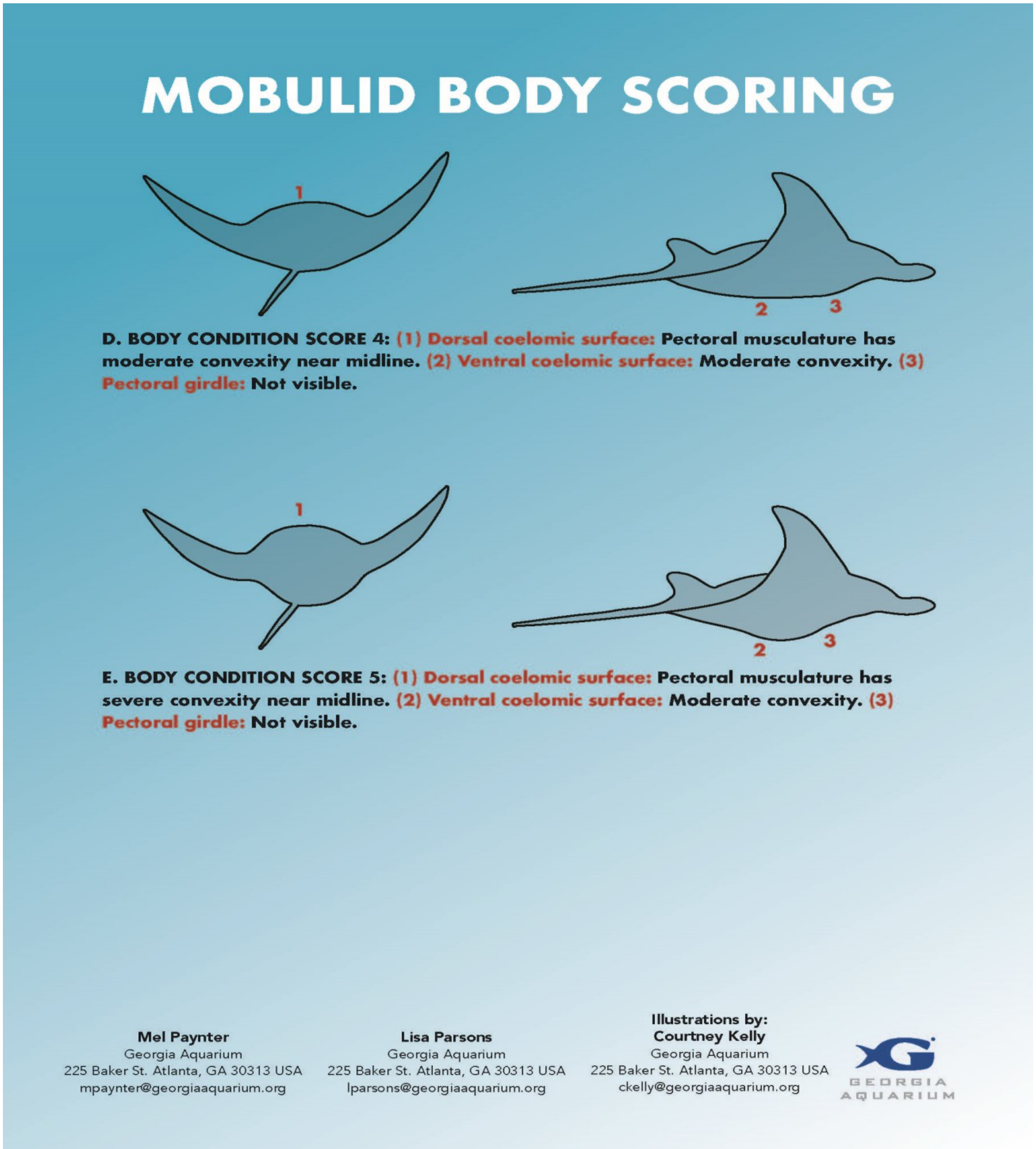

Figure 1b. Mobulid Body Condition Scoring utilizes a manta illustration to show body proportions and key anatomical features viewed from the rear and laterally. Scores 4 and 5 shown.

AQUACULTURE OF GIANT SEA BASS AT THE CABRILLO MARINE AQUARIUM

Atsuhiro Kubo, Christopher Bautista, Karla G. Burgos, Kathleen T. Burton, Eric I. Dean, Cristina Fuentes, Chris L. Okamoto, Nathan Perrin, Dominique T. Richardson, Milinda A. Thompson, Juliann Vannordstrand, Emily Wilson, and Andres Carrillo

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Introduction

The giant sea bass (*Stereolepis gigas,* Family: Polyprinidae) is a large bony fish that can reach lengths of up to 2.3 meters, over 7 feet, and weights over 250 kilograms, 551 pounds (Hawk and Allen, 2014, House *et al.*, 2016).). As adults, giant sea bass (GSB) reside near deep rocky reef and kelp forest habitat off the coast of California and Mexico (Domeier, 2001; Hawk and Allen, 2014). Historic fishing practices significantly impacted the GSB, and by 1934 the California population had fully collapsed (Allen, 2017). Regulations established in 1981 prohibit the harvest of GSB in California, and in 1996 the GSB was listed as critically endangered by the International Union for Conservation of Nature.

Since implementing fishing restrictions, the GSB populations are slowly recovering (House et al., 2016). Conservation efforts of GSB could further benefit through aquaculture practices which could be used to restock GSB populations, and also serve as a model for other large fish species. The purpose of this paper was to describe small-scale aquaculture methods used to rear GSB from embryos to early young stage at the Cabrillo Marine Aquarium. In addition, growing GSB during this project provided a unique opportunity to observe and describe the early-life development of this cryptic species.

Obtaining Eggs

Fertilized eggs were obtained from three mature GSB held at the Southern California Marine Institute in Los Angeles, CA from four separate spawning events that occurred on June 18, 22, and 28, and August 12 of 2019. Fertilized eggs were transferred to Cabrillo Marine Aquarium, San Pedro, CA where they were acclimated in 16-L rectangular tanks supplied with flowing seawater, maintained at approximately 20°C, until they hatched.

Rearing GSB

Approximately 700 larvae were transferred into 80-L pseudokreisel or 60-L conical tanks supplied with flowing seawater maintained at approximately 20°C to keep larvae suspended in the water column (Fig. 1). Larvae were not fed until 3-days post hatched, because GSB did not develop mouths until 2 days-post hatched and they possess sufficient yolk reserves. At 3-days post hatched, larvae were fed live rotifers (L-type *Brachionus plicatilis*) by maintaining the larval rearing tank at a density of 2 to 3 rotifers mL^{-1} throughout the day. When GSB were 10 days-post hatched, they slowly weaned onto brine shrimp nauplii by keeping larval tanks at densities of 0.5 to 1.0 nauplii mL^{-1}, in addition to rotifers. Once larvae were 16 days post-hatched, GSB were fed nauplii only.

Live foods, rotifers and nauplii, were enriched in 5-L of seawater dosed with 10 mL of a microalgae mixture for two hours prior to feedings. The microalgae mixture was made by combining Instant Algae® (Reed Mariculture) pastes: 500 mL of "*N-Rich PL plus*", 300 mL of "*N-rich Ultra PL*", and of 100 mL "*Shellfish diet*" supplemented with 100 mL of Selcon™ (American Marine Inc.) to enhance DHA's and vitamins available to GSB. Live foods were provided to larvae during two periods: daytime (800 to 1600 hours) completed manually and nighttime (1700 to 700 hours) using an automated feeder to accommodate Cabrillo Marine Aquarium hours of operation (8am to 5pm). The automated feeder was created by attaching a programmable low-pressure sprinkler tap timer (Toro® unit:53453, The Toro Company) to a bucket holding live foods under enrichment conditions, which was programmed to release calibrated portions of the bucket's contents into rearing tanks every hour to maintain the desired densities of live foods (Fig. 2).

GSB were maintained in the larval tanks until fish began to settle near the bottom of the larval tanks, starting as early as 20 days-post hatched. Settled GSB were transferred into 35-L settlement tanks supplied with seawater maintained at approximately 20°C (Fig. 3). GSB in settlement tanks were fed enriched nauplii and were weaned onto finely chopped mysid shrimp starting at 25 days post-hatched. During this weaning period, GSB were fed nauplii while they slowly transitioned to eating chopped foods, which included shrimp, fish, squid, and clam. Once weaned, GSB were transferred into a 260-L conical tank, when they were about 10 mm in total length at densities of 60 to 80 fish per tank (Fig. 3), and they remained in these conditions for over one year.

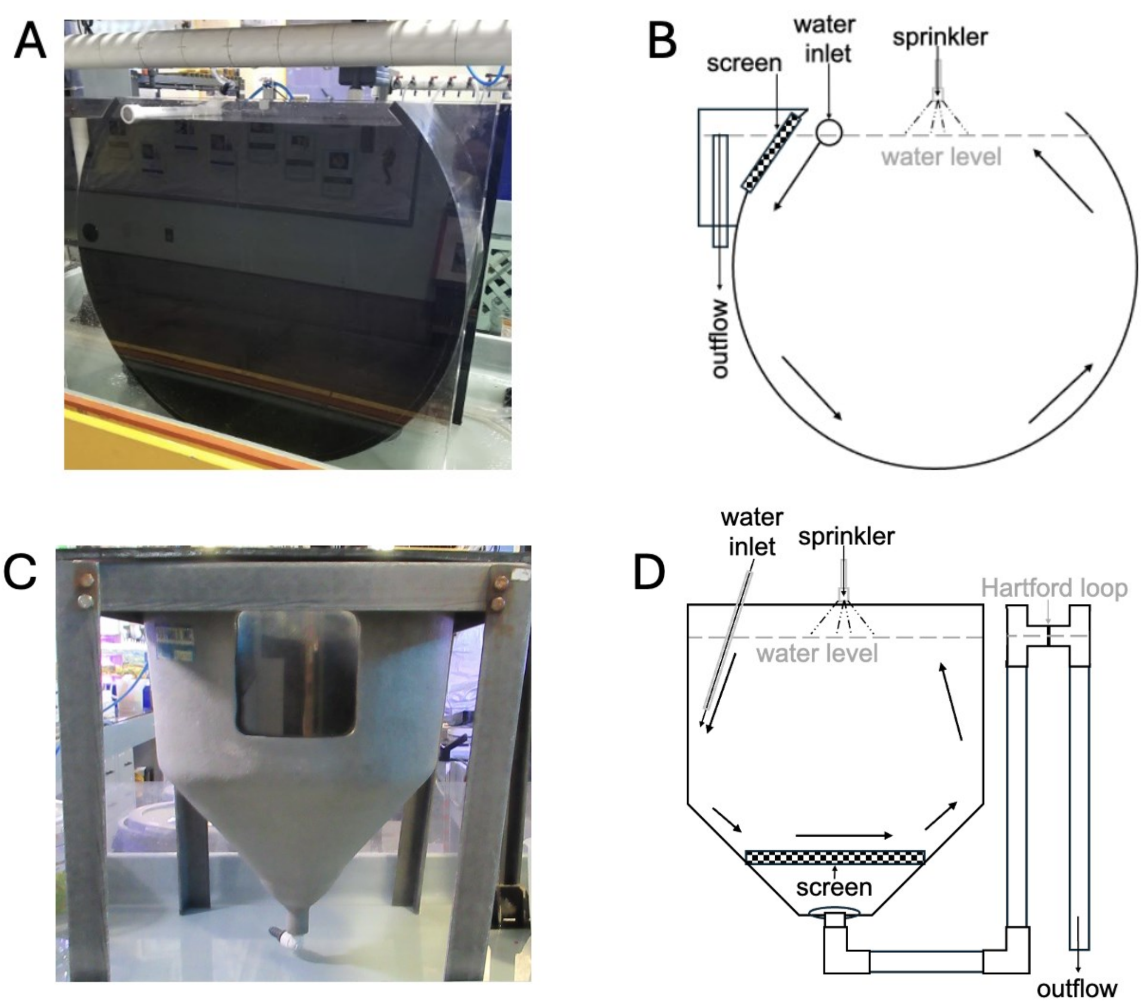

Figure 1. Larval rearing tanks: Consisted of A. pseudokreisel tank to keep GSB larvae. B. Schematic of pseudokreisel tank setup. C. Conical tank also used to hold larvae. D. Schematic of conical tank setup.

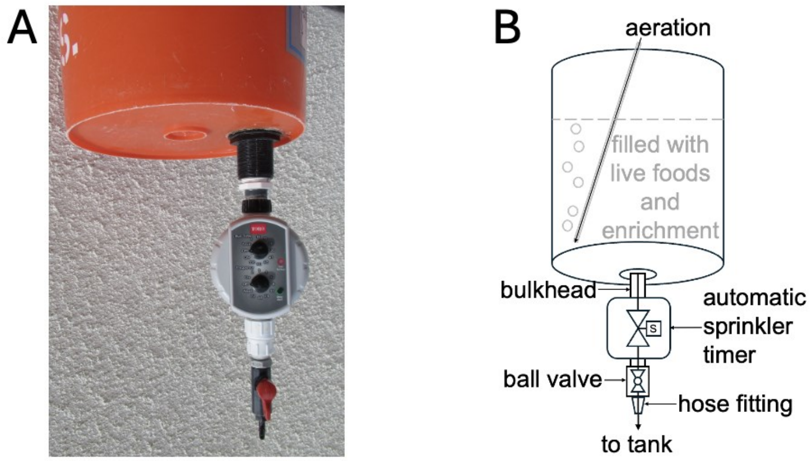

Figure 2. Automated feeding system designed to maintain live food densities at nighttime: A. Consisted of a 5-gallon bucket fixed to a low-pressure sprinkler timer. B. Schematic of feeding bucket setup.

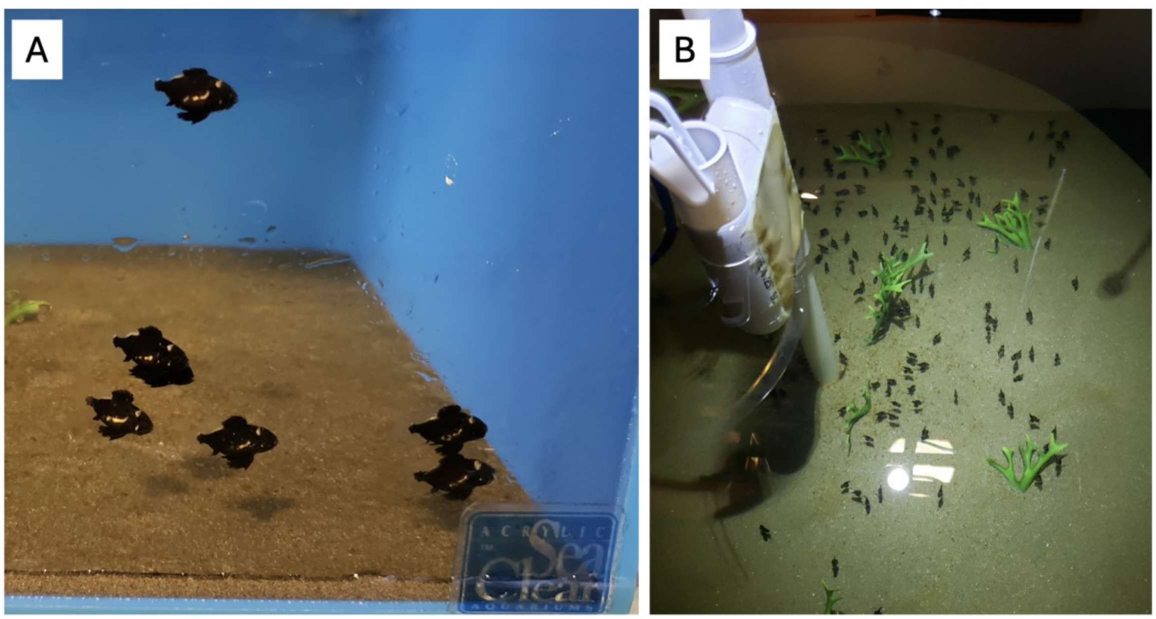

Figure 3. GSB settling in tanks: A. 35-L tank held newly settled GSB. B. 260-L conical tank held young GSB.

Observing GSB Development

GSB embryos, larvae, and juveniles were carefully removed from tanks to observe under a compound microscope where they were photographed using a Canon SX620 digital camera. Specimens were observed while fish were alive to reduced challenges with shrinkage and color changes which typically occurs when preserving specimens in formalin. After initial observations and images were captured, the specimens were preserved in 5% formalin for reinspection purposes. Scientific illustrations were completed using live observations and digital images throughout early GSB development.

Embryonic Development

The fertilized eggs of the GSB were between 1.5 to 1.7 mm in diameter. At about six hours after fertilization the embryos had reached the 60 to 120 cell stage of development (Fig. 4A). At 10 hours post-fertilization, the embryos had begun to close the germ ring (Fig. 4B). After 1 day-post fertilization the embryos had formed their head and tail regions, and at this stage the eye formation was observed (Fig. 4C). At 3 days-post fertilization the body was well formed and chromatophores appeared along the body of the embryo (Fig. 4D). GSB embryos hatched when stimulated with sufficient water agitation at 3 days-post fertilization, which was observed when embryos were sampled for observations.

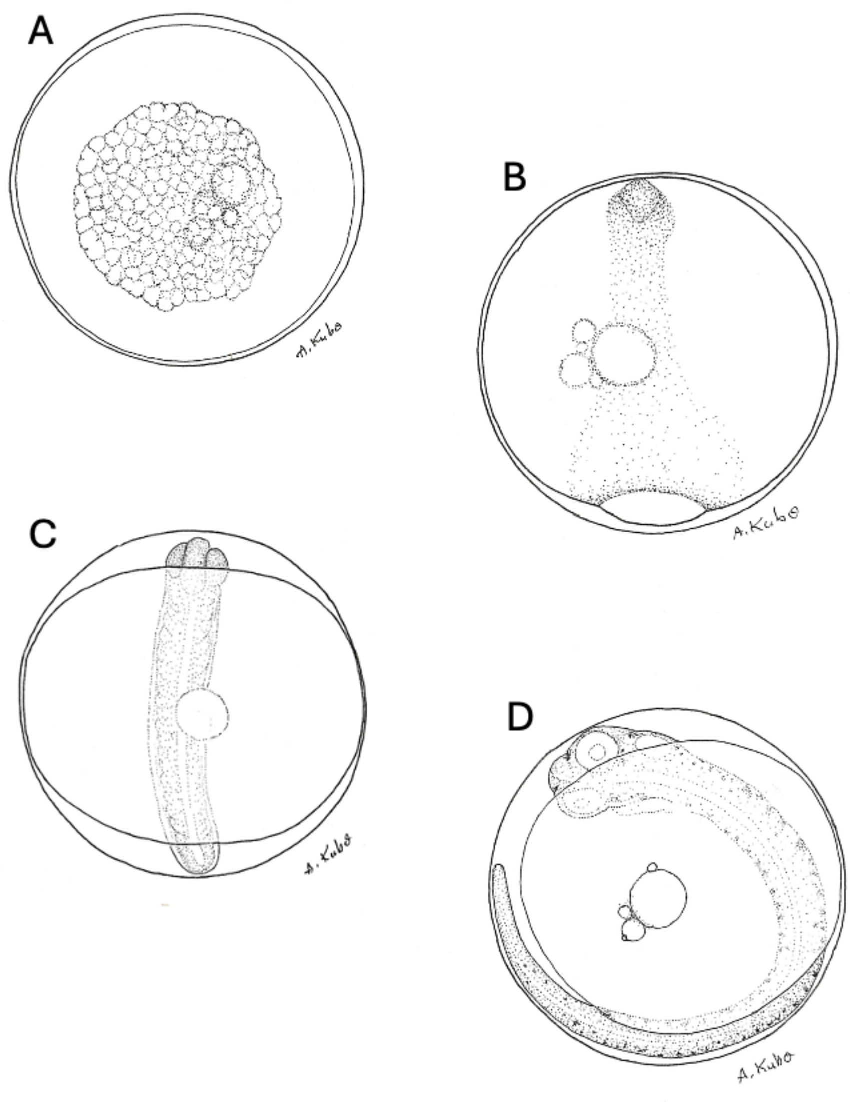

Figure 4. Illustrations of GSB embryos at various ages: A. 6-hour embryo. B. 10-hour embryo. C. 1-day embryo. D. 3-day embryo.

Larval Development

The GSB hatched at 3 days-post fertilization ranging from 3.4 to 3.7 mm in notochord length (NL). At hatching no jaw formation was observed in GSB and the fish lacked any eye pigmentation (Fig. 5A). At 3 to 4 days post-hatched, larvae are approximately 3.7 mm in NL and completed jaw formation and some eye pigmentation (Fig. 5B). At about 5 days-post hatched the larvae were 4.5 to 5.4 mm in NL and had increased body depth and chromatophore development (Fig. 5C). At around 14 days-post hatched, larvae were 6.0 to 7.0 mm in NL and entered the pre-flexion larval stage (Fig. 5D).

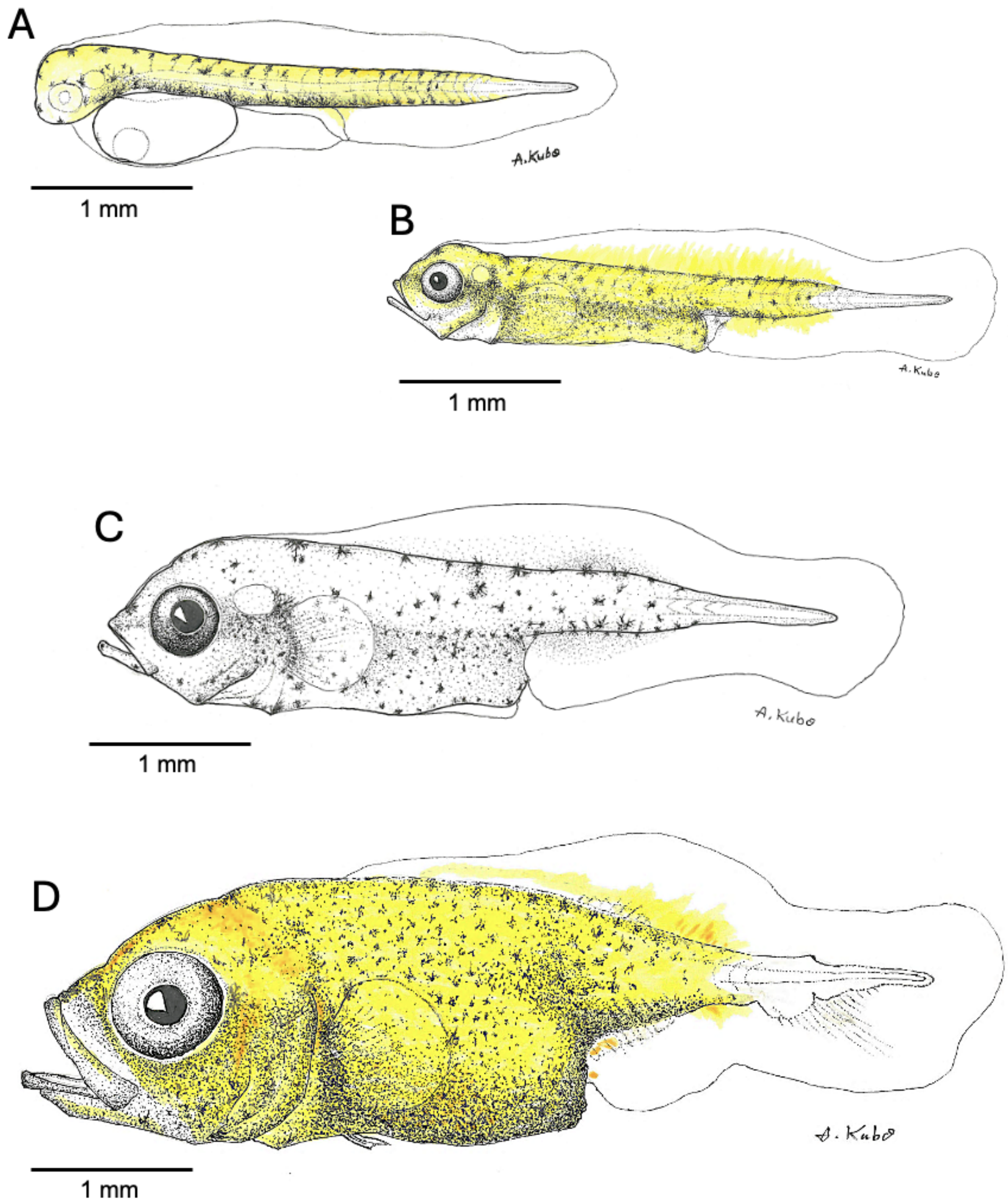

Figure 5. Illustrations of larval GSB at various ages: A. larva at hatch. B. 3-day old larva. C. 5-day old larva. D. 14-day old larva. Yellow coloration represents xanthophore pigmentation included in some illustrations.

Post-flexion was observed around 21 days post-hatched when fish are approximately 9.0 mm in standard length (SL; Fig. 6A). At 30 days post-hatched, GSB entered the juvenile stage and were approximately 12.6 mm in SL, at this life stage all adult fin-complements are present (Fig. 6B)

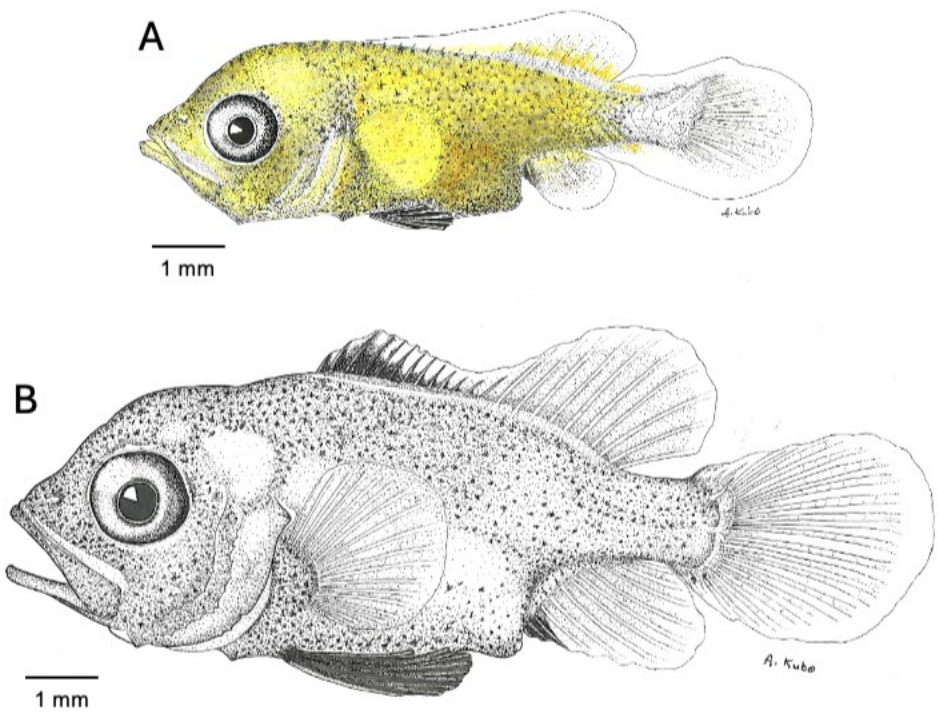

Figure 6. Illustrations of young GSB at various ages: A. 21-day old GSB. B. 30-day old GSB. Yellow coloration represents xanthophore pigmentation included in some illustrations.

Discussion

This was Cabrillo Marine Aquarium's first successful attempt to raise GSB in captivity from eggs. Over 350 GSB were grown to juvenile stages (over 100 mm length), which were shared with other aquarium facilities and a vast majority of fish raised from this project were released into southern California beaches to promote GSB conservation. Furthermore, observing this fish throughout early-life development has provided great insights to GSB ontogeny. Previous studies presented limited details of larval GSB from wild collections (Shane *et al.*, 1996), likely to the fact that they are difficult to identify. The illustrations made during this project provide a detailed account of early-life history of GSB, which can be used to help with ichthyoplankton identification and other related studies.

Previous attempts to grow GSB at Cabrillo Marine Aquarium under ambient temperatures (around 16°C) proved to be unsuccessful. Maintaining seawater at 20°C likely attributed to the successful rearing of GSB, in addition, the unique microalgae enrichment adopted during this project may have also played a key role in GSB rearing success. Additional attempts are required to fully support these arguments; however, acquiring additional GSB eggs to repeat and fully test these methods has become challenging with the critically endangered status of this species. In addition, the parents of GSB grown in this study were released into the wild shortly after this project started, terminating the original source of GSB embryos. The purpose of this brief paper was to present summarized details of rearing GSB in captivity to an audience who may benefit utilizing similar aquaculture techniques. However, it remains a goal to publish a highly detailed description to thoroughly describe the early GSB development observed throughout this project, despite the limited sample size of GSB grown during this study.

These fish were straightforward to raise in aquarium settings, and the methods used to raise GSB in this should still be tested to discover improvements to aquaculture practices. There remains much promise for improving and developing a standard protocol for raising GSB in captivity, which could be highly beneficial for future conservation efforts and commercial aquaculture practices of fishes with similar early life-histories to GSB.

Acknowledgments

We would like to thank the City of Los Angeles Department of Recreation and Parks, the Port Los Angeles, and the Friends of the Cabrillo Marine Aquarium for providing the financial and operational support used to complete this project. This project was supported by many parties (including a long list of contributing authors). A special thanks to Dr. Larry Allen and team at California State University Northridge for providing GSB eggs and facilitating the permits requirements for this project. A huge thanks to Nate Jaros and team at the Aquarium of the Pacific for assisting in animal husbandry and the collaborative efforts to release juvenile GSB grown during this project. Special shout-outs to Michael Couffer at Grey Owl Biological Consulting, and to Mark Loos and Team at the Southern California Marine Institute for assisting in animal husbandry and assistance with food supplies.

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EMBRYOLOGY, REARING, AND HUSBANDRY OF GRUNT SCULPIN LARVAE *Rhamphocottus richardsonii*: A CASE STUDY

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Abstract

While Grunt Sculpin have been cultured successfully in aquariums before, the amount of available information online and in textbooks is sparse. As a small, non-commercial cold-water fish with a long developmental period, comparisons between grunt sculpin development and other readily available larval rearing information, such as clownfish (*Amphiprion ocellaris*) development is tenuous. Through a literature review, data collection, and communication with local partners, an unexpected grunt sculpin egg clutch and subsequent larvae were cared for from spawning to recruitment, with photo/video observations of parental behavior, pre- and post-hatch development, and a baseline for future larval rearing projects. The goal of this project is to create a written and photographic timeline of grunt sculpin embryology and planktonic larval development, with a focus on larval rearing in an open system.

Introduction

Grunt Sculpin (*Rhamphocottus richardsonii*) are often described as "cute" fish. At a maximum length of 4 inches (Love, 2011) and with a cryptic coloration mimicking a Giant Barnacle (*Balanus nubilis*), they are a sought-after fish for both cold-water aquarists and Pacific Northwest dive photographers. They inhabit the nearshore waters from Alaska to California. A second grunt sculpin species, *Rhamphocottus nagaakii* was recently described as a separate, prominent species in the waters surrounding Japan (Munehara et al, 2022).

Figure 2. Female Grunt Sculpin in Barnacle (summer 2024).

Grunt sculpin have been cultured successfully in aquariums in the past (pers comm; Lavoie, 2012), and are known to live up to 13 years in human care (Love, 2011). Unfortunately, when the MaST Center Aquarium staff discovered eggs on exhibit, there was minimal information publicly available about their embryological or larval development. Based on what information was pieced together from local partners and online sources, it pointed to a long in-egg developmental period (Matarese, 1989). Eggs are approximately 2.5-2.8 mm in diameter, and larval fishes hatch at 6-7 mm. Larval fish recruit as small as 14-15 mm (Love, 2011). Little else was found.

MaST staff took this opportunity to study and document the process, with the goal of contributing to available data. Photographs and videos were taken throughout the process, featuring parent behavior, in-egg development, early hatches, and larval development throughout the planktonic stage to recruitment. This article will include an overview of what did and did not work during our experience, and feature selected photos and results from a year's worth of data.

Methods and Materials

The spawning pair of Grunt Sculpin in this case study are long-term inhabitants of the MaST Center Aquarium. Age is difficult to determine, but based on collection reports, the two individuals were collected in 2017 as adults, estimating an age of 8-10 years at the time of egg production. This pairing has produced eggs in years past; however, this is the first record of embryo development and successful hatching. Within the species, there is a range of colors and patterns, so the two individuals were easily identifiable in comparison with each other. The female ranges in lighter shades of cream with less evident patterning. The male has a slightly narrower profile, tan to orange base coloration with a consistently vivid pattern.

The MaST Center Aquarium features an open system, and operates with a five-horsepower submersible pump ~30 feet below the surface (tidally dependent) in the central Puget Sound, Washington State. It features approximately 15 tanks from 10-900 gallons, and features only local coldwater marine fish and invertebrates. Filtration is minimal, limited to a cage around the pump (~0.25-inch holes) to avoid accidental suction of animals, and some mechanical filtration (filter pads) on certain displays. High planktonic content results in well fed filter feeders and invertebrate recruitment, but also increased biofouling. As an open system, temperature and salinity are monitored weekly and match the ambient temperatures of the Puget Sound. Temperatures vary seasonally from high 40s to low 60s Fahrenheit, and salinity varies from estuarine to marine levels, depending on weather and currents.

These two grunt sculpin inhabit a jewel system: 6 tanks connected by a sump, within a larger open system. At the time of spawning, there were three fish (the two grunt sculpin and a small Mosshead Warbonnet *Chirolophis nugator*), with a variety of invertebrates in the 11-gallon tank. The six-tank interconnected system totals approximately 100 gallons and has an approximate turnover of 15 minutes. According to several sources, grunt sculpins have some parental care (Love, 2011; Matarese, 1989), though it is debated whether the male or female takes a primary role. In our case, the male was observed as the sole guardian (resting within the barnacle or closely outside the opening) during every observation. The female was observed within the nursery barnacle only during the 24-hour window before and after laying the eggs.

Spawning

The first notes recorded by staff occurred on November 22nd, 2023, when it was noted that one individual looked abnormally round. For ease of understanding here, individuals will be referred to by their sex, however that was not certain until the eggs were confirmed fertilized a month later due to the presence of eyespots. The female and male were both observed in the barnacle together on November 29th, displaying shimmying behaviors. Eggs were visible the next day; bright white in coloration and guarded by the male. The female remained in her usual position in the back half of the tank. At the time of spawning, the tank temperature was 50 degrees Fahrenheit; salinity was 30 ppt. After an online search, no cases of parthenogenesis were found.

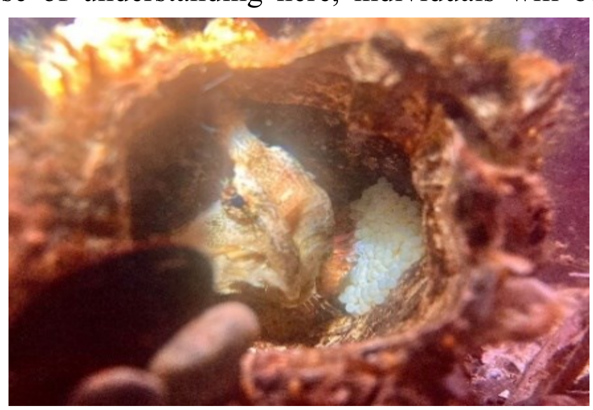

Figure 3. Male Grunt Sculpin with Eggs (12/4/23).

Based on the literature review in search of information, staff estimated that embryo development would take between 16-20 weeks. In reality, it took 11-13 weeks to hatch, though that could be due to a number of factors specific to this case. Breakdowns of the major stages are listed below, grouped by milestones hit at each stage. On December 29th, eggs were removed from the exhibit during regular maintenance, and from then on were monitored by staff daily. The female produced a second clutch of eggs the day after eggs were removed from display, however the male was much less diligent about guarding this second clutch, and the female was not observed guarding at all. The eggs were eaten by a Graceful Kelp Crab (*Pugettia gracilis*) in the display tank within weeks.

Embryology and Hatching

Grunt Sculpin eggs are opaque (white, in this case), which made the determination of fertilization difficult for the first five weeks. During this time, the male was diligent with guarding them, blocking close examination without risk of abandonment. After eggs were removed from the display tank (week 5), they were examined using light microscopy. Developing embryos were clearly visible, including eyes and beginnings of a nervous system, but no heartbeat. One embryo was removed from an egg for observation, and was measured at approximately 2.5 mm. In-egg movement was first recorded on January 6th (week 6).

On January 19th (week 8) a heartbeat was recorded on video in a viable egg via dissecting scope, observed through a thinning point on one of the shells. During the following two weeks, there were several partial hatches (deemed "pre-term") through such thinning points, embryos ranging in total length from 4-6.5mm. These fish had very large yolk sacs attached, and while they had active heartbeats, swam very little even with constant, directed water flow. It is unknown why the shells thinned at this time, as the fish were not fully developed larvae. Shell thinning was first noticed one month after spawning.

Larval Development:

In the first hatching event, over 100 larvae hatched between February 5th and 6th (week 11). Yolk absorption was variable, ranging from a small bulge to a very large, prominent sac. Newly hatched larvae were fed rotifers enriched with RGComplete™ (Reef Nutrition®). Hatch length averaged 6-7 mm total length, which was consistent with literature findings. Due to space constraints, staff added centered airlines to small buckets to create a closed, upwelling system as larval tanks. Larvae showed alternating "swimming" and "resting" stages, and were initially divided by this characteristic, though all larvae showed both behaviors some of the time.

Figure 4. Larval Rearing Setup.

After hatching, staff focused on water quality in the closed system buckets and heavy feeding, a delicate balance. 50-60% water changes were performed daily, and live food was refilled after each water change. New saltwater was filtered to 40 microns for the first 8 weeks and during periods of high plankton content in the raw seawater. For the first 3 weeks, rotifers were the primary food item, followed by a 48-hour brine shrimp and rotifer mix. In early-March (30 dph), the Puget Sound was experiencing a plankton bloom, and wild zooplankton was caught and offered. By mid-March (40 dph), most of the larvae were eating brine shrimp regularly, and rotifers were removed from feeding rotation. The 48-hour brine shrimp was enriched with Selco®, RGComplete™, and a few drops of GarlicGuard™ (Seachem®). Between spawning and recruitment, temperatures increased from 50 degrees F to 56 degrees F, after which offspring were

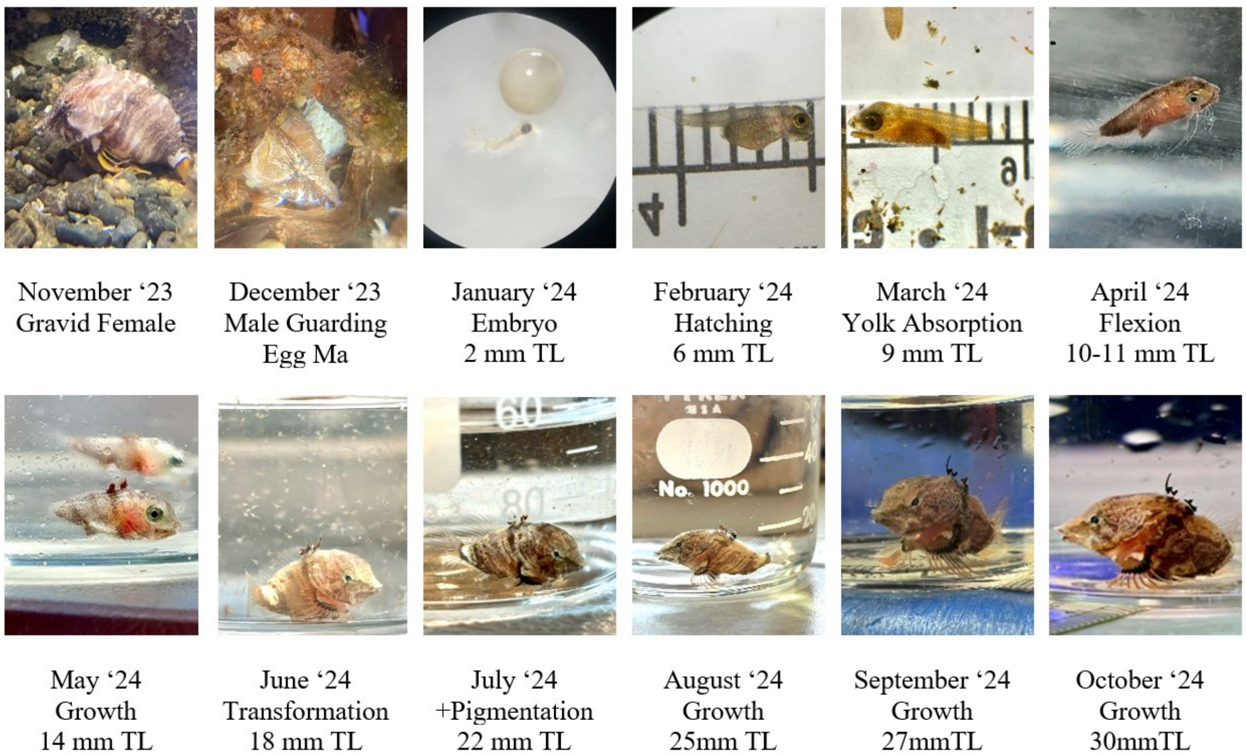

Figure 5. A Year in the Life of Grunt Sculpin. Lengths were taken from randomly selected individuals each month.

moved to a closed system.

MaST staff found two diagrams of larval grunt sculpin developmental stages (Saruwatari, 1986; Alaska Fisheries Science Center, 2021) during the initial literature review, and these were used as comparisons throughout development. Photos were also taken throughout the development process to create a similar timeline for future use. The following are selected photos during this process that best represent the milestones of each month. In total, over 2,000 photos and videos were taken.

Results

Of a total of 148 hatchlings, 11 survived to recruitment, which began at 5 months post-hatch. Data collected include written, photo, and video observations, weekly temperature and salinity, hatch event observation, daily deaths/removals tally, and daily estimated living

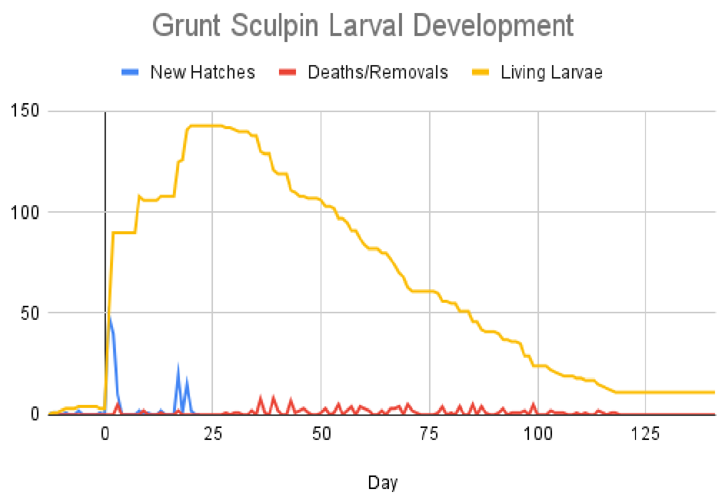

Figure 6. : Grunt Sculpin Population from the first hatching event to recruitment (150 dph).

population. While this number was lower than desired, the information that has been gathered throughout the year-long process will be invaluable for future grunt sculpin and other larval rearing pursuits at the MaST Center Aquarium. As visible in the chart, there were multiple hatching events over the course of approximately 2 weeks. Complete yolk sac absorption took approximately 30 days, which limited early die-off. Rotifers were offered early, within the first few days of hatching, and evidence of feeding was seen approximately a week post-hatch.

Microorganisms were observed sporadically on dead individuals between days 50-85, but increases in water changes seemed to solve that issue. After nearly 2 months of a stable population of 11 (170 dph), a ciliate outbreak occurred, and 6 individuals were lost in two days. Based on microscope ID, ciliates were determined to be scuticociliates, and staff treated with 10 days of Metroplex™ (SeaChem®), added daily after water changes. After the treatment concluded, the five remaining fish were moved from the open system aquarium into a newly acquired chilled, closed system and temperatures were brought down to 52 degrees Fahrenheit. Fish reached 1-inch total length at 190 dph.

These microorganisms were associated with three more deaths at 204 dph, even with the decreased temperature. This time, deaths were noticed within 3 hours of the first, and symptoms included sporadic swimming, loss of equilibrium, and heavy breathing. Interestingly, a necropsy on one of the recent deceased (<1 hour post-mortem), there were less than 10 ciliates seen within the fish, so while they likely played a part, it is inconclusive whether they ultimately caused this mortality event. As of October 1st, 2024, 2 fish remain of the original cohort, and are approximately 29 mm in total length.

Discussion

While this case study successfully collected data and establishing a baseline of grunt sculpin development, this project was not without significant setbacks. Due to space constraints, the larvae rearing tank design was small, which required diligent attention to water changes and frequent fouling. As the water source for the aquarium is raw seawater, even fine mesh does not remove all microorganisms. During both the egg and larval development, microorganisms (including opportunistic copepods, sessile rotifers, and ciliates) were associated with mortalities.

Culturing a species with a prolonged planktonic stage proved a challenge that resulted in trial and error. The small, air driven upwelling tanks functioned well, but improvements are planned to increase survival of future egg batches. This year of information will provide a base timeline that will be used in planning the next batch of grunt sculpin larvae should the parents produce eggs again in Winter 2025.

Using a mixture of rotifers and brine shrimp proved to be a successful diet for the larvae, and the supplementation with RGComplete™, Selco®, and GarlicGuard™ improved steady growth patterns, based on staff's written notes.

The closed, chilled system that staff acquired after the first ciliate outbreak will likely become the home for larval rearing projects in the future. While the open system at MaST is beneficial for seasonal invertebrate recruitment and feeding the diverse collection of filter feeders, the microorganisms that can build up in small, closed systems quickly became an issue.

Figure 7. Father grunt sculpin with offspring, 143 dph.

The MaST Center Aquarium is an open system, and while natural events (seasonal recruitment, mating cues, etc.) occur in tandem with the local Puget Sound ecosystem, staff are unable to release any organisms without extensive permitting. As such, these fertilized eggs resulted in an incredible learning opportunity for staff and volunteers alike. As this was the first larval fish rearing attempt at the MaST Center Aquarium, in addition to the species' extended planktonic stage and space constraints, it yielded a high hatch rate but low long-term survival rate. If eggs are produced in the future, staff will be able to take what they have learned to increase the long-term survival rate, and hope to provide a source of grunt sculpin for partner aquariums in Washington state, lessening collection pressures off wild populations.

Lessons Learned:

In summary, here are a few key takeaways:

- Small, non-commercial coldwater fish, such as Grunt Sculpin, often have minimal information available online about their life history and early development.
- While sources pointed to a development timeline of 16-20 weeks, MaST grunt sculpin eggs hatched between 11 and 13 weeks after spawning. Whether that is normal for this part of their geographic range or due to conditions specific to this case remains to be determined.
- Filtering raw seawater with 40-micron mesh for the initial air driven upwelling tanks minimized but did not eliminate fouling or small microorganisms.
- After adding 1-2 drops of GarlicGuard™ to the supplements in daily feeds in week 18, there were no deaths until the scuticociliate outbreak 7 weeks later. Whether this is a

correlation or causation is unknown, but supports the benefits of low garlic levels (Delgado, 2023) in aquatic animal diets.
- While time consuming, larval rearing of more obscure fish species, like Grunt Sculpin, is a rewarding learning opportunity.

Acknowledgements

I would like to thank the MaST Center Aquarium staff for supporting this project throughout its duration, and give additional recognition to Lily Gray, MaST's part time aquarist, who provided secondary animal care coverage on this project. I would also like to thank aquarists that were kind enough to share information, brainstorm and review, including (but not limited to): Sid Stetson (Hatfield Marine Science Center), Trevor Erdmann (HMSC), Jamie Hart (HMSC), Ali Redman (Port Townsend Marine Science Center), Tamara Galvan (Feiro Marine Life Center), and the aquarist teams at the Shaw Center for the Salish Sea and the Padilla Bay National Estuarine Research Reserve.

About the MaST Center Aquarium

The MaST Center Aquarium is located in Des Moines, Washington, about 30 minutes south of the SeaTac Airport. It is the marine lab, classroom, and public community aquarium for Highline College, and open to the public on Saturdays from 10-2pm.

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Coelacanth, Bruce Koike

A KRAKEN BY ANY OTHER NAME… NOTES ON RECENT CHANGES IN CEPHALOPOD TAXONOMY

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Introduction

In 2001, the late Dr. Roland Anderson of the Seattle Aquarium penned a note for this journal to make aquarists aware that the giant Pacific octopus had recently had its name changed from *Octopus dofleini* to *Enteroctopus dofleini*. While some may see these changes as merely academic, they do bear importance, not only so that our graphics may reflect the current scientific thinking, but also so that aquarists are aware of the relevance of new studies as they are published. Nomenclature is also tied to the conservation status of a species, making it important to keep up with changes. Practicing husbandry through ecology is a cornerstone for aquarists and is especially important to continually refine husbandry and management practices utilizing the most current information available.

While taxonomy is always in flux, recent years have seen substantial changes to the taxonomic status of a number of cephalopods, including many species commonly displayed in North American public aquaria. Some of the pertinent changes from recent years are detailed herein.

Nautiloids

Family Nautilidae includes all extant species of nautiluses which are in one of two genera: *Allonautilus* or *Nautilus*. The once ubiquitous species, *Nautilus pompilius*, was once applied to most populations of nautiluses but has been refined recently. Nautiluses inhabiting the island nations of American Samoa, Fiji, and Vanuatu, which are geographically separated by deepwater (Fig. 1), were recently described as the new species *N. samoaensis*, *N. vitiensis*, and *N. vanuatuensis*, respectively. While these updates do not impact the Appendix II listing of nautiluses under the Convention on International Trade in Endangered Species (CITES), they would impact future import and export of the species. Of particular note here, is the difference in shell pattern/color between the new species (Fig. 1) and other nautiluses.

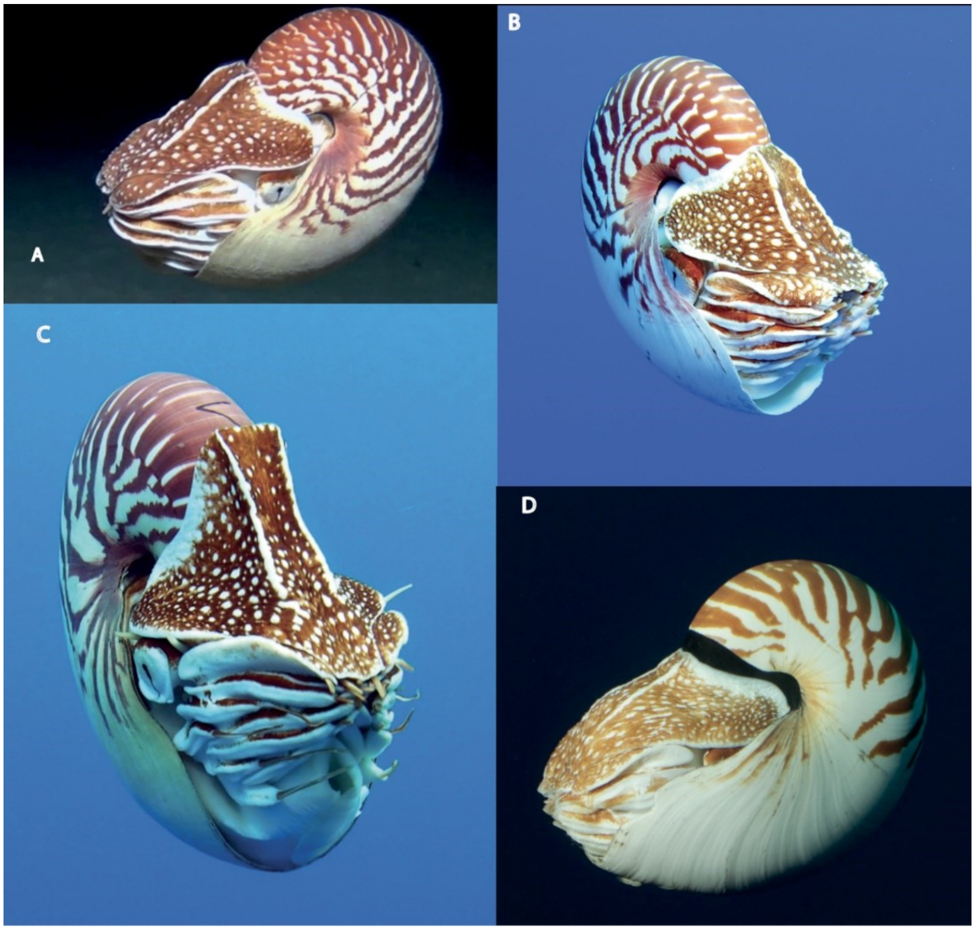

Figure 1. Lateral underwater photos of the new species, *Nautilus samoaensis* (A,B), *N. vanuatuensis* (C), and *N. vitiensis* (D). from Barord et al. (2023) [Figure reproduced here from Barord et al. 2023]

Cuttlefishes

The cuttlefish complex of *Sepia* has been updated, and truly broken apart based upon the most recent genetic analyses of Lupše et al. (2023). The genus *Sepia* now includes just a few species, and most notably retains *Sepia officinalis* as the type specimen. Four other common aquarium species once classified as *Sepia* are now described as *Acanthosepion pharaonis*, *Ascarosepion apama, A. bandense*, and *A. latimanus* (Table 1). Additionally, the genus *Metasepia* has been completely rejected with the two species now being described as *Ascarosepion pfefferi* and *A. tullbergi*.

Squids (The Artist Formerly Known as *Loligo*)

Few true squids are displayed routinely in aquaria, however the California market squid, *Loligo opalescens* is a very common seafood item in the diets of captive animals. In 1998, Vecchione et al. revised the family and *L. opalescens* became *Doryteuthis opalescens*. The genus has been further revised (Jereb and Roper, 2010) and split into two subgenera, as such the species is often seen as *Doryteuthis (Amerigo) opalescens* in the current literature. Despite the change in name, the authors find no change in their deliciousness when battered and fried as calamari.

Table 1. Summary of Recent Cephalopod Taxonomy Changes Among Species Kept in Public Aquaria

Old Binomial	New Binomial	Range	Reference
Nautiluses			
Nautilus pompilius	*Nautilus pompilius*	Indonesia, Philippines, Papua New Guinea, Thailand	Nikolaeva et al., 2018
Nautilus pompilius	*Nautilus vitiensis*	Fiji	Barord et al., 2023
Nautilus pompilius	*Nautilus samoaensis*	American Samoa	Barord et al., 2023
Nautilus pompilius	*Nautilus vanuatuensis*	Vanuatu	Barord et al., 2023
Squids			
Loligo opalescens	*Doryteuthis opalescens*	Alaska to Mexico	Jereb and Roper, 2010
Cuttlefishes			
Sepia officinalis	*Sepia officinalis*	Mediterranean, Japan to Australia, Andaman Sea to Indian Ocean, Persian Gulf to Red Sea	Linnaeus, C., 1758*
Sepia pharaonis	*Acanthosepion pharaonis*	Red Sea	Lupše et al., 2023
Sepia apama	*Ascarosepion apama*	Australia	Lupše et al., 2023
Sepia bandensis	*Ascarosepion bandense*	Philippines to Australia	Lupše et al., 2023
Sepia latimanus	*Ascarosepion latimanus*	Japan to Australia	Lupše et al., 2023
Metasepia pfefferi	*Ascarosepion pfefferi*	Philippines to Australia	Lupše et al., 2023
Metasepia tullbergi	*Ascarosepion tullbergi*	Japan to Philippines	Lupše et al., 2023
Common Octopus Species Complex			
Octopus vulgaris	*Octopus vulgaris*	Mediterranean	Avendaño et al., 2020
Octopus vulgaris Type I	*Octopus americanus*	Canada to Argentina	Avendaño et al., 2020
Octopus vulgaris Type II	*Octopus insularis*	Antilles, Venezuela to México	Leite et al., 2008
Octopus vulgaris Type III	*Octopus vulgaris Type III*	Namibia to Mozambique	Norman et al., 2014
Octopus vulgarisType IV	*Octopus sinensis*	Japan to Shanghai	Gleadall, 2016
Octopus vulgaris	*Octopus maya***	México: Yucatan Peninsula	Voss & Solís-Ramírez, 1966
Octopus vulgaris	*Octopus tetricus***	Australia	O'Shea, 1999
Octopus vulgaris	*Octopus taganga*	Colombia	Guerrero-Kommritz et al., 2016
Giant Pacific Octopus			
Enteroctopus dofleini	*Enteroctopus dofleini*	Japan to California	Hollenbeck & Scheel, 2017
Enteroctopus dofleini	*Enteroctopus sp. aff.****	Alaska	Hollenbeck & Scheel, 2017

**Original description by Linnaeus, 1758 confirmed by Lupše et al., 2023*

***Species not redescribed or changed, per se, but part of O. vulgaris species complex*

****Genetically and morphologically distinct species noted, full description forthcoming*

The *Octopus vulgaris* Species Complex

The common octopus, *Octopus vulgaris,* has long been assumed to have a cosmopolitan worldwide distribution in tropical to temperate waters, and was by default considered the ubiquitous octopus occurring worldwide. Norman et al. (2014) noted that the broadly distributed species, as it was then known, was uncertain, and proposed four distinct population segments based on geography as follows:

O. vulgaris Type I – Tropical Western Atlantic
O. vulgaris Type II – Subtropical Southwestern Atlantic
O. vulgaris Type III – Southern Africa and Indian Ocean
O. vulgaris Type IV – Temperate Asia and Australia

Octopus maya had been known from the 1960's from the Campeche and Yucatan coasts of México (Voss and Solis-Ramírez, 1966). In 1999 O'Shea separated the New Zealand octopods as *Octopus gibbsi*, later revised to be *Octopus tetricus*. In 2008, *Octopus insularis* was found to be a cryptic species within *O. vulgaris* in parts of the Caribbean and South America (Leite et al.). In 2016, Guerrero-Kommritz et al. described *Octopus taganga* from Colombia and that same year Gleadall established *Octopus sinensis* as a valid species in Asia. These are summarized in Table 1, and ranges illustrated in Figure 3.

The taxonomic confusion was sorted out by Avendaño et al. in 2020 which clarified the state of the *O. vulgaris* species complex, including all of the species and morphotypes listed above. Avendaño et al. (2020) established seven distinct species, largely separated by geography (see Fig. 3). In this work, *O. tetricus* and *O. cf. tetricus* are separated in Australia, and *O. vulgaris* Type III is retained (Avendaño et al., 2020); these designations may result in additional species described and added to the *O. vulgaris* species complex in the future. Most importantly, the older name *Octopus americanus* was resurrected for species in North America extending to Brazil, meaning there is considerable overlap in range of *O. americanus* and *O. insularis* in the lower Caribbean and South America.

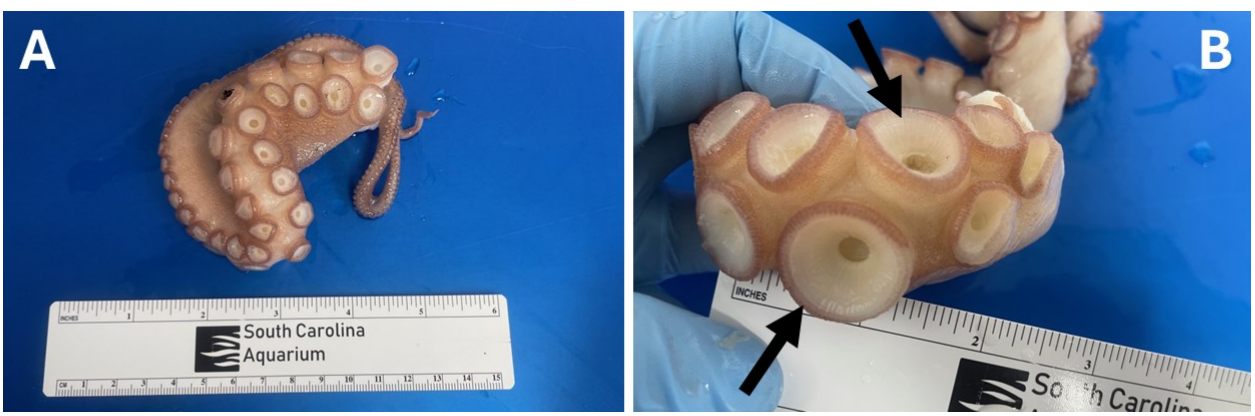

Figure 2. Arm morphology of *Octopus americanus*, following Avendaño et al. (2020) morphological characteristics may be used to differentiate *O. americanus* from *O. insularis*. The former has 224-258 suckers per arm, the latter 220-238, among other features. The specimen pictured (A) from South Carolina had 244 suckers per arm. Note the enlarged suckers (B), in *O. americanus* these are present on the 7^{th} and 8^{th} proximal row in males, and in *O. insularis* these are present on the 8^{th} and 9^{th} proximal row (Avendaño et al., 2020). Note also the distinct lack of colored patches on the ventral arm (A), characteristic of *O. americanus* (O'Brien et al., 2021).

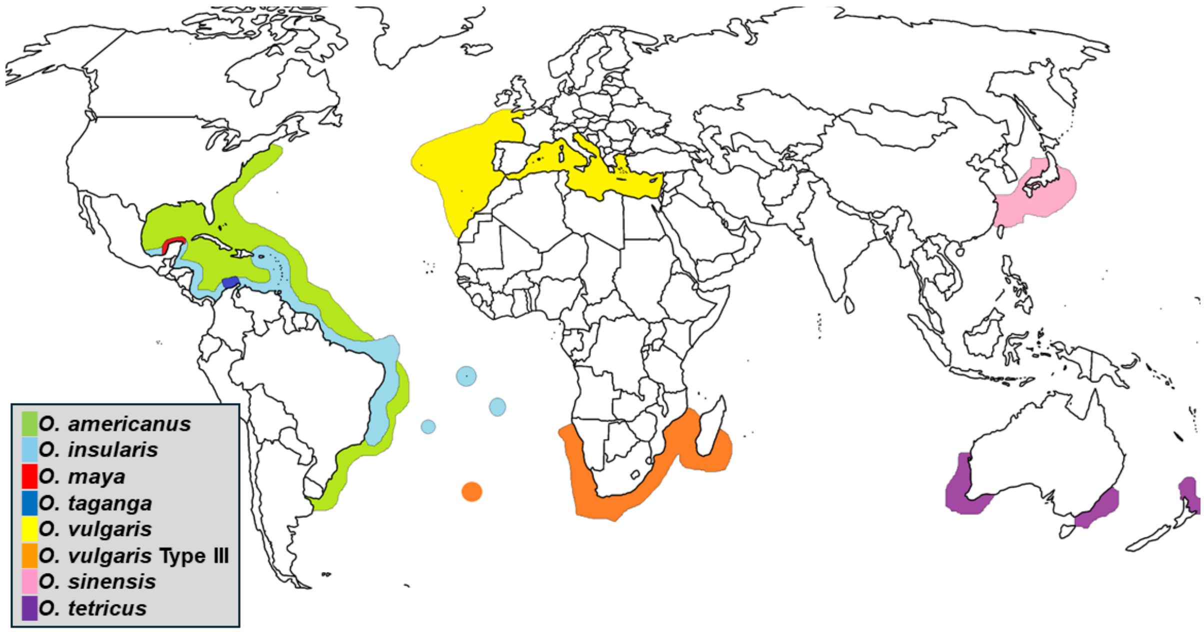

Figure 3. Distribution of members of the *Octopus vulgaris* species complex, re-drawn from Avendaño et al. (2020). Recently, *O. vulgaris* has been split into multiple species and no longer occurs in the western Atlantic, having been replaced by *Octopus americanus* and *Octopus insularis* throughout most of its former new world range. Note that this map is a simplified version for the aquarist and omits some of the variation within *Octopus sinensis* and *Octopus tetricus*. See the original reference for a more detailed account of the distribution of these species.

What does this mean for the aquarist? The major implications for aquarium specimens are that wild-caught animals from the Mediterranean and Eastern Atlantic are the only ones which are truly *O. vulgaris*, and new world species vary, as *O. vulgaris* does not occur in the Western Atlantic. Specimens collected in the Caribbean or South America may be either *O. insularis* or *O. americanus*, and animals from the Gulf of Mexico (north of the Yucatan peninsula), Northern Caribbean, and Eastern United States are *O. americanus*.

If in doubt between *O. americanus* and *O. insularis*, morphological characteristics are described in detail in Avendaño et al., 2020, and a field guide to distinguishing the species was published by O'Brien et al. (2021). In living specimens, dark ventral patches on the arms are characteristic of *O. insularis* (O'Brien et al., 2021). When deceased specimens may be examined closely, the sucker counts (224-258 for *O. americanus*, 220-238 of *O. insularis*), ratio of mantle size to sucker width (10.0-10.8 *O. americanus*, 8.0-14.0 *O. insularis*), and the position of enlarged suckers in males (proximal row 7/8 *O. americanus*, row 8/9 *O. insularis*) are useful to distinguish the species (Fig. 2), among other morphological characteristics (Avendaño et al., 2020).

Frilled Giant Pacific Octopus

A few years before the pandemic, a landmark paper was published that changed our understanding of the giant Pacific octopus (GPO), *Enteroctopus dofleini* as a species. Hollenbeck and Scheel (2017) described a novel species from Alaskan waters that had been cryptic within the GPOs and termed it the frilled giant Pacific octopus. Morphological differences (notably a lateral frill of tissue along the mantle below which no papillae exist ventrally) exist between this new species and the GPO. The new morphotype was also found to be genetically distinct (Hollenbeck and Scheel, 2017), though a name was not assigned to this new species by the authors. As a scientific name has yet to be established, the species is denoted as *Enteroctopus sp. aff.* in Table 1. The extent of the range of this new species has yet to be determined, but as the vast majority of living specimens in North America come from British Columbia these can be assumed to be *E. dofleini*, and aquarists keeping them should be aware that a second, as yet unnamed, species exists in Alaskan waters.

"The only constant in life is change" **-Heraclitus**

Acknowledgements

Thanks to Dr. Álvaro Roura for correspondence on the state of *O. vulgaris* taxonomy and guidance on the differences between new world species. Thanks to Shannon Howard, Laura Buker, and Whitney Daniel of the South Carolina Aquarium for collecting octopods and preserving material after necropsy for speciation.

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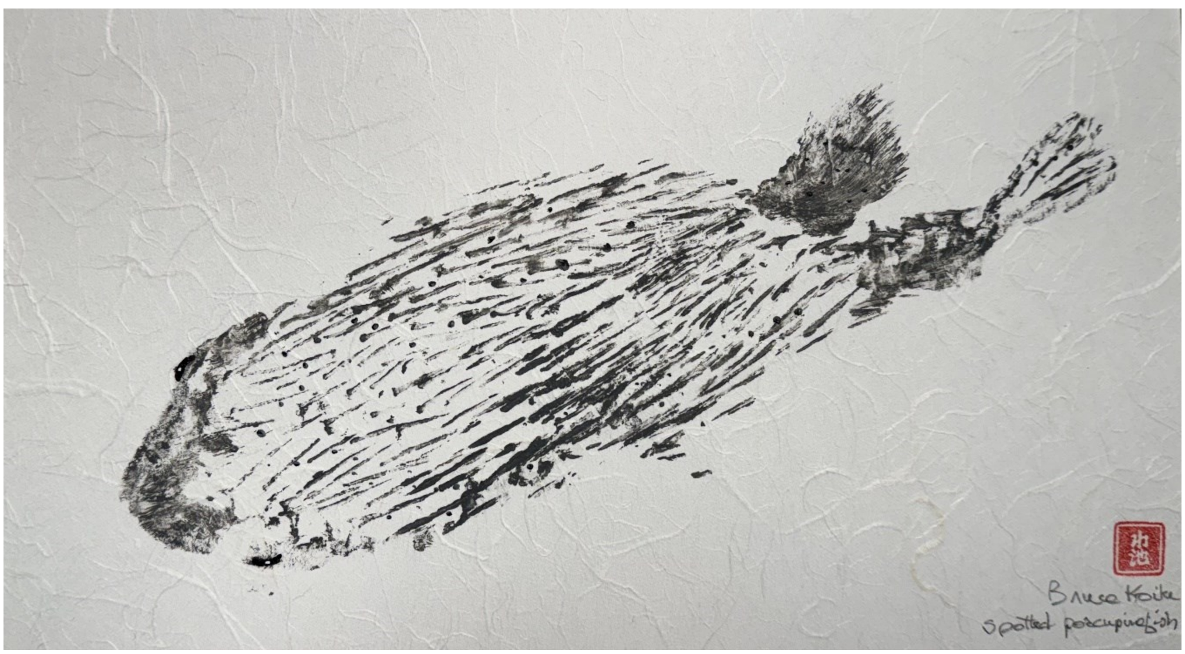

Spotted Porcupine Fish, Bruce Koike

"THE MAGNIFICENT BUTTERFLYFISH", *Prognathodes falcifer*: A TIMELINE OF ITS CONNECTION AND HISTORY WITH SCRIPPS INSTITUTION OF OCEANOGRAPHY AND BIRCH AQUARIUM AT SCRIPPS

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Introduction

On November 16, 1954, the first Scythe Butterflyfish, *Prognathodes falcifer*, was collected, making 2024 the 70th anniversary of the discovery, by Scripps Institution of Oceanography (SIO), of this this new species of fish. On November 16, 1970, exactly 16 years later, Scripps divers collected a live Scythe Butterflyfish that was displayed for the first time at Scripps Aquarium (now Birch Aquarium at Scripps) or possibly any aquarium. Birch Aquarium at Scripps (BAS) has displayed this species since 1970. Its striking appearance, its discovery by SIO scientists, and it being displayed solely for many years at SIO's very own public aquarium (BAS) led this fish to be the Aquarium's emblem/logo for decades.

Other than one or two specimens that might reside in private hobbyist aquariums, our current pair, collected in 1999 by BAS staff, are believed to be the only Scythe Butterflyfish on display at any public aquarium. Outside of captivity SCUBA divers occasionally observe them most commonly off Santa Catalina Island, CA. Several individuals who were directly involved in bringing this fish to the scientific community and to the public are no longer with us. The author was fortunate to know and work with some of them and had the opportunity to interview one of the collector's first-hand experience collecting and displaying the 1970 specimen.

Prognathodes falcifer (*Chaetodon falcifer* Hubbs and Rechnitzer 1958) is a temperate to tropical species of butterflyfish in the family Chaetodontidae (Fig. 1). *Falcifer*, Latin for sickle or scythe bearing describes its black scythe-shaped marking which overlays its yellow and white body. Along with its vibrant colors, its pronounced snout and prominent dorsal spines, typical within the genus *Prognathodes,* make it a striking fish and its first collector accordingly called it a "magnificent butterflyfish" (Hubbs and Rechnitzer, 1958).

Inhabiting cooler waters off the coast of Southern California in the most northern part of its range to the tip of Baja California, Mexico, and slightly south off mainland Mexico, it is seldom seen in the wild and is rare in public aquariums. This species is found in greater depths of 90-150 m (Robertson and Allen, 2024) in the southern part of its range.

Because of its rarity in the northern part of its range, it is understandable that this fish is not commonly seen by divers or collected for public aquarium display. Adding to the difficulty of collection, much effort and time is required to obtain a permit to collect in Mexico where Scythe Butterflyfish are more abundant.

Figure 1. Male Scythe Butterflyfish currently displayed in a 5,300L exhibit at Birch Aquarium at Scripps. This specimen along with the female were collected by aquarium staff in 1999.

1954. The Very first Scythe Butterflyfish Collection

Seventy years ago, Dr. Carl Hubbs, ichthyologist with Scripps Institution of Oceanography, led a team of 13 researchers to Guadalupe Island, Mexico. The mission was to collect, identify, and describe the endemic fishes inhabiting the waters around Guadalupe Island which is approximately 1/3 of the way down and roughly 240 km west of the Baja California peninsula.

One of the six SCUBA divers on the team was Andreas Rechnitzer, a graduate student of Carl Hubbs (see Fig. 2). On Nov. 16, 1954, Rechnitzer dove along a vertical wall of rocky reef to a depth of approximately 6 m, but cloudy water made for poor visibility and difficulty finding a targeted species. Rechnitzer then dove deeper into clearer water and at approximately 30 m, under a ledge and 0.3m above the sandy bottom, he caught sight of a "magnificent butterflyfish" which he was able to spear. This specimen was the first Scythe Butterflyfish ever collected and came to be the holotype for the species. This was the sole Scythe Butterflyfish observed during the expedition although "six divers with self-contained underwater breathing apparatus were underwater much of the time during seven consecutive days" (Hubbs and Rechnitzer, 1958).

Figure 2. Scripps Divers at Guadalupe Island in 1954. (Left to right) James Stewart (former SIO Dive Safety Officer), Andreas Rechnitzer, Chuck Fleming (marine technician), Johnny Carter, Tom Thies (UDT), Earl Murray (SIO Shore Processes Lab). Photo courtesy of UCSD Digital Library.

1958. Hubbs and Rechnitzer Describe a New Species

In 1958 Carl Hubbs and Andrew Rechnitzer described the Scythe Butterflyfish in their paper "A New Fish, *Chaetodon falcifer*, from Guadalupe Island, Baja California, With Notes on Related Species." The holotype, CAS 20734, is maintained at the California Academy of Sciences in San Francisco (Frable, pers. comm). Their paper contrasts this new species to other chaetodontids in the area; *C. humeralis* (Gunther 1860*),* and *Johnrandallia nigrirostris*, (*C. nigrirostris* Gill 1862) which differ greatly in appearance. They also concluded that this species "is not a stray from the present Indo-Pacific fauna." Instead, they found many shared characters with *C. aya* and *C. marcellae* from the Atlantic. Furthermore, it was thought that it would be "improbable" that this species would occur further south along Mexico's mainland given the number of research collecting trips that had taken place prior to their own expedition (Hubbs and Rechnitzer, 1958). However, deeper submarine and SCUBA dives at Cabo San Lucas, Mexico, in the following years, revealed that there was an "abundance" of this species.

1965. Dr Rosenblatt's Observations

In 1965, SIO ichthyologist, Dr. Richard Rosenblatt, a former student of Dr. Boyd Walker, UCLA, and of Dr. Carl Hubbs, and who eventually succeeded Dr. Hubbs, dove in Jacques Cousteau's "Diving Saucer" (SP-350 Denise, Fig. 3) at the tip of Cabo San Lucas, Mexico. Wilkie (1970), Scripps Aquarium Director at the time, stated that Dr. Rosenblatt found this species in abundance between 60-90 m. Allen (1979) comments on Rosenblatt's same observations, stating Rosenblatt observed this species inhabiting rocky areas from depths of 30-150 m, but the greatest concentration was observed at about 100 m. Allen (1979) also stated that Scythe Butterflyfish observations have been made in waters as shallow as 10-13 meters at Galapagos and Santa Catalina Island where water temperatures ranged from 16-20°C.

Figure 3. Possibly the same submarine Dr. Richard Rosenblatt dove in 1965. The Jacques Cousteau diving saucer, equipped with a grabber/manipulator, cameras, headlights and underwater jets. The oxygen tank could support two persons for up to 24 hours. Photo: Jimmy Stuart, courtesy of UCSD Digital Library.

1967. David Powell and Robert Kiwala's Collection

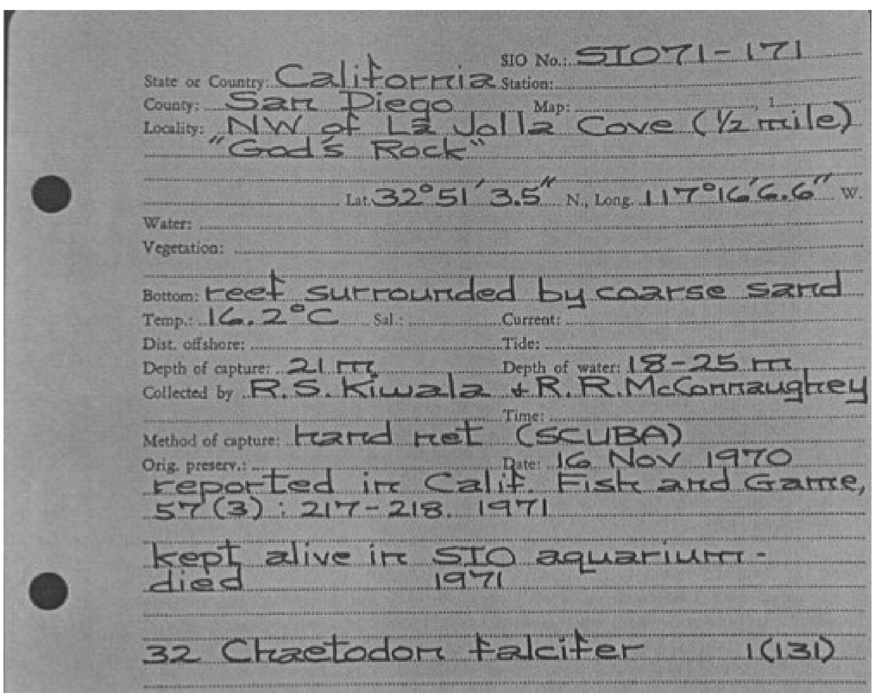
In 1967 David (Dave) Powell, then Curator of SeaWorld, San Diego, organized a collecting trip to Baja California, Mexico and was joined by Robert (Bob) Kiwala, Scripps Aquarium Collector. At their Cabo San Lucas dive site, Bob and Dave dove to a depth of approximately 56 m where Bob successfully netted a Scythe Butterflyfish (Powell, 2001). While ascending to the surface Bob used a hypodermic needle to carefully deflate the fish's gas bladder, relieving the expansion that would have occurred otherwise. This was the "first living specimen" collected (Wilkie, 1985) and flown back live to Scripps Aquarium. However, Bob and Dave discovered that Dr. Rosenblatt had preserved the fish for research because it was a rare opportunity for study. More about this story can be found in "A Fascination for Fish" (Powell, 2001). A photo of this fish and the first color photo of this species, taken by Dave Powell, was published in "*Butterfly and Angelfishes of the World*" (Allen, 1979).

As a side note, in a 1970 UC San Diego press release Wilkie mentions "…it was Bob Kiwala who captured one at 175 feet (~53m) as he was skin diving" referring to the 1967 collection of the Scythe Butterfly fish at Cabo San Lucas. Powell's description which doesn't specifically mention SCUBA diving, does mention making multiple deep dives using the buddy system and the possible "euphoric effects of nitrogen narcosis". The term "skin-diving", in Wilkie's press release, was used interchangeably with SCUBA diving in the early days of SCUBA and not indicative of "free diving" (McDonald, pers. comm.).

1970. Ronald (Ron) McConnaughey and Robert (Bob) Kiwala La Jolla, CA Collection

On November 16, 1970, exactly 16 years after the very first Scythe Butterflyfish was collected by Andy Rechnitzer, Bob Kiwala (Scripps Aquarium Collector) and Ron McConnaughey (Scripps Research Technician) spotted a Scythe Butterflyfish at a rocky reef, "God's Rock" at 21m (see Fig. 4), west of La Jolla Cove (San Diego, CA). Bob Kiwala was able to collect this specimen and successfully bring it to the surface. This fish was the first live Scythe Butterflyfish displayed at the old Scripps Aquarium and possibly the first displayed at any aquarium in the world! The collection of this fish caught the attention of several local newspapers (see Fig. 5) and seemed to have a great impact on the Aquarium's identity. Sam Hinton, former Curator of Scripps Aquarium (1946-1964), included his drawing and short description of the Scythe Butterflyfish in a series of newspaper articles, entitled "The Ocean World" (see Fig. 6). In the following years Scripps Aquarium would adopt the Scythe Butterflyfish as its logo.

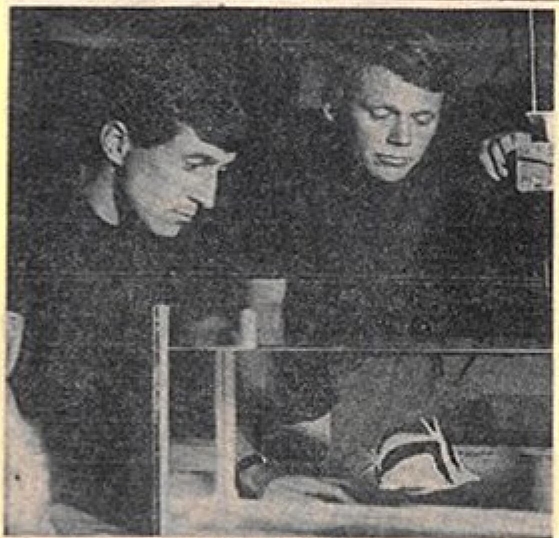
In a phone conversation with the author, Ron McConnaughey described how the fish was captured, paraphrased here: "while SCUBA diving at God's Rock, Bob (Kiwala) had spotted a Scythe Butterflyfish. Bob tried to alert me by making sounds through his regulator and even by writing "Chaetodon" in the sand, but I had no clue what Bob was trying to convey. I eventually spotted the fish and both of us attempted to net it. When we tried to net the fish, it would swim into a cave which ended up having another opening. We waited at both ends of the cave trying to catch it. It would quickly swim back and forth when it noticed a net was waiting at the other end. It may have looked like we were playing tennis underwater! Eventually, Bob was able to net the fish. I swam back up to the boat where we kept a hypodermic needle in a dry box. Bob was able to bleed gas from the fish's gas bladder as we ascended." After its death, this fish was preserved at SIO's Marine Vertebrate Collection (see Fig. 7 and 8).



SIO No.: SIO71-171
State or Country: California Station:
County: San Diego Map:
Locality: NW of La Jolla Cove (½ mile) "God's Rock"
Lat. 32°51′3.5″ N., Long. 117°16′6.6″ W.
Water:
Vegetation:
Bottom: reef surrounded by coarse sand
Temp.: 16.2°C Sal.: Current:
Dist. offshore: Tide:
Depth of capture: 21 m Depth of water: 18-25 m
Collected by R.S. Kiwala + R.R. McConnaughey
Time:
Method of capture: hand net (SCUBA)
Orig. preserv.: Date: 16 Nov 1970
reported in Calif. Fish and Game, 57(3): 217-218. 1971
kept alive in SIO aquarium - died 1971
32 Chaetodon falcifer 1(131)

Figure 4. The collection form with date and location of the 1970 Scythe Butterflyfish collected by Bob Kiwala and Ron McConnaughey.

THE SENTINEL
THURSDAY, NOVEMBER 26, 1970



RARE DENIZEN
Now on display at Scripps Institution of Oceanography's Vaughan Aquarium-Museum, this scythe butterflyfish—note marking on side—is observed by Robert S. Kiwala, left, Scripps scientific collector, who caught fish in 60 feet of water in La Jolla Canyon, and Ronald R. McConnaughey, marine technician and driver, who spotted it.

Rare butterflyfish displayed at Scripps

A scythe butterflyfish —a species never before seen in local waters — has been taken in La Jolla Canyon, off La Jolla, and is now on display at the Vaughan Aquarium-Museum at UCSD's Scripps Institution of Oceanography.

This marks the first time the species has been recorded from the California mainland, Donald W. Wilkie, aquarium-museum director, said.

The six-inch, bright yellow specimen has a striking scythe-shaped black marking on its side that gives rise to the common and scientific name, Chaetodon falcifer, by which it is known, Wilkie said.

The specimen is displayed in Tank 15, the Farnsworth Bank (Catalina Island) exhibit of the aquarium.

Ronald R. McConnaughey, Scripps marine technician and diver, spotted the specimen, which was caught by the aquarium scientific collector Robert S. Kiwala in some 60 feet of water.

"The only other similar specimen taken in California was collected with a spear at 40 feet off Catalina Island," Wilkie said.

To our knowledge, our specimen marks only the 10th ever caught and the first of the species ever to be displayed.

"It is a beautiful example of a fish that lives in deep water in the warmer part of its range and can inhabit surface waters at the cooler extremes of its distribution.

"Although most butterflyfishes are tropical, shallow-water species, the scythe butterflyfish belongs to a small group that normally lives in deep water.

"Since it is adapted to a lower temperature range than its surface-dwelling cousin, it is not completely surprising to find it extend-

ature waters of Southern California where the surface-water temperatures approximate the deep-water temperatures of the tropics."

Wilkie said the discovery of the species is of historical interest.

He said the species was first discovered in 1954 near Guadalupe Island, off Baja California, by Dr. Andreas Rechnitzer, then a student of Dr. Carl L. Hubbs, now professor emeritus of marine biology. The species was named and described by both men in 1958.

"In 1965, the species was discovered in abundance at depths of 200 to 300 feet at Cape San Lucas, off the tip of Baja California, by Dr. Richard H. Rosenblatt, curator of fishes at Scripps, as he was diving in the Cousteau diving saucer," Wilkie said.

"No other specimens were collected at the cape until 1967, when, oddly enough, it was Bob Kiwala who captured one at 17 feet as he was skin diving.

"Bob removed the air from the fish's swim bladder with a hypodermic needle and successfully brought it alive to the surface.

"That same year another specimen was discovered and taken dead, in shallow, relatively cold water in the Galapagos Islands area."

The Scripps Aquarium-Museum is open daily to the public at no charge, from 9

Figure 5. Newspaper clipping from 1970 showing the Scythe Butterflyfish Bob Kiwala and Ron McConnaughey collected off the coast of La Jolla, CA. This was one of several newspaper articles that got the attention of local media.

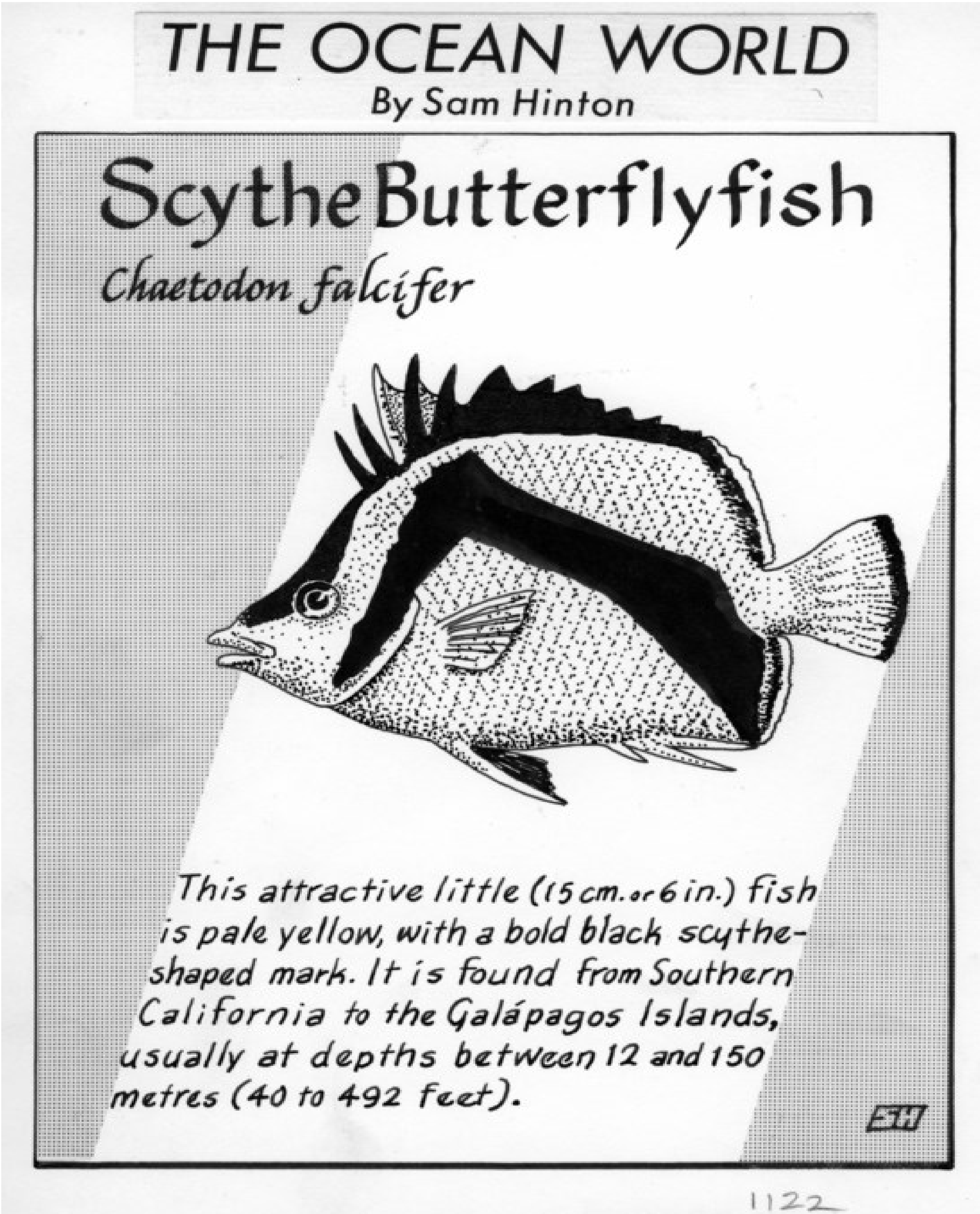


Figure 6. Sam Hinton's drawing and notes about the Scythe Butterflyfish in "The Ocean World" series of articles in a San Deigo, CA newspaper. Courtesy of UCSD Digital Library.

Figure 7. CT scan of the 1970 Scythe Butterflyfish collected by Kiwala and McConnaughey.

1971. McConnaughey and Kiwala's Published Article

In a California Fish and Game journal, Ron and Bob share their experience in "A Second Record of the Scythe Butterflyfish, *Chaetodon falcifer*, From California" (McConnaughey and Kiwala, 1971). They describe the collection site, depth, water temperature, and environment. They also mention that in between Rechnitzer's collection in 1954 and their collection in 1970, only seven other specimens were recorded (Freihofer in McConnaughey and Kiwala, 1971). They further state that although many dives have been made in the La Jolla area by SIO personnel, this was the only individual seen and they conclude that "it seems most likely that both individuals represent strays, and that California is not within the primary range of the species" and "it is probable that the shallower occurrences of the species at the limits of the range represent poleward emergence of a deeper-water tropical form" (McConnaughey and Kiwala, 1971).

A photo of the fish collected in 1970 appears on the cover of the 1972 Scripps Aquarium Newsletter. It's unknown exactly when, but sometime near 1980 is the period when the Scythe Butterflyfish became Scripps Aquarium's official logo (Snodgrass and Wilkie, 1985). The fish's photo and image appeared in a number of publications, staff polo shirts, t-shirts, stickers, and other items including post cards and a holiday card. Former BAS Director, Donald Wilke stated "…this fish became the emblem of the Scripps Aquarium; you will find depicted in the logo on all aquarium publications" (Snodgrass and Wilkie 1985, see Fig. 9 and 10).

Figure 8. Ben Frable, SIO Marine Vertebrate Collection Manager holding the preserved Scythe Butterflyfish collected by Bob Kiwala and Ron McConnaughey.

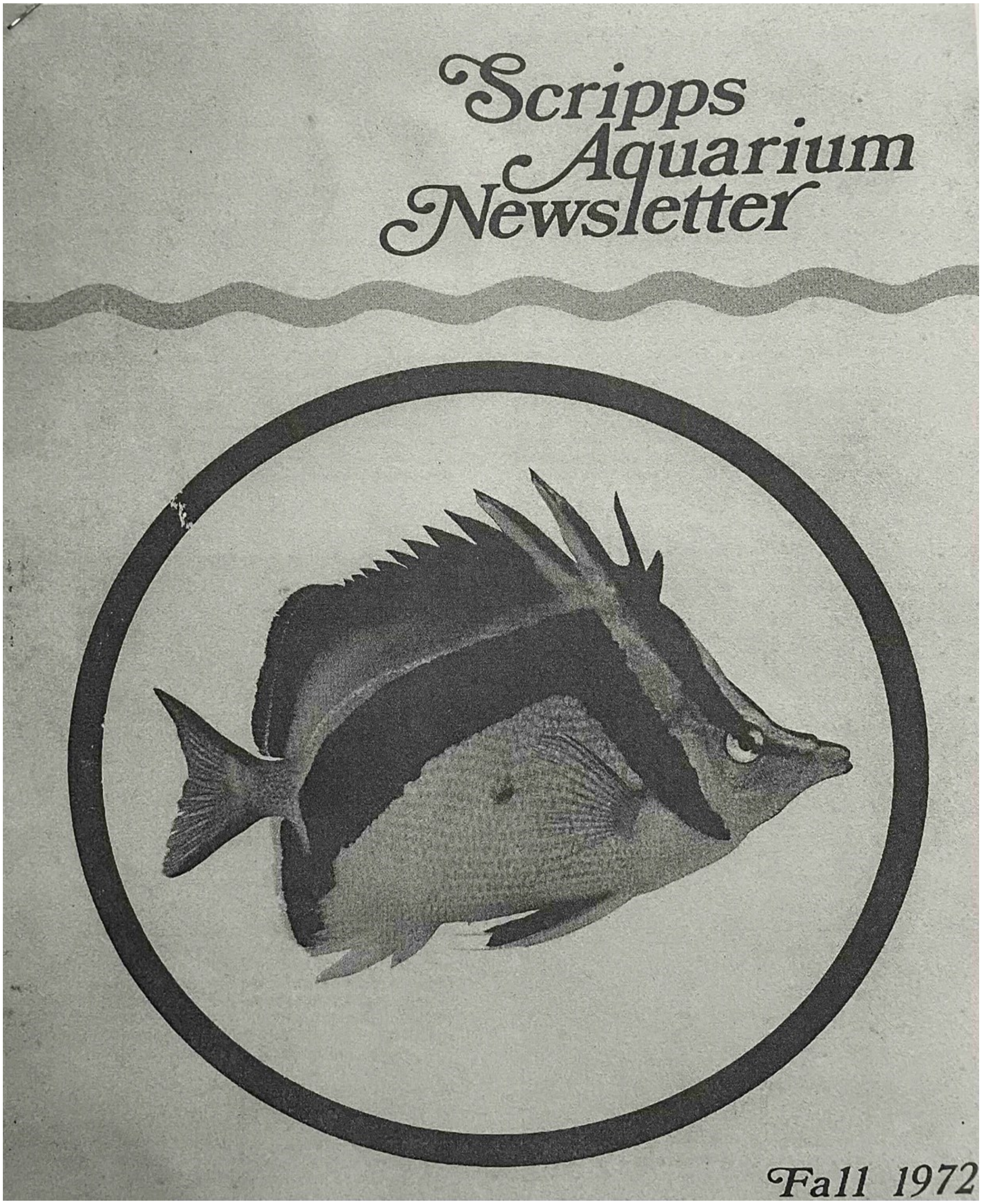


Figure 9. The Scythe Butterflyfish collected by Kiwala and McConnaughey in 1970 appears on the cover of the Fall 1972 Scripps Aquarium Newsletter. Note the black spot behind the pectoral fin. McConnaughey confirmed that is where Bob Kiwala inserted the hypodermic needle.

Figure 10. Some Scythe Butterflyfish memorabilia throughout the years.

1984. Robert (Bob) Snodgrass and Rich West Collection

Senior Aquarist Bob Snodgrass with Aquarium Collector Rich West led a trip to Islas San Benito located on the west coast of the Baja California peninsula, Mexico. On this trip eight Scythe Butterflyfish were collected (Snodgrass and Wilkie, 1985).

1995. One or Two Species, taxonomic change of *Chaetodon* to *Prognathodes*

Teodor Nalbant, a Romanian ichthyologist, described a Scythe Butterflyfish from the Galapagos Island. He named it *Prognathodes carlhubbsi*, in honor of Scripps ichthyologist, Carl Hubbs, a distinct species from the Scythe Butterflyfish from Mexico and Southern California (Nalblant, 1995).

Dr. Yi-Kai Tea, in a more in-depth article, elaborates on similarities and differences between these "sister" species (2022). Several differences are noted in Robertson and Allen (2024) who recognize the validity of both species as does Eschmeyer's Catalog of Fishes (2024). Ben Frable, Senior Collection Manager of Marine Vertebrates, SIO, states that the subject of one or two species is still controversial and that genetic analysis would help solve the question (Frable, pers. comm.). Robertson and Allen (2024) also echo Frable's comments.

Nalbant applied the genus name *Prognathodes* to the Scythe Butterflyfish, thus placing this species into a subgroup of butterflyfishes which is composed of about seven species that inhabit deeper, cooler waters. *Prognathodes* basically translates to "first mouth" and may refer to the more elongated snout in this group of butterflyfishes.

Further Collections and Sightings

On August 18, 1995, BAS Associate Curator Leslee Matsushige and former Curator Robert Snodgrass collected eight specimens at Islas San Benito, Mexico. Leslee observed a school of 10 Scythe Butterflyfish in a sand channel at 20 m. She observed that they were not shy and even curious, swimming up to take a closer look at the divers (Matsushige, pers. comm.).

On August 13th, 1997, one Scythe Butterflyfish was observed at 7.5 m at Santa Cruz Island, CA (Richards and Engle, 2001).

On July 19th,1999, BAS Associate Curator Leslee Matsushige and former Curator Robert Burhans, traveled to Islas San Benito, Mexico and collected several Scythe Butterflyfish including the current pair that are on display. They observed several Scythe Butterflyfish between 10-24 m but most between 12-18 m (Matsushige, pers.com). From this collection two Scythe Butterflyfish were loaned to Colorado Ocean Journey (Downtown Aquarium).

On July 2019, Scott Mau, Research Fisheries Biologist Southwest Fisheries Science Center (La Jolla, CA) observed *P. falcifer* at approximately 62 m swimming within a sunken U88 submarine off San Pedro Harbor, California. He states that water temperature at that depth was 10.5°C (Mau, pers. comm.).

Hollarsmith, et al. (2020) report observing Scythe Butterflyfishes with ROV's at the Revillagigedo Islands, Mexico at depths from 41-94 m.

On December 2022, BAS Assistant Dive Officer/Aquarist Melissa Torres spotted Scythe Butterflyfish off Santa Catalina Island, CA. She observed a pair at 12m in a kelp forest who were curious and came closer to the divers. At 21 m another specimen was observed in a rocky crevice where water temperature was approximately 13.5°C (Torres, pers. comm.).

Recently (Sept. 2024) Elliot Lim, an avid free diver, shared his videos with the author of five Scythe Butterflyfish while free diving a rocky reef/kelp forest off the coast of Orange County, CA. He spotted them between 16-21m, with water temperature at 20.5°C above a 17m thermocline and 14.5°C below (Lim pers. comm.).

Final Comments and Husbandry Observations

BAS has been fortunate to display Scythe Butterflyfish for many years. The current pair collected in 1999 have been the longest-lived specimens in the Aquarium's history (24 years) and probably at any other facility. Two Scythe Butterflyfish from the BAS 1999 collection were loaned to Colorado Ocean Journey. Both were maintained at 16.7°-18.9°C for 20 years (Brynda, pers. comm.)!

Three significant factors may explain the difference between the longevity of our current pair and those maintained in the past: first, improved tank design incorporating greater volume (5,300L) and vertical use of habitat (1.8L x 1.5W x 2.4H m). Tank dimensions lent itself to a more natural, rocky aquascape, resembling what is described in the papers herein and what is observed in video footage of their natural habitat. Past exhibit volumes were approximately 1,500L-1,900L and cube shaped (1.2L x1.2W x 1.0H m). Lastly, consistent water temperature throughout the year is another major difference. Prior to 1992, at the old Scripps Aquarium, ocean water temperature varied based on season (open system-approximately 15.5-23.0° C.) At BAS (semi-open system) a chiller maintains a temperature averaging 15.5°C throughout the year, approximating temperatures reported by divers in this paper (Lim, Mau, Matsushige pers.comm. and Kiwala and McConnaughey, 1970). Salinity measures 34 0/00 and pH at 8.0. A varied diet of krill, mysis shrimp, squid tentacles, chopped shrimp, and chopped clams seem to keep these fish in good health while maintaining their vibrant colors. The current pair have spawned several times, however fertile eggs were never observed. The pair have done well living with other fish species: *Sebastes spp*. and *Hypsurus caryi.* and various invertebrates: *Muricea spp., Lophogorgia spp., Megastraea unduosa, and Megathura crenulata.* Overall, *Prognathodes falcifer* is a hardy species of butterflyfish. By providing a varied diet, cool water temperature, and a relatively large volume with areas to hide, this species seems to thrive in captivity. Wilkie (Snodgrass and Wilkie,1985) stated that up that point Scripps Aquarium was able to keep Scythe Butterflyfish for "more than seven years" and their diet consisted of "…brine shrimp, worms (black worms), chopped shrimp, and chopped squid."

Photos/Figures

1. Scythe Butterflyfish at BAS. Photo courtesy of Jordann Tomasek, Birch Aquarium Photographer.
2. Scripps Divers at Guadalupe Island in 1954. James Stewart Papers, SMC 29. Special Collections & Archives, UC San Diego Library.
3. Ocean World. Sam Hinton Papers, MSS 683. Special Collections & Archives, UC San Diego Library [for the Scythe butterflyfish image].
4. Jacques Cousteau Diving Saucer. James Stewart Papers, SMC 29. Special Collections & Archives, UC San Diego Library.
5. SIO Specimen Collection Form. SIO Marine Vertebrate Collection. Courtesy of Ben Frable, Collection Manager.
6. Newspaper clipping, The Sentinel Paper. Courtesy Birch Aquarium at Scripps.
7. Scythe Butterflyfish CT scan. SIO Marine Vertebrate Collection. Courtesy of Ben Frable, Collection Manager.
8. Ben Frable photo, Fernando Nosratpour.
9. Scripps Aquarium Newsletter cover image, 1972. Courtesy Birch Aquarium at Scripps.
10. Aquarium memorabilia collection from Leslee Matsushige and Fernando Nosratpour. Photo, Fernando Nosratpour.

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Acknowledgements

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ABSTRACTS from the 2024 Symposium & Workshop, March 2- 6.
Pittsburgh Zoo & PPG Aquarium, Pittsburgh PA.

Are We Sure It's Ready? Modeling Animal Nitrogen Excretion for Effective Biological Filter Cycling

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Living Exhibits operates outdoor seasonal elasmobranch touch exhibits at institutions throughout the country. This involves draining the exhibits for the winter and restarting them in the spring. Cycling the biological filter is one of the most important steps in preparing exhibits for animals. Daily ammonia production for each exhibit was estimated based on the amount of food introduced. Biological filters were cycled using increasing doses of ammonium chloride until the full estimated ammonia production was nitrified in 24 hours. This talk will review the results of biological filter conditioning and water quality after animal additions of seven exhibits.

Getting More Value out of Your Value Engineering: Repair and Modification of Three Large Fabricated-in-House Foam Fractionators

Evan Jamison
Loveland Living Planet Aquarium 12033 Lone Peak Pkwy, Draper UT, 84020, USA

During the planning and construction of Loveland Living Planet Aquarium's 280,000-gallon tropical marine habitat in 2013, budget constraints drove many necessary value engineering decisions in designing and installing the Life Support System. One of these creative solutions was fabricating three 2000-gallon foam fractionators in-house by plastic welding standard rotomolded HDPE tanks and large diameter butt-fusion flanges. After a decade of use and some important lessons learned along the way, we planned and made necessary modifications and repairs to these fractionators in 2023 to ensure their continued safe functionality. This relatively small investment should keep these critical parts of our largest Life Support System in operation for many years to come.

Preventing Your Next Plague: Using UV to Avoid and Treat Large Scale Outbreaks

Steve Bitter
511 Timberlane Dr, Branson, MO 65616, USA

Diseases tend to break out at the most critical stages of a project, and the ensuing reaction can put real strain on a facility's animal collection and care staff. Whether commissioning a new exhibit/gallery, completing building renovations, or introducing new animals, diseases seem most likely when the stakes are also highest for an institution. While medications and environmental adjustments are often in our toolkits, they have significant drawbacks for fish health. An established and low-stress alternative is ultraviolet sterilization. However, many designs and installations still frequently omit or undersize UV systems. This talk will review multiple case studies to discuss UV success and failures, including the 2021 installation of an unusually large UV disinfection system. It will also cover the fundamentals of UV system sizing and maintenance, with an eye toward being prescriptive and actionable for anyone to successfully implement UV in future projects.

Old & Busted, Meet New Hotness: ACS 1 & 7 Retrofit Upgrades

Rivers Ludden
Georgia Aquarium, 225 Baker St NW, Atlanta, GA 30313, USA

Over the past year, we have completed 2 controls systems upgrades on our building that have enabled us to continue operating reliably far into the future. The Opto-22 G4 gear is very old, and since it's not made anymore, we have begun the exciting task of swapping the I/O into a more modern system. The difficulty and importance of keeping the building running while simultaneously rewiring it cannot be stressed enough. The water must keep flowing and remain clean for the animals. There was lots of prep work to label and plan out the wiring. We had temporary controls loops operating critical systems while we took the permanent systems offline for the upgrade and were able to complete each upgrade in just 5 days. There were minimal periods of system downtime when switching the controls wiring from permanent to temporary I/O, and there were wires whose labels were long since worn off that took some tracing to find why they were there, but overall, it was a very successful transition from 20-year-old equipment that is no longer supported or manufactured to brand-new reliable equipment that will need to be replaced in another 20 years!

Rare Lobster Rearing: Enhancing the Genetic Analysis of Rare Exoskeleton Coloration in Homarus americanus through System Design for Rare Larvae

Claire Fecteau-Volk
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Biddeford, ME 04005, USA

Rare lobsters have long fascinated lobstermen, media, and scientists. As climate change impacts the population that sustains the vital lobster industry, it is crucial to understand how lobsters will respond to rapidly warming waters in the Gulf of Maine. Rare lobsters provide incredible opportunity to examine the unique cases of lobster development as they have already been studied in regards to epizootic shell disease. Paired with the current understanding of how typical lobsters respond to thermal stress, rare lobsters can provide a more complete understanding. Currently housed at the University of New England (UNE) are a blue, split, yellow, orange, calico, and purple lobster. This invaluable group provides great potential for understanding how rare coloration in lobsters works. It is understood that rare shell colors are influenced by diet and genetic mutations, but to what extent? Many studies are currently looking into this, and UNE has the potential to compare various lobster colorations with the added benefit of our orange lobster, Peaches', next generation soon on the way. Peaches' eggs are projected to hatch early this summer, and the design and implementation of a larval rearing system would allow us to raise lobster larvae from hatch for further study on how her genetic material is passed on. In designing this system, the aim is to utilize a hybrid, informed approach: attempting to incorporate traditional protocols with newer hatchery methods for rearing the rare larvae.

Conserving Water Through System Upgrades for the Lake Sturgeon Reintroduction Program at Tennessee Aquarium Conservation Institute

Teresa Israel
Tennessee Aquarium Conservation Institute, 175 Baylor School Rd,
Chattanooga, TN 37405, USA

At the Tennessee Aquarium Conservation Institute, we raise juvenile lake sturgeon in a recirculating system for reintroduction into the Tennessee River. High ammonia and nitrite levels throughout the rearing process led to multiple water changes daily and excessive water usage. The filtration on the system could not keep up with the amount of fish, food, and waste present. New filtration was needed to improve water quality, save water, and increase survival rates for juveniles in our lake sturgeon system. To improve the system's filtration, we added new bead filters and four fluidized beds to increase the total number to six. In addition, we increased the overall water volume of the system by combining two 1600-gallon systems into one 3200-gallon system and then added more volume by replacing two rectangular raceways with larger, round tanks. The round tanks also increased water depth for the fish. These changes to the system resulted in a reduction of more than 100,000 gallons of water usage in our lake sturgeon system between 2022 and 2023. The water quality in the system greatly improved in 2023 resulting in decreased water usage. The round tanks also allowed the juvenile lake sturgeon to exhibit more natural behaviors and have increased space and water depth throughout the winter and spring.

DIY: Water Recovery Systems! How to Recycle Water During Resource Scarcity and Why It Matters

Sarah Thompson
Georgia Aquarium, 225 Baker Street NW, Atlanta GA 30313, USA

Climate swings and exceptional weather conditions are quickly becoming the new 'normal'. With an uptick in droughts, floods, and extreme weather events, the world urgently needs to combat the perilous decline of ecosystems and their waterways. Maintaining healthy landscapes by proper water resource allocation is the cornerstone for sustainability for all species. By integrating a generalized water recovery system into everyday operations, life support teams around the nation can benefit from decreased water loss by cleaning their dirty salt or freshwater though effective filtration. Water recovery systems like those at Georgia Aquarium, are integral for promoting a greener future for LSS: namely for landlocked institutions, urban environments, and arid climates where water is scarce, and restrictions proliferate. These blueprints for successful water recycling have been shown to save money (over $35,660 in salt costs and ~250,000 gallons annually in only our smallest recovery system) by reducing water down our drains.

Animal Life Support and Other Environmental System Innovations at SeaWorld Abu Dhabi

Jeffrey J. Keaffaber, Ph.D.; Michael Tucker
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Orlando, FL 32819, USA

SeaWorld Abu Dhabi (SWAD) greeted its first guests in May 2023. Starting as an idea in 2016, it evolved to be a next generation SeaWorld park with 16 million gallons of natural seawater featuring dynamic habitats that display a vast biodiversity. This indoor facility is home to nine (9) major habitats. Besides fish and invertebrates throughout, iconic species include penguin, walrus, sea otter, puffin, sea lion, dolphin, dugong, shark, manta, and other rays. Here we present advances in aquatic animal life support processes to include regenerative media filtration (RMF), fractionation/protein skimming, combining habitat water, seawater intake, and wetland filtration discharge systems. Also included is a discussion of advances in animal habitat lighting utilizing full spectrum LED, UVA, and UVB to deliver photoperiods specific to the animals' habitat latitude in the natural world.

Changing the Tides: Making an Event Center an Aquarium in Record Time

Cameron Bishop; Danielle Lynn-Vogel
Mississippi Aquarium, 135 Courthouse Rd, Gulfport, MS 39507, USA

In November 2022, Mississippi Aquarium began the process of expanding an existing event space into three new galleries. Construction on the building did not truly begin until April, meaning exhibits were not moved into the building until May. Despite untimely delays, the Facilities team (comprised of Life Support, Water Quality, and Maintenance staff) modified, installed, plumbed, and cycled 23 new systems for a cold water, tropical saltwater, and terrestrial gallery all within a three-month window. Due to equipment delays the team finished the expansion later than scheduled, but the galleries opened with every habitat housing animals. Our presentation speaks to the trials and tribulations of this short timeline, our perspectives of Life Support and Water Quality when opening an expansion, and our takeaways from the experience.

Demolition and Build of FW-3/2

Rivers Ludden
Georgia Aquarium, 225 Baker St NW, Atlanta, GA 30313, USA

Gallery redesigns and construction in general come with headaches for everyone, but learning from those mistakes is most important so you and others won't make them next time.

During the renovation of our Freshwater Gallery, River Scout, we moved our piranha to another habitat and built out a much larger habitat for Tigerfish. We have run into many and varied roadblocks, mistakes, miscommunications, successes, even triumphs, and eventually a fully automated habitat. Concrete cutting took months longer than expected and 4-foot saws severed live underground piping for other exhibits. We had to coordinate construction teams between different projects. There were design changes mid-project including missing a critical structural element for the building forcing a redesign of the tank. In repurposing equipment from previous systems, we had to rebuild and move piping between multiple floors and through multiple galleries. The automation required a hybrid of bringing existing equipment back online and tying in new equipment. It was quite the year, but it is so satisfying to see it up and running and soon have fish swimming around in it!

Get Ready with Me: Accreditation Edition

Katelynn Parmeley
Georgia Aquarium, 225 Baker St. NW, Atlanta, GA 30313, USA

Zoological professionals across the world share the commitment to a higher standard of animal welfare by focusing on maintaining a portfolio of certifications, accreditations, and licenses. The Georgia Aquarium is an internationally recognized and prestigious institution with a wide range of certifications, including accreditation from the Association of Zoos and Aquariums (AZA). During this presentation, the methods and procedures of AZA-specific preparation by Georgia Aquarium employees will be explored, focusing within the Life Support Department. Get Ready for accreditation with me and explore the range of certifications and accreditations available to you and your zoological institution, and the impact specific training and licensing within Life Support and other departments have on obtaining these accreditations and licenses.

A Refined Approach to Handling Pygmy Hippo Waste

Justin Andelin
Metro Richmond Zoo, 8300 Beaver Bridge Rd, Moseley, VA 23120, USA

The Metro Richmond Zoo, a privately owned and operated ZAA accredited zoo in Richmond, Va opened its Pygmy Hippo Exhibit in 2018. The exhibit features 2 exhibit pools totaling 12,000 gallons, one indoors and one outdoors. We review many of the initial design limitations, and creative problem solving used to achieve a pleasurable underwater viewing experience for our guests. Some of these include balancing two exhibit water levels with a single LSS, limited freshwater supply, single phase electricity, and how to maintain a good turnover rate while handling substantial waste loading from hippos. We refined our original system over the past 6 years by trying additional filters and other design approaches to improve solids handling and water polishing. We will discuss our multistage approach in handling the hippo waste by means of solids handling pumps, strainers, static sieves, drum filters, sand filters, bead filters and ozone treatment.

Zebrafish (*Danio rerio*) Husbandry in a Scientific Research Setting

Christine Archer, BS RVT RLAT VTS-LAM
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Zebrafish (*Danio rerio*) are an increasingly common model organism in scientific research settings. Housing them in small to moderately sized indoor aquaculture facilities have presented a number of challenges for animal care professionals in the lab animal science field. In this presentation, the unique needs for the care and use of zebrafish in a scientific setting will be discussed, along with past and ongoing challenges faced by care staff and life support system professionals. Opportunities to improve and refine husbandry will also be discussed.

How Hard Can It Be? Bacterial Testing in the Comfort of Your Own Lab

Chris Emmet
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Testing for bacteria in animal systems can be a valuable, and depending on regulations, mandatory way to monitor water quality. However, setting up an in-house testing regimen can seem daunting depending on staff experience and scale of testing needed. This presentation will review some of the most common approaches to bacterial testing, including target organisms, different methods of testing, and regulations for animals & humans. Last year, Birch Aquarium began in-house testing for Total Coliforms and Enterococcus, which has resulted in significant cost savings as well as promoting the welfare of the animals in our collection through more frequent sampling & quicker responses to potential health issues.

Zebrafish (*Danio rerio)* as a Laboratory Animal Model, their Life Support Systems, and the Zebrafish Husbandry Association

Logan Fehrenbach; Logan Bern; Alexander Kramer
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Zebrafish (*Danio rerio*) are tropical freshwater fish native to South Asia found in a wide variety of habitats ranging from stagnant pools to streams. Zebrafish are a popular aquarist species known to be hardy and tolerate a wide range of water parameter conditions. The hardiness of zebrafish, transparent embryos, willingness to reproduce, and fully sequenced genome make them an ideal laboratory animal model. It is estimated that currently over 3,000 labs use zebrafish and that there are more than 5,000,000 zebrafish jointly housed between them. This wide use of zebrafish as an animal model has caused a need for laboratory setting life support systems that can house high densities of fish in small spaces. There is still a need for husbandry standards to be developed across institutions. The Zebrafish Husbandry Association is a non-profit group that focuses on working toward husbandry standards, education of zebrafish users, and collaboration between institutions.

Do Phosphates Really Matter? A Look into the Impact of Water Quality on Sea Turtle Rehabilitation Patients

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While the subject of water quality has been thoroughly researched, very little research exists regarding the connection between water quality and sea turtle health. Even less research has been performed in regards to the impacts water quality may have on the health of rehabilitating sea turtles. This paper aims to examine the water quality issues that may arise in sea turtle rehabilitation facilities and whether those issues have any effect on the health of sea turtles, particularly loggerhead turtles, undergoing rehabilitation. When considering these potential water quality issues, phosphates must be a consideration. Phosphates can be found in many different forms, but, for the purpose of this study, the term phosphates will refer to organically bound phosphates. These phosphates are the result of uneaten fish and the waste produced by sea turtles. When rehabilitating sea turtles are kept in smaller volumes of water in relation to their wild counterparts, the phosphates within the water become more concentrated. While phosphorous is an important nutrient for plants and animals, adverse effects on both the environment and animal health have been observed when concentration levels become too high. This presentation examines the potential health affects phosphates may have on sea turtles specifically as well as strategies for mitigating high phosphate levels within rehabilitation facilities.

Treefish, Bruce Koike

QUANTIFYING OZONE INHIBITION BY NITRITE IN A MARINE MAMMAL LIFE SUPPORT SYSTEM

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Introduction

While not nearly as sensitive to water chemistry as fishes and invertebrates, marine mammals and other charismatic megafauna remain staples of aquarium and zoo collections and present their own challenges with regards to life support system (LSS) and water quality needs. Historically, much attention has been paid to bacterial analysis, disinfectants, and disinfection byproducts (DPBs) in marine mammal water (Van der Toorn, 1987; Spotte, 1991) with little written about the management of nitrogenous compounds. It has been known since the 1970's that ozone has powerful interactions with nitrogenous compounds in closed seawater systems (Honn and Chavin, 1976), and herein we will present a case study where these interactions contributed to serious declines in both water clarity and quality, and construct a theoretical model to predict the inhibition of ozone by nitrite rendering it unavailable for use in disinfection, flocculation, or decolorization of exhibit water.

Case Study: Pinniped Cove Exhibit, Maritime Aquarium

A new seal exhibit, Pinniped Cove, and associated LSS was commissioned in June of 2021, containing 168,000 gallons of water at a depth of up to 24 feet. The water was manufactured with NSF60-grade NaCl brine rather than synthetic sea salt, at a concentration of 30-33‰, and sterilization was accomplished solely with ozone (O_3) to avoid the use of chlorine, which is associated with eye issues and other medical conditions in marine mammals (Joseph et al., 2010; Gage and Francis-Floyd, 2018).

The exhibit was equipped with four rapid sand filters (Neptune-Benson, custom built vertical filters to accommodate space available) capable of filtering up to 900 GPM each (with a design flow rate of 600 GPM), two ozone contact chambers, two foam fractionators (RK2, RK300), and an ozone generation plant capable of producing 3.89 kgO_3/d (Ozone Water Systems). Three of the four sand filters utilized pulverized glass media (AFM) which does not support colonization by nitrifying bacteria, and one used traditional sand media to allow for nitrification in the system.

From time of commissioning until November of 2021 (five months) the waterborne bacteria levels and turbidity were well regulated by the ozone sterilization components of the LSS, maintaining total coliforms <200 CFU/100mL and turbidity from 0.1-0.8 NTU.

Beginning on 27 November 2021 the total coliforms (which had averaged between 3-63 CFU/100mL) began to rise above 200 CFU/100mL, but still within the acceptable 1000 CFU/100mL threshold specified by the U.S. Animal Welfare Act (USDA, 2020). By 10 December 2021 the levels had risen to 1200-1400 CFU/100mL accompanied by a notable decline in pH (Fig.

3). The ozone output to the contact chambers was boosted to create higher ORP while maintaining safe levels in the tank, backwashing of filters was performed more frequently, and the frequency of SCUBA dive maintenance to remove animal feces and detritus was increased. Despite these corrective actions, total coliforms continued to increase, reaching a maximum of 1980 CFU/100mL (Fig. 3), and an addition of calcium hypochlorite (1.00 mg/L total Cl-) was made as a chemical sterilant.

Following the chlorine disinfection, all water quality parameters changed dramatically (Fig. 3), characterized by decreases in pH and alkalinity, rises in ammonia NH_3 and nitrite NO_2^-, and steadily decreasing ORP readings (mV) both in the exhibit water and the contact chambers (Fig. 2). At this time a notable decrease in water clarity was also noted, with turbidity values increasing to >5 NTU, an order of magnitude above normal readings. It is worth noting, that a decrease in ORP and increase in turbidity did not begin until 17d after the initial increase in coliforms was observed.

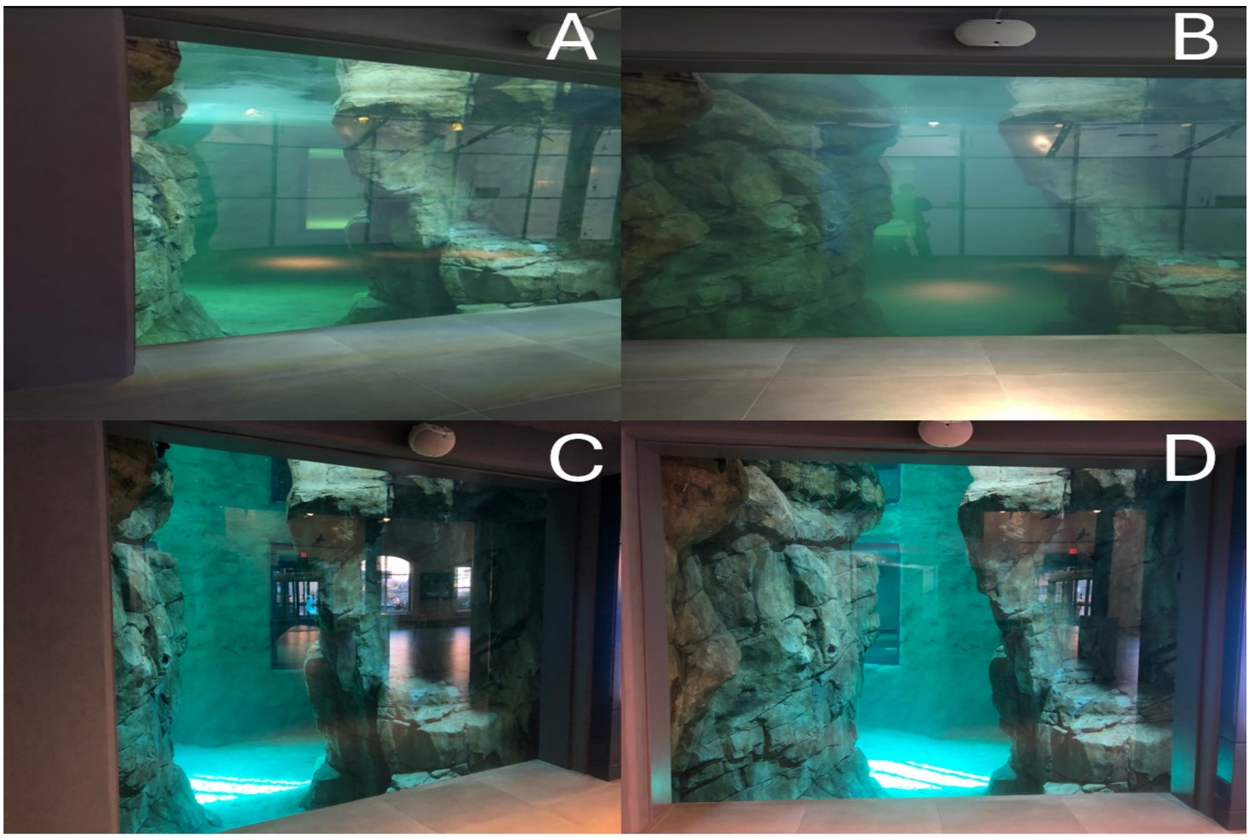


Figure 1. Top (A, B) views of the Pinniped Cove exhibit at the Maritime Aquarium in November 2021, bottom (C, D) the same view on Christmas day 2021, after troubleshooting and reduction in nitrite, NO_2^-, allowing more ozone, O_3, for sterilization. Photos Jacob Salazar, Maritime Aquarium.

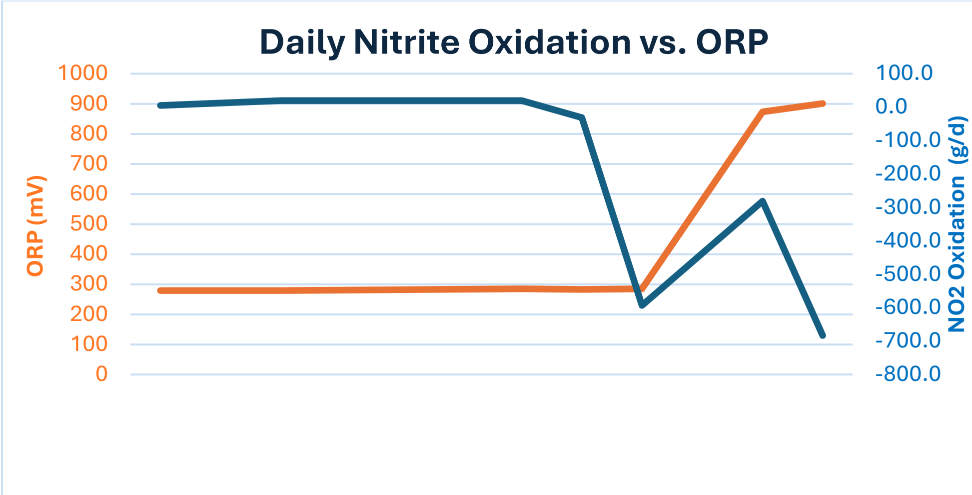


Figure 2. Dynamics of ORP (mV) and Nitrite (mg NO_2^-) removal following re-seeding of biofilter and boosting alkalinity to increase nitrification.

Methods/Troubleshooting

In consultation with the LSS designers and engineers, and industry experts, the functionality of each component of the LSS was verified to troubleshoot the decline in both water clarity and quality.

While a number of theories for the issues were explored, there was not a readily apparent mechanical cause, as all equipment was functional. To explore biotic causes the water chemistry data stored in the Tracks database (Zier-Niemann/Tracks Data Solutions). At the time of the decline in water quality and exhibit clarity, most tracked values deviated wildly from their historic trends, giving the plotted data a chaotic appearance, as if everything went haywire (Fig. 3).

The analysis of lab water data (explained in detail below) identified nitrite NO_2^- as having the strongest statistical relationship with total coliforms (CFU/100mL). Nitrite (NO_2^-) is known to react rapidly with ozone, where it is oxidized to nitrate (NO_3^-), short-circuiting the nitrogen cycle (Honn and Chavin, 1976). Because the NO_2^-/O_3 reaction is strongly favored and proceeds rapidly, the amount of ozone which reacts with nitrite is "stolen" from the LSS and unavailable for sterilization.

The performance of the biofilter was measured by modifying the pressure gauges on the influent and effluent sides of the sand filter containing sand media to accommodate a labcock valve, and samples pre- and post-filter were taken over 10 days at various flow rates from 300-600 GPM. Nitrite removal (ΔNO_2^-) was found to range between 0.03-0.31 mg/L, optimal nitrification was found to be at 300 GPM. The filter was set to a flow rate of 300 GPM using the variable frequency drive (VFD) pump and re-seeded with nitrifying bacteria (Fritzyme Turbo-Start 900). Alkalinity was adjusted with an addition of 660lb (300kg) sodium bicarbonate and 110lb (50kg) sodium carbonate. Nitrification recovered rapidly, and the system recovered on 25 December 2021 (Fig. 1).

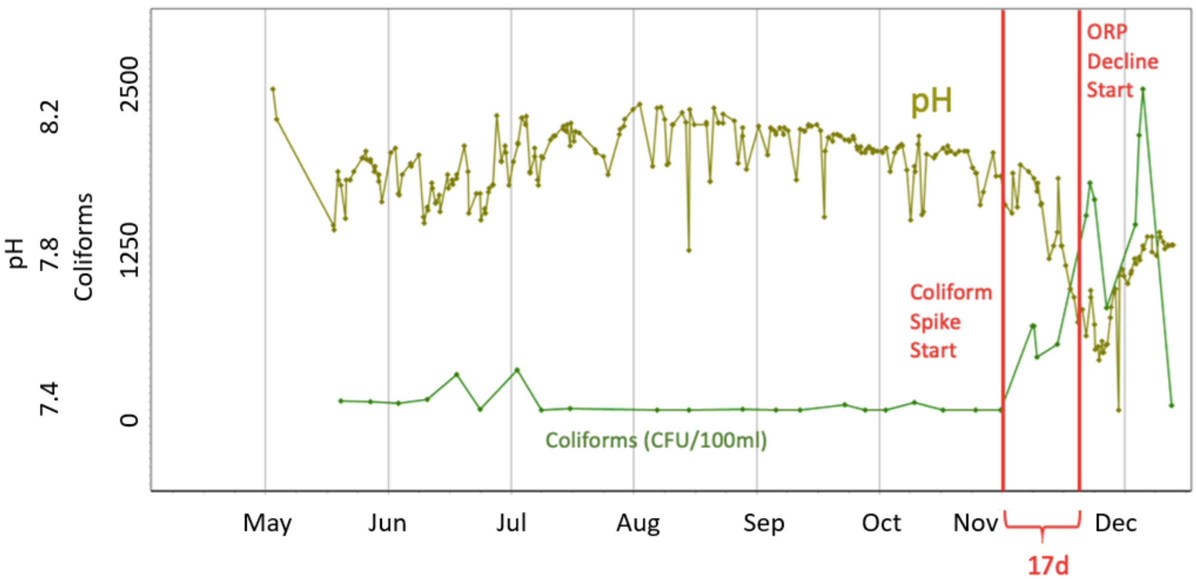
In retrospect, it was evident that a loss of nitrification resulted in an excess of nitrite which inhibited sterilization, leading to increased turbidity and total coliforms. Prior to the increase in total coliforms, buffering had been conducted based on system pH rather than total alkalinity. When commissioned, the system (which contained over 195 yards of concrete) had been acid leached with HCl for 10 days of an intended 30 with a pH controller, cut short due to pressures of scheduling. While the abbreviated leaching period prevented serious cosmetic issues with efflorescence and gypsum crystal formation, the lime in the concrete kept the pH high while carbonates and bicarbonates were being consumed by the biofilter. When these were exhausted, ammonia and nitrite rose, inhibiting ozone and allowing coliforms to reproduce, when chlorine was used to control bacterial flora the biofilter was further damaged, and the practical effect was as if gasoline were poured on a fire.

In summary, the effect of nitrite on ozone, while known, was unexpectedly significant. The lessons learned from troubleshooting this issue were as follows:

1) Nitrification should be monitored as closely in marine mammal systems as it is in fish systems.
2) Adequate concrete leaching time for new exhibits is essential for both aesthetic reasons, and water chemistry reasons.
3) Nitrogen cycling in new mammal systems should not be overlooked.
4) Careful attention to trends in water quality data can provide early warnings of developing issues.
5) Nitrite can have a profound effect on LSS performance where ozone is used for sterilization.
6) Carefully consider the use of chlorine in mammal pools where biofiltration may be impacted.
7) Diligent and frequent SCUBA maintenance to remove feces and detritus is essential, no amount of LSS can compensate for accumulations of fecal material if not continuously removed.

Water Chemistry Analysis

In order to narrow in on the most likely cause, all water chemistry parameters were exported into a spreadsheet, and correlation analysis between all factors was examined using the CORREL function of Microsoft Excel. The results of these analyses (Pearson's coefficient of correlation, ρ) were arrayed into a matrix (Table 1), and a cluster diagram was created based on the strength of the numerical association (Fig. 4). Only one pair of parameters had a coefficient of correlation greater than ±0.95 (NH_3 and total Cl^-, ρ=0.9744), however seven interactions had a ρ>±0.30, and for six interactions ρ>±0.50, the latter indicating a mathematical relationship was more likely than not.



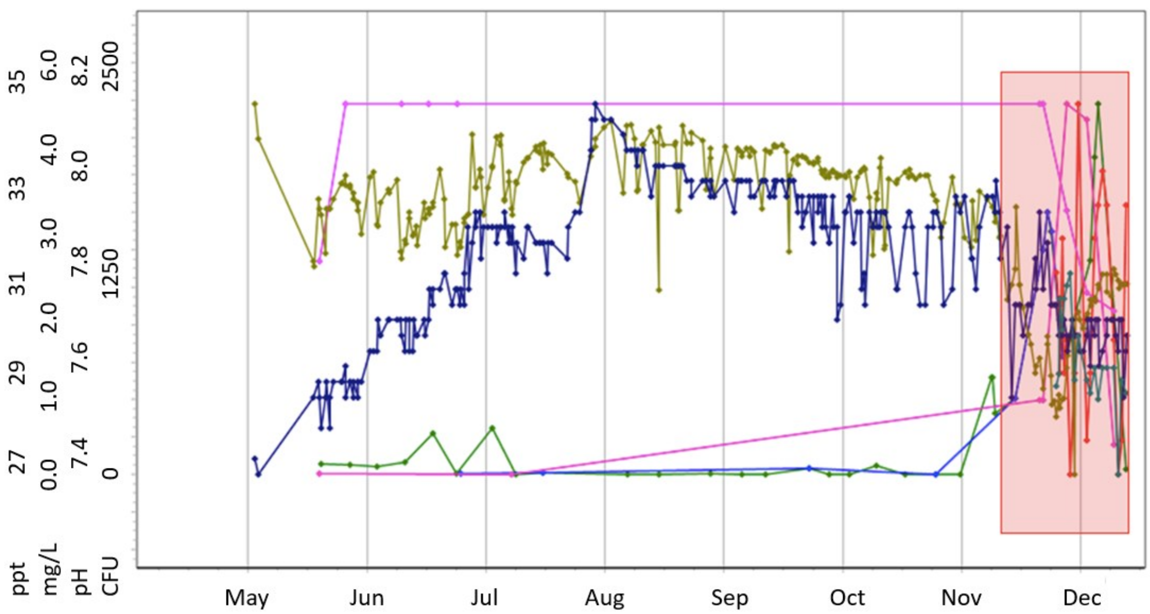


Figure 3. Water chemistry parameters of the Pinniped Cove exhibit at the Maritime Aquarium. (Top) Coliforms and pH, vertical red lines indicate the start of total coliform rise, and 17d later the beginning of ORP decline and turbidity increase (gold=pH, green=coliforms). (Bottom) All measured parameters, the area in red showing where all deviated severely from historic trends, making a clear causative relationship difficult to identify (gold=pH, dark blue =salinity, pink=nitrite, purple=ammonia, green=coliforms). The specific values here are less important than the trends, especially into Nov/Dec of 2021.

Coefficient of Correlation (ρ=)

	pH	NH3	NO2	CFU	Cl-F	Cl-T	Sal	Temp
pH	1.000	-0.841	-0.256	-0.362	0.382	-0.423	0.324	-0.007
NH3	-0.841	1.000	0.100	0.105	-0.679	0.974	-0.563	0.000
NO2	-0.256	0.100	1.000	0.885	-0.065	0.261	-0.570	0.000
CFU	-0.362	0.105	0.885	1.000	-0.234	-0.034	-0.182	0.351
Cl-F	0.382	-0.679	-0.065	-0.234	1.000	-0.214	0.449	-0.021
Cl-T	-0.423	0.974	0.261	-0.034	-0.214	1.000	-0.378	0.045
Sal	0.324	-0.563	-0.570	-0.182	0.449	-0.378	1.000	0.156
Temp	-0.007	0.000	0.000	0.351	-0.021	0.045	0.156	1.000

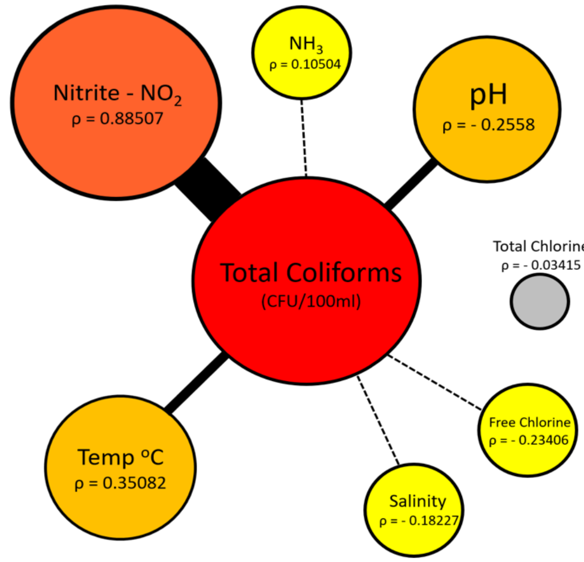


Figure 4. (Left) Matrix of Pearson's coefficients of correlation between all water quality parameters in the pinniped cove exhibit. Cells in red indicate the strongest correlations, cells in yellow indicate weak to moderate correlations. (Right) Cluster diagram of relationships between selected water chemistry parameters, the size of the circle and thickness of the line indicate the strength of the mathematical relationship with total coliform values. Note that nitrite, NO_2^-, has the strongest relationship with coliforms in this case, not because of a direct interaction with the bacteria, but indirectly by removing ozone, O_3, used for sterilization.

Among the interactions examined only two factors had a weak relationship with coliform levels, pH (ρ=-0.36206) and temperature (ρ=0.350823). Only nitrite (NO_2^-) had a strong relationship with total coliforms (ρ=0.88507). These relationships are outlined in the cluster diagram in Fig. 4. Nitrite itself does not have any known effect on coliform bacteria growth in a marine system, however it will readily react with ozone, which oxidizes NO_2^- to NO_3^- by the following reaction:

$$NO_2^- + O_3 \rightarrow NO_3^- + O_2$$

There was not a strong association between temperature and CFU or salinity and CFU, as would be expected, however this is likely because neither the salinity or temperature varied significantly in the exhibit. There was also not a strong negative correlation between total coliforms and either free or total chlorine, as might be expected, likely because the microflora in the tank were reproducing so rapidly, and because of the strong relationship with ammonia (ρ=0.9744), resulting in free chlorine being rapidly converted to monochloramine (NH_2Cl) via the following reactions:

$$Ca(OCl)_2 \rightarrow Ca^{2+} \rightleftharpoons 2OCl^-$$

$$OCl^- + NH_3 + H^+ \rightarrow NH_2Cl + H_2O$$

The presence of chlorine in the water can also result in the formation of disinfection byproducts, such as trihalomethanes, haloacetic acids, and chloroform (AALSO, 2024) which can be toxic both to animals and microflora in the system.

Modeling NO_2^-/O_3 Dynamics to Quantify and Predict Ozone Inhibition

Knowing that one mol of ozone will react with one mol of nitrite, and that the molecular weight of NO_2^- is 46.005 and O_3 is 47.997 the amount of ozone that will be consumed by a given amount of nitrite in a known volume (in gallons) can be calculated by the following equation:

$$mgO_3 = V\,(3.785)\,(NO_2^-\ mg/L)\,(1.0433)$$

Note that here the correction factor 1.0433 resolves the discrepancy in molecular weight between nitrite and ozone. The amounts of ozone that would be consumed by nitrite is given in Table 1 for a wide range of concentrations and volumes. However, this simple estimate is a snapshot, giving the amount of ozone consumed by nitrite (and thus unavailable for disinfection, flocculation, and decolorization) at a single point in time. For an ongoing problem, such as the scenario described above, several other factors are needed to produce a model that is predictive, and able to project forward in time. These factors include the biomass in the system, food input and composition (protein and lipid), nitrite oxidation performance of the biofilter, flow rates through the biofilter, and starting concentration of nitrite in the system.

It is also worth noting, that because of the propensity for ozone to react with nitrite, that during system cycling ozone should not be applied to the water, because of the risk of creating a biofilter colonized exclusively with ammonia oxidizing bacteria (AOB) with little to no nitrite oxidizing bacteria (NOB).

The equation for determining daily ammonia output as a function of biomass and diet was adapted from Spotte (1992) using the following equation:

$$mgNH_3\text{-}N\ d^{-1} = R_f\ B_m\ (N_L/16)\ \ N_U\ N_E]\ (1.0^6)$$

Where R_f = daily feed as a percentage of biomass (B_m), N_L = percent protein in feed, N_U = protein assimilation as a percentage, and N_E= nitrogen excreted as a percentage. Protein assimilation varies by species, up to 99% for some cephalopods, as low as 35% for some salmonids, for harbor seals an estimated assimilation (N_U) of 56% was used by approximating a wide range of reported values from the literature (Trumble et al., 2003; Stanberry, 2003; Trumble and Castellini, 2005, Zhao et al. 2006, Ochoa-Acuña et al. 2009), factoring in the dietary composition of lipid rich (herring, *Clupea spp*.) and lean (capelin, *Mallotus villosus*) feed items. Because this equation gives ammonia values as NH_3-N, there is a 1:1 translation to NO_2-N as the nitrogen cycle progresses, which can then be corrected to NO_2^- by multiplying by a factor of 3.28 (AALSO, 2024).

Performance of the biofilter can be calculated by averaging multiple measurements of the influent and effluent water streams, and calculating ΔNO_2^- Which can be applied to the flow rate (GPM) to create a daily removal (1440 minutes) by the following equation:

$$\Delta NO_2^- d^{-1} = S_f F_g (3.785)(1440)$$

Where S_f equals the NO_2^- removal per pass of the filter, and F_g equals flow in GPM.

Daily nitrogen flux (ΦN) the dynamic change in nitrogen can be calculated by putting the above formulas together. This assumes all ammonia produced is oxidized to nitrite, and all nitrite is oxidized to nitrate, and can be calculated by adding daily ammonia production to the starting nitrite concentration, and subtracting the amount removed by the filter, by the following equation:

$$\Phi N = [NO_2^- V(3.785)] + \{[NH_3\text{-}N\ d^{-1}] / [V(3.785)\} - \Delta NO_2^- d^{-1}$$

Table 1. Grams of Ozone (g O_3) Consumed by Nitrite in Varying Concentrations and Volumes

Volume	Nitrite Concentration (mg/L NO_2^-)										
(Gal)	0.10	0.20	0.30	0.50	0.75	1.00	1.50	2.00	4.00	5.00	10.00
100	0.04	0.08	0.12	0.20	0.30	0.40	0.59	0.79	1.58	1.98	3.95
250	0.10	0.20	0.30	0.49	0.74	0.99	1.48	1.98	3.95	4.94	9.88
500	0.20	0.40	0.59	0.99	1.48	1.98	2.97	3.95	7.91	9.88	19.77
750	0.30	0.59	0.89	1.48	2.22	2.97	4.45	5.93	11.86	14.83	29.65
1,000	0.40	0.79	1.19	1.98	2.97	3.95	5.93	7.91	15.81	19.77	39.54
1,500	0.59	1.19	1.78	2.97	4.45	5.93	8.90	11.86	23.72	29.65	59.30
2,000	0.79	1.58	2.37	3.95	5.93	7.91	11.86	15.81	31.63	39.54	79.07
2,500	0.99	1.98	2.97	4.94	7.41	9.88	14.83	19.77	39.54	49.42	98.84
5,000	1.98	3.95	5.93	9.88	14.83	19.77	29.65	39.54	79.07	98.84	197.68
7,500	2.97	5.93	8.90	14.83	22.24	29.65	44.48	59.30	118.61	148.26	296.52
10,000	3.95	7.91	11.86	19.77	29.65	39.54	59.30	79.07	158.14	197.68	395.36
15,000	5.93	11.86	17.79	29.65	44.48	59.30	88.96	118.61	237.22	296.52	593.04
20,000	7.91	15.81	23.72	39.54	59.30	79.07	118.61	158.14	316.29	395.36	790.72
25,000	9.88	19.77	29.65	49.42	74.13	98.84	148.26	197.68	395.36	494.20	988.40
30,000	11.86	23.72	35.58	59.30	88.96	118.61	177.91	237.22	474.43	593.04	1186.08
40,000	15.81	31.63	47.44	79.07	118.61	158.14	237.22	316.29	632.57	790.72	1581.43
50,000	19.77	39.54	59.30	98.84	148.26	197.68	296.52	395.36	790.72	988.40	1976.79
75,000	29.65	59.30	88.96	148.26	222.39	296.52	444.78	593.04	1186.08	1482.59	2965.19
100,000	39.54	79.07	118.61	197.68	296.52	395.36	593.04	790.72	1581.43	1976.79	3953.59
150,000	59.30	118.61	177.91	296.52	444.78	593.04	889.56	1186.08	2372.15	2965.19	5930.38
200,000	79.07	158.14	237.22	395.36	593.04	790.72	1186.08	1581.43	3162.87	3953.59	7907.17

Daily nitrogen flux (ΦN) the dynamic change in nitrogen can be calculated by putting the above formulas together. This assumes all ammonia produced is oxidized to nitrite, and all nitrite is oxidized to nitrate, and can be calculated by adding daily ammonia production to the starting nitrite concentration, and subtracting the amount removed by the filter, by the following equation:

$$\Phi N = [NO_2^- V(3.785)] + \{[NH_3\text{-}N\ d^{-1}] / [V(3.785)]\} - \Delta NO_2^- d^{-1}$$

Putting all these together including the Spotte (1992) ammonia output formula into the nitrogen flux calculation we can plug them into a model capable of determining ozone consumed by nitrite in a dynamic system where NO_2^- is being actively produced and consumed at varying rates. Ozone produced can be reconciled against nitrogen flux in a system to predict inhibition of ozone (ΨO_3), as a percentage, via the following equation:

$$\Psi O_3 = \left[\frac{[(O_3)(G)(1000)] - \left\{ \left[[(NO_2)(V)(3.785)] + \left[[(R_f)(B_m)(N_L/16)(N_u)(N_e)(3.28)] \right] - [(S_f)(F_g)(3.785)(1440)] \right] (1.0433) \right\}}{[(O_3)(G)(1000)]} \right] (100)$$

Where O_3 = total ozone production of the generators (g), G = generator output (%), NO_2 = nitrite concentration (mg/L), V = volume (gal), R_f = daily feed as a percent of biomass, B_m = biomass (kg), F_g= flow rate (GPM), N_L = percent protein in feed, N_U = protein use factor, N_E = nitrogen excretion as NH_3-N, and S_f = NO_2 removal mg/L by biofilter per pass.

This large equation above is, however, unwieldy and cumbersome for the end user, so a basic model was created using Microsoft Excel to easily perform these calculations and extrapolate the trends indicated by the values out for 30 days into the future. Using this model, one can manipulate variables such as volume, flow, biofilter performance, feed rates, and ozone output to see how a theoretical system would respond (Fig. 5). This model had good performance when compared to empirical water quality data from the Pinniped Cove exhibit at the Maritime Aquarium (Fig. 6), with predicted values correlating strongly to actual lab results (ρ=0.96889). A copy of this Excel model is available by contacting the authors, or may be downloaded at the following link: https://www.dropbox.com/scl/fi/ko0qp8k70cahuecv5p6fs/Nitrite-Ozone-Inhibition-Model.xlsx?rlkey=u97bt8w5kbnmprgz0g93ei6f6&st=ns2qc5qp&dl=0

Summary

Nitrogenous compounds (NH_3, NO_2^-, NO_3^-) are not of health concerns to mammals and other higher vertebrates in a closed system aquarium, but they are nevertheless critically important to the functionality of LSS. Monitoring nitrification should be done in mammal pools just as in fish systems, as nitrite accumulation may have a profound impact on ozone sterilization. When designing LSS for mammal systems, the end user should insist that biofiltration is incorporated into the design to maintain water quality and prevent sterilization issues.

Acknowledgements

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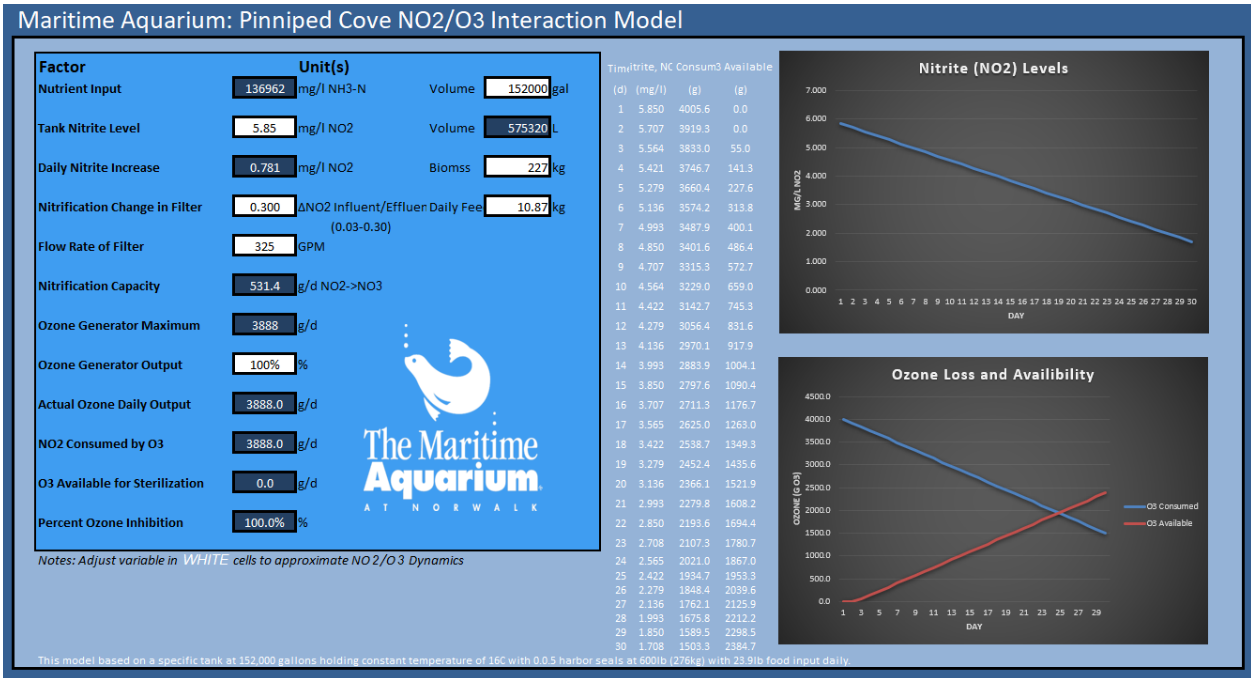

Figure 5. Screenshot of Microsoft Excel model of the ΨO_3 equation above, allowing rapid calculation of the percentage of ozone inhibition by nitrite based on volume, flow, nutrient input, and biofilter performance. Graphs at right display predictive values for nitrite values as a result of nitrogen flux (ΦN), and O_3 loss and availability for disinfection over a 30d period.

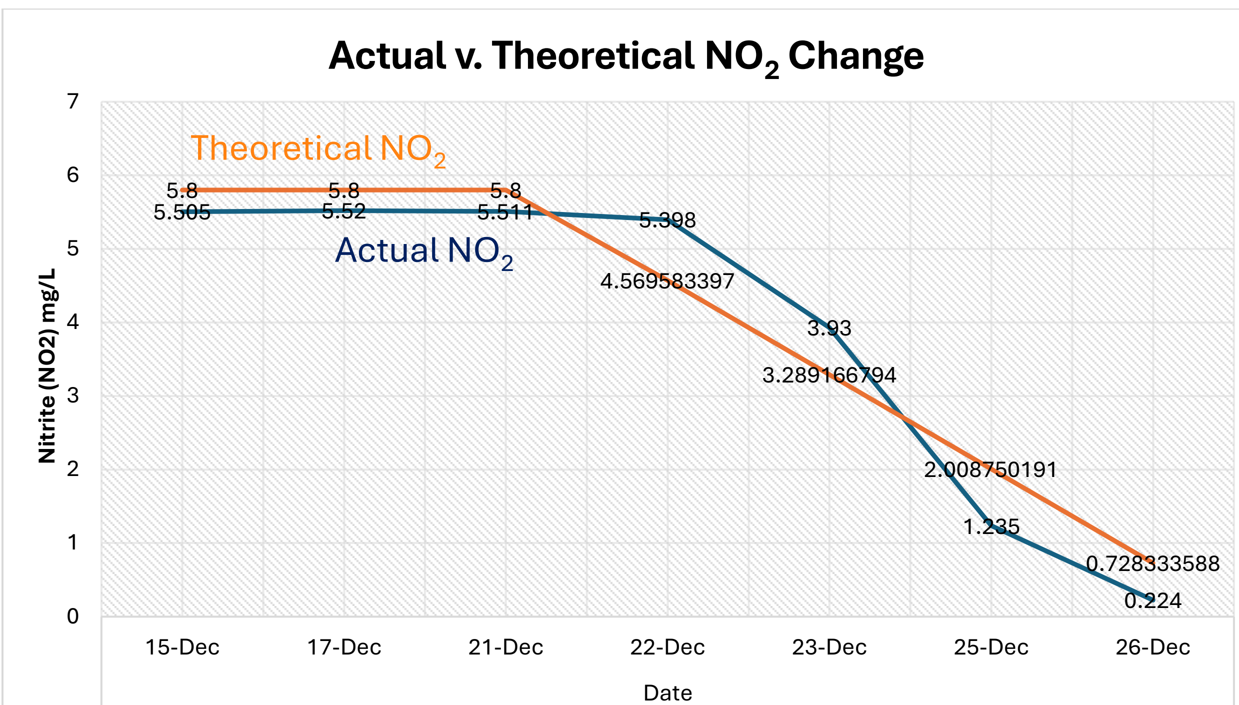

Figure 6. Comparison of actual nitrite levels and predictions from the ΨO_3 model above. Theoretical values predicted by the model showed a strong correlation with actual values (ρ=0.96889), validating the model.

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MEDIA FILTRATION – A POORLY UNDERSTOOD BUT VERY IMPORTANT ASPECT OF ANY WELL-FUNCTIONING FACILITY

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This article is not meant to be a thesis on media filtration but rather to draw out the main items to be aware of, without using complicated turns and theories. It is not a scientific paper but comes from accumulated experience over many years in the filtration field.

Introduction

To think that media filtration, as a technology has been around for centuries, but is often so poorly understood that the required performance, misses the mark by a long shot. Media filtration can take many forms: Slow Gravity Filtration, Rapid Gravity Filtration, Pressure

Filtration and Multimedia Pressure Filtration (to keep it simple)

The main concepts: 1) dirt is trapped between the media grains during the filtration phase and 2) particles adhere to the grains. In both cases the particles should be ejected during the backwash phase. Figure 1 explains the concepts involved. I believe that it is the perceived simplicity that has resulted in the under appreciation of the complexity of a well performing media filtration system

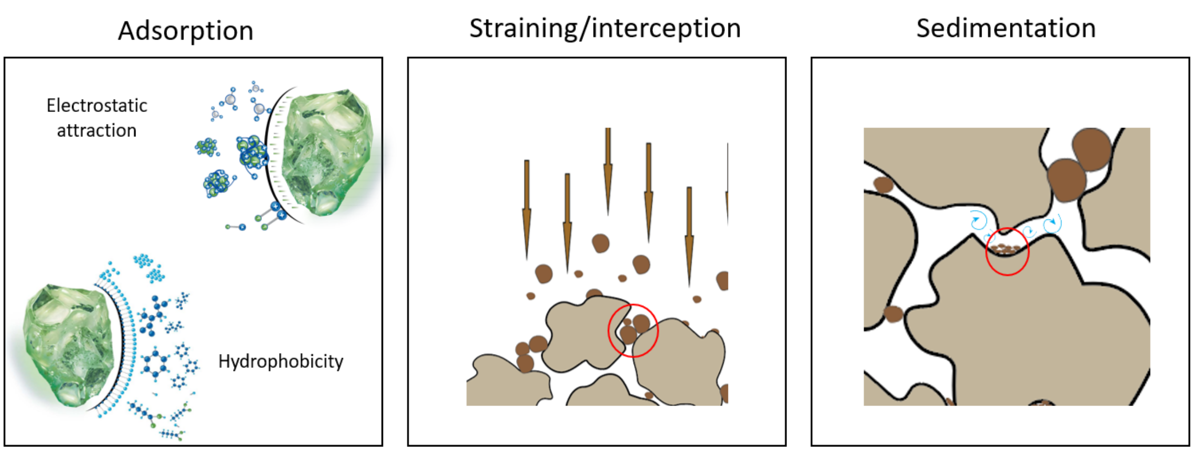


Figure 8. Media filtration mechanisms.

Main Impacts on Media Filtration Performance

1. Filtration velocity ($m^3/h/m^2$ or gpm/ft^2)
   a. Particle size
   b. Particle density
   c. Loading rate
2. Media bed depth
3. Backwash velocity & Bed expansion
4. Filter vessel hydraulic design

5. Media filtration in Aquaculture

Filtration Velocity

I suppose the interesting question to ask is what is the right filtration velocity? Well, that is very dependent on your water source quality, what you want to remove from that source, the efficiency of removal you want to achieve and what filtration method you are using (Table 1).

Table 1. Recommendation vs. frequently observed filtration velocities

Filtration Type	Application	Recommended		Often used	
		m/h ($m^3/h/m^2$)	gpm/ft^2	m/h ($m^3/h/m^2$)	gpm/ft^2
Gravity filters	Water treatment	5 - 10	2 - 4	5 - 10	2 - 4
	Aquariums	5 - 10	2 - 4	8 - 12	3 - 5
	Pools	5 - 10	2 - 4	10 - 15	4 - 6
Pressure filters & Multimedia	Water treatment	5 - 15	2 - 6	5 - 30	2 - 12
	Aquariums	15 - 25	6 – 10	15 - 40	6 - 16
	Pools	20 - 30	8 – 12	30 - 50	12 - 20
	Aquaculture	10 - 25	2 – 10	15 - 40	6 - 16

Ok, so let's take a step back; why is velocity so important?

a. Water source quality:

   Due to the lack of ionic charges in soft water that prevents the coagulation of particles to a size that can be filtered out, the filtration performance is generally compromised. Ideal alkalinity and hardness values for good filtration performance is 50 to 150 mg/l alkalinity and 80 to 200 mg/l hardness.

b. Particle size:

   If your velocities are very high and you are trying to remove mostly fines (sub 10 microns), the slower you filter the more chance that you will allow fine particles to settle out between the media. While at higher velocities the particles flow with the water stream and through the media bed (an example in Figure 2).

c. Particle Density:

   In any applications where the particles that you are trying to remove, might be very soft, such as soft organics (notice I separated the Aquaculture application in Table 1), the higher velocities tend to shear the particles into smaller and smaller pieces while travelling through the media bed, resulting in very little removal. This same effect is often seen in drum filters too, where the particles are squeezed through the mesh by the differential pressure caused by the water height differences between inside and outside the drum. Our studies have shown that in aquaculture RAS systems the filtration velocities should not be higher than 15m/h or 6gpm/ft^2.

d. Loading rate:

   In applications where there is a high TSS loading rate (>30mg/l), higher velocities cause a shift from depth filtration to surface filtration and therefore cause a quick increase in the differential pressure across the bed, resulting in particles being sheared into smaller pieces, but also increasing the backwash requirements substantially.

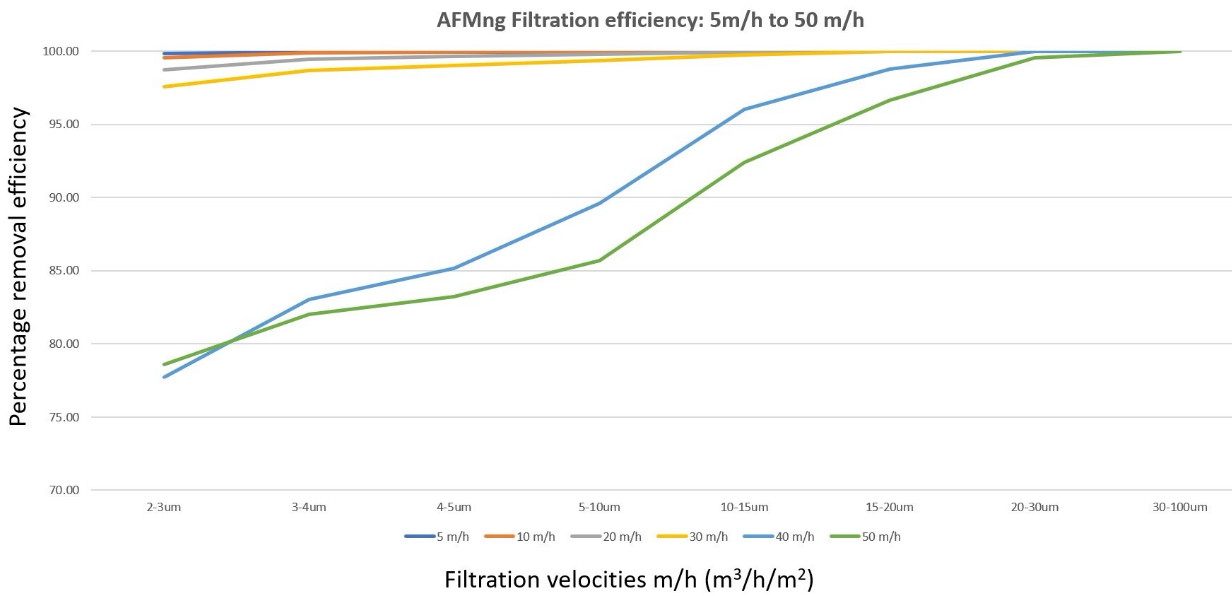


Figure 9. Filtration efficiency at different filtration velocities (0 to 50m/h (0 to 20gpm/ft2) (Dryden Aqua).

Media Bed Depth

As media filtration is not a barrier filtration such as cartridges, bags or membranes, it not only relies on surface blockage, but rather on all the principles described in Figure 3. Therefore, the more media depth you have the better your filtration efficiency.

Of course, this is more important when considering a once through flow, such as seawater intakes, and less impactful on recirculation systems or is it? Unfortunately, although the overall thought is that in recirc system eventually all the particles are removed, it is more common that the particles are sheared into smaller pieces and the bulk of small micron particles increases overtime, never actually being removed and therefore contributing to an increasing load which can often be seen in the increasing COD and BOD values (Chemical and Biological oxygen demands).

A minimum bed depth of 750mm (29 inches) of the filtration media grade will ensure the best possible performance for that particular media.

Backwash Bed Expansion and Backwash Velocity

Often the most underestimated impact on the overall system performance is the backwash velocity to ensure sufficient media bed expansion to allow for the removal of the dirt. Somewhere along the line a figure of 1.5 to 2 times the filtration velocity crept into recommendations and in swimming pools where their filtration velocities are 30m/h and they are therefore backwashing at 45m/h or 18gpm/ft^2, it can work to sufficiently expand the media and to lift the dirt out the filter, but when you are filtering at 15m/h or 4gpm/ft^2, then a backwash velocity of 22.5m/h or even 30m/h (6 or 12gpm/ft^2) is not even enough to expand the bed to allow for the dirt to move out the media never mind lifting that dirt out the filter. Of course, each grain size has a different expansion vs velocity, but Table 2 provides some generalizations for good backwash velocities used in industries:

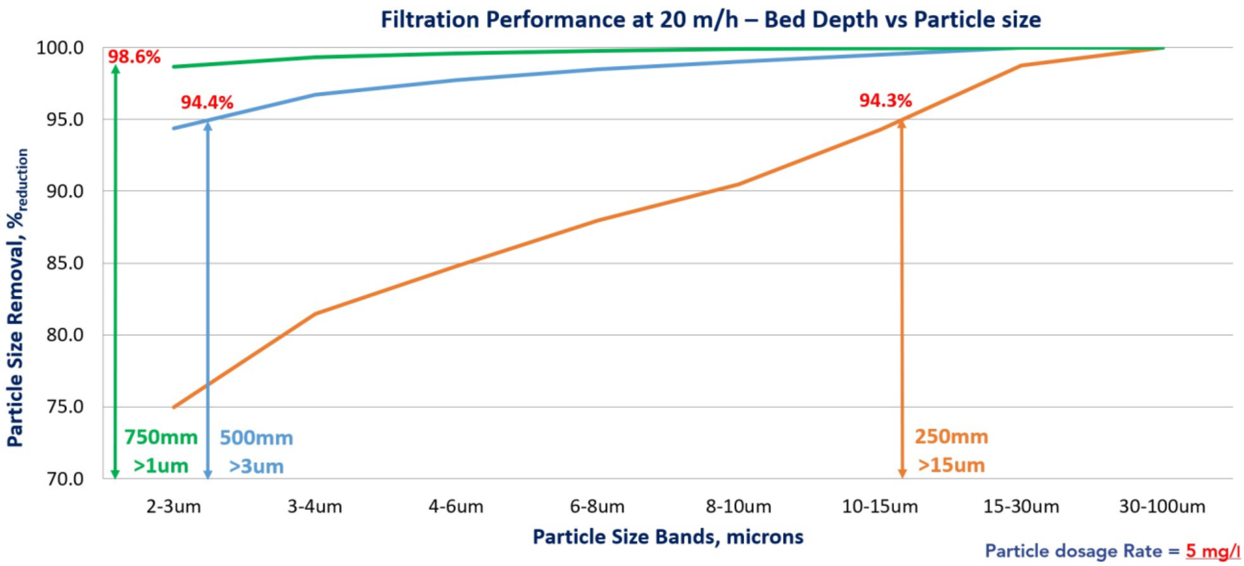


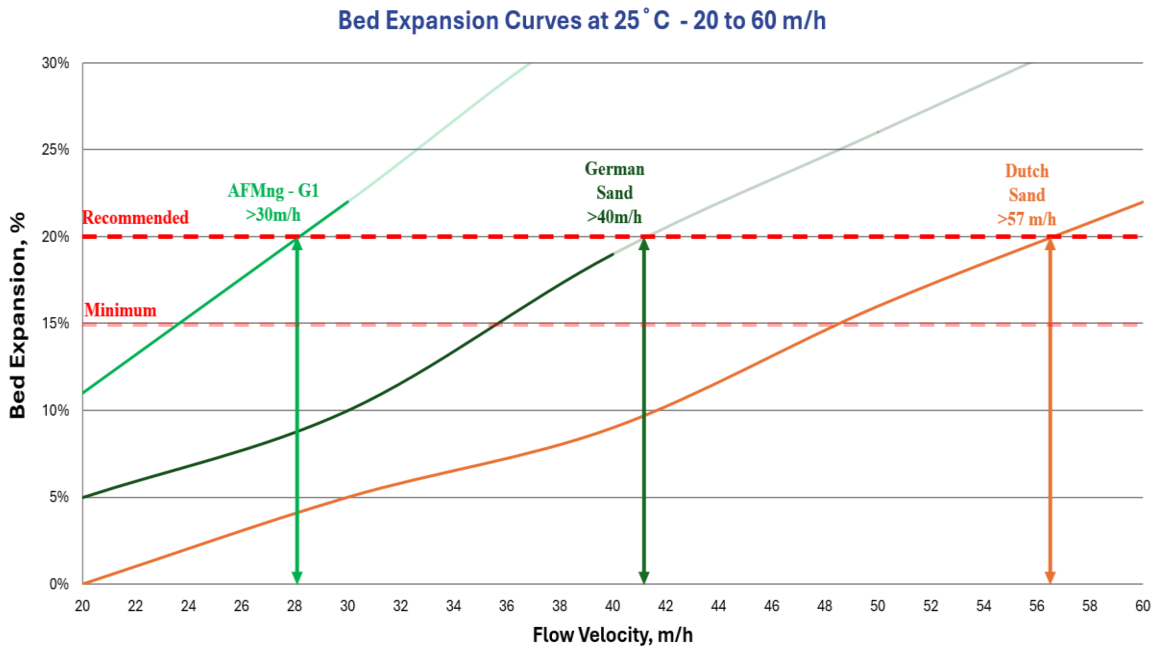
Figure 10. Filtration performance versus media bed depth @ filtration velocity of 20m/h (8gpm/ft2).

Table 2. Recommended vs frequently used backwash velocities. (Dryden Aqua)

Filtration Type	Application	Recommended		Often used	
		m/h ($m^3/h/m^2$)	gpm/ft^2	m/h ($m^3/h/m^2$)	gpm/ft^2
Gravity filters	Water treatment	15 - 60	6 - 25	15 - 35	8 - 14
	Aquariums	15 - 60	6 - 25	15 - 35	8 - 14
	Pools	15 - 60	6 - 25	15 - 35	8 - 14
Pressure filters & Multimedia	Water treatment	50 - 75	20 - 30	5 - 30	2 - 12
	Aquariums	35 - 45	14 - 18	15 - 40	6 - 16
	Pools	35 -45	14 - 18	30 - 50	12 - 20
	Aquaculture	40 - 50	16 - 20	15 - 40	6 - 16

However, everything is dependent on the media size and shape (Table 3), i.e. large grain sizes need higher velocities to get them to the required expansion, while elongated media, often found in some glass medias, requires very high velocities to get them to expand due to their shape. Secondly it also depends on the type of particles you need to get rid of i.e. heavy metal particles (oxidized from intake systems) require >50m/h or 20gpm/ft^2. Without naming products, Figure 4 (a, b) shows just how different bed expansions can be for different materials and even depending on from which mine the sand may have come from (red and orange lines are sand medias).

The German DIN standard requires a bed expansion of 15% to ensure that the media is separated enough to release the particles from the media, but depending on the specific gravity of the particles, even those that reach the expansion of 15 % at lower velocities does not mean that the particles will be lifted out of the filter and that is why most water treatment applications take 40m/h or 16gpm/ft^2 as a minimum requirement for backwash velocities. Even more importantly and contrary to most people's belief, higher backwash velocities actually save water as shown in Figure 5.



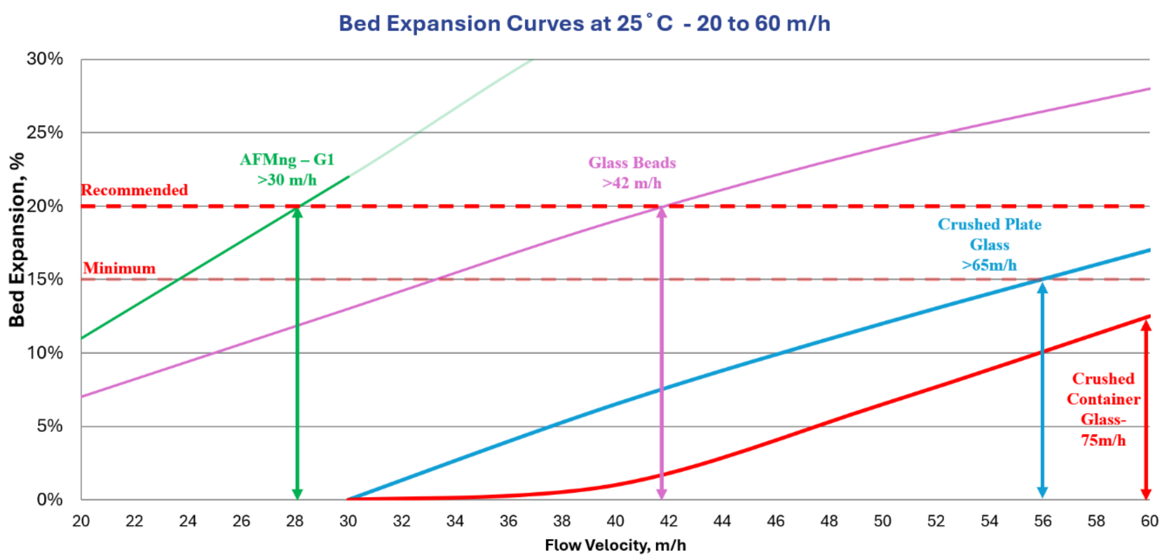


Figure 11a & b. Bed expansion curves of different media at the same temperature and flow velocities. (Dryden Aqua). This shows that not all medias are the same.

Table 3. Shows how the velocities can be quite different depending on the grain sizes (Evers Water Technologies):

Filter material Type	Grain size combinations (mm)		
Type	1	2	3
Anthracite	0.6 – 1.6	1.4 – 2.5	2 – 4
Quartz Sand	0.4 -0.8	0.71 – 1.25	1 - 2
Support layer Gravel	3.15 – 5.6	5.6 - 8	8 - 12
Backwash rate (m/h)	35 - 40	50 - 60	80 - 95
Backwash rate (gpm/ft^2)	14 - 16	20 - 25	33 - 39

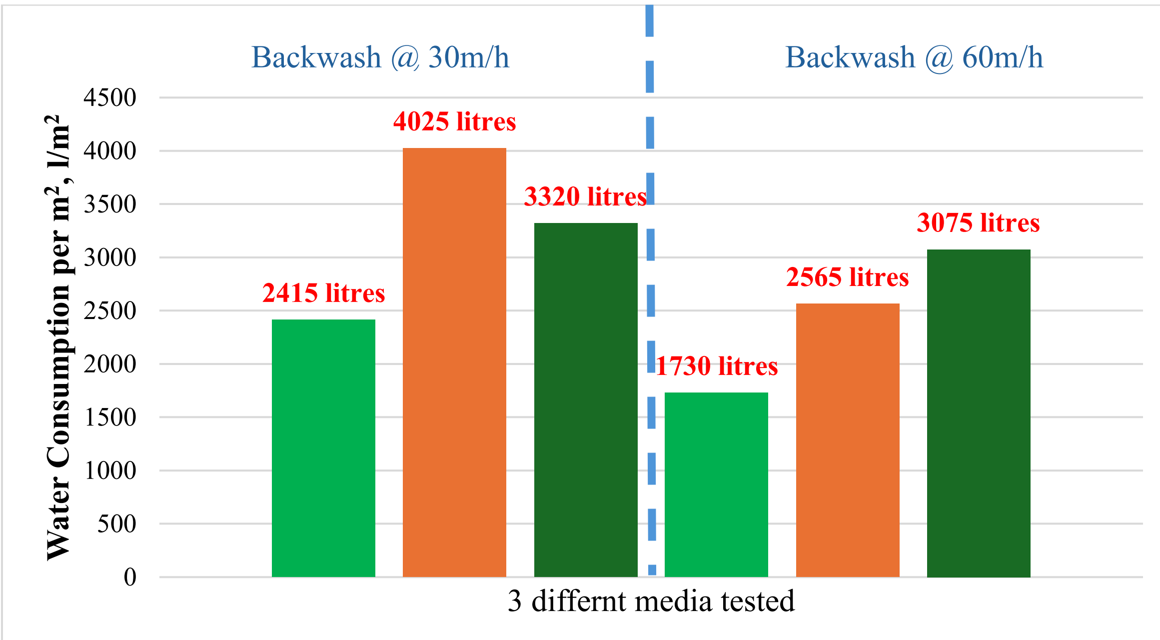


Figure 12. The faster your backwash flow the more water you save. Green vs Green, Orange vs Orange and Dark Green vs Dark Green at the different flows 30 vs 60m/h (12 vs 24gpm/ft2) (Dryden Aqua).

Filter Vessel Hydraulic Design

Unfortunately, over the years and with heavy competition to supply the cheapest filters, the swimming pool industry, Aquarium and aquaculture industries have been sucked into using filters that just can't perform for the requirements of the application.

1. A promise of filtration velocities of 50m/h or 20gpm/ft^2, which as shown above is not possible to achieve effective filtration performance.
2. Poorly design laterals that are either too short or too large in diameter to properly distribute the flows to create bed expansion instead of boiling the media. This results in only a portion of the filter surface area being used correctly, resulting in preferential flows through a much smaller surface area and therefore operating at much higher filtration velocities than you have designed for (Figure 6).

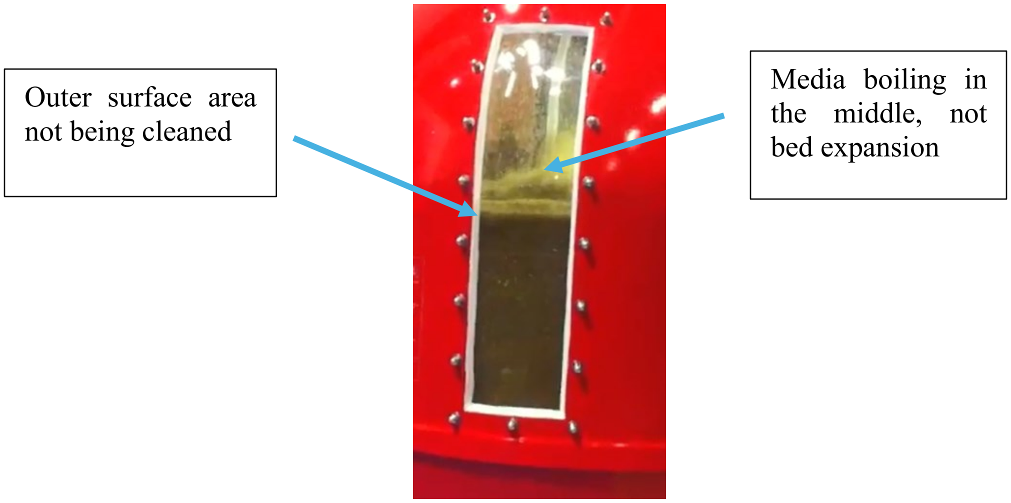


Figure 13. Ineffective backwashing, only the middle of the media is being cleaned (Dryden Aqua).

To demonstrate an extreme example that we have encountered before:
The client was filtering their public pool, at the manufacturers recommendation of 50m/h (20gpm/ft^2), and backwashing at 50m/h (20gpm/ft^2), but as the laterals were very short, the filter was only clean a 3rd of the surface area during the backwash, so when recalculating the filtration velocities of the actual surface area being used, the system was filtering at over 110m/h (45gpm/ft^2) resulting in no filtration performance, as the particles were just being sheared into smaller and smaller pieces increasing the overall COD and BOD while the water became more and more opaque (Figure 7).

Figure 14. Water seems white/opaque from high turbidity due to no particle removal, rather the particles being broken into smaller and smaller sizes.

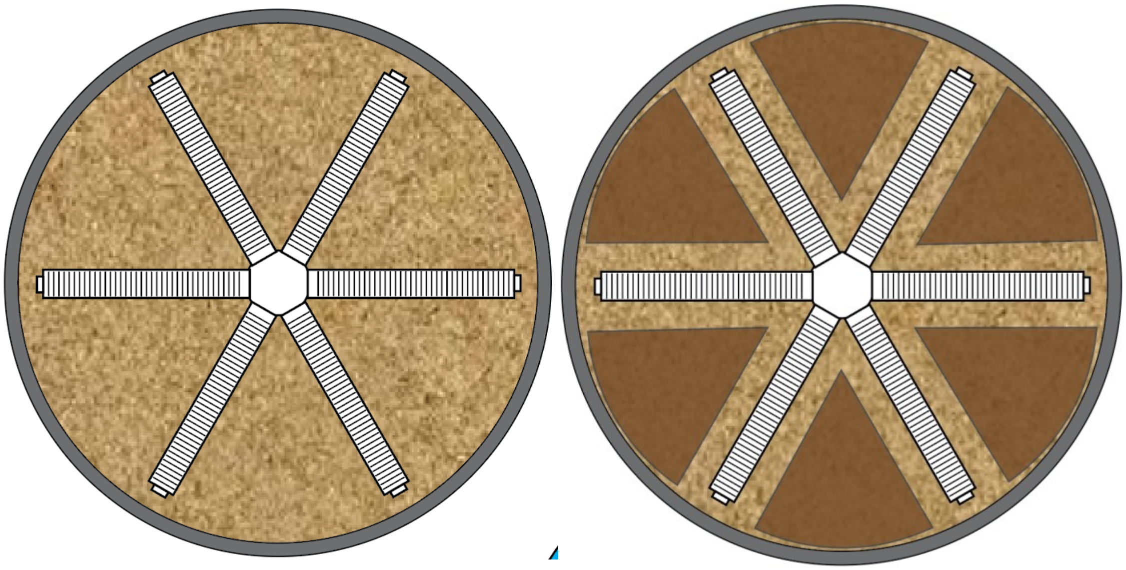


Figure 15. Demonstrates what happens with generic filters of larger diameters that use star shaped laterals

3. Filter laterals that do not have a good enough surface area coverage i.e. star shaped laterals with too few laterals section and in large diameter filters (>900mm) (Figure 8). The brown areas in the diagram on the right shows what isn't being cleaned during the backwash process. In the worst case where the laterals are also oversized in diameter, you would be able to see the star shape on the surface of your media.

4. Poorly designed inlet distribution, which causes the media to pile in the middle or around the edges, resulting in preferential flows through a much smaller surface and therefore operating at much higher filtration velocities than you have designed for (Figure 9).

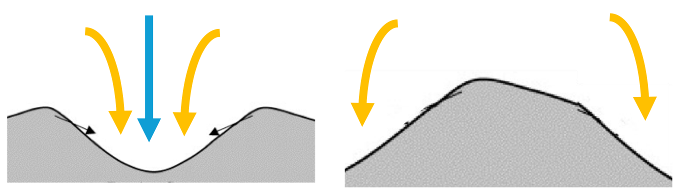


Figure 16. Poor inlet design leads to uneven filtration surface area and preferential flows

So, as can be seen from the above, media filtration can actually be far more complicated than it sounds, but taking a few basic concepts into account, can dramatically improve the performance of your filtration system, the overall efficiency of your system and future design considerations.

Media Filtration in Aquaculture

Media filtration is often used in intake water filtration, larval rearing flow through filtration, hatchery recirculation, brood stock filtration and wastewater filtration. However, with the importance of fine solids removal becoming more dominant in the overall efficiency of grow out RAS's, media filtration is again starting to be considered as a possible side loop solution for cropping out the particles that aren't being removed by the drum filters and are too big for the protein skimmers. These particles end up in the biofiltration component and shift the bacterial biome predominantly to the heterotrophs to first break down the particles before any nitrification can happen. This leads to increasing oxygen demands, pH and alkalinity corrections being needed and the requirement for excessive sludge to be removed from the system on a periodic/frequent basis.

Pacific Bluefin Tuna, Bruce Koike

SUPERSATURATION: THE INTERVIEW QUESTION WE OFTEN FUMBLE

Steve Bitter

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Having worked in several institutions, I've noticed that departments often have a prewritten list of interview questions to evaluate aquarist candidates. Among those questions there is almost always something pertaining to gas supersaturation, and how to handle an emergency. For whatever reason, this frequently seems like a weak spot in an interview. Despite being ubiquitous in interviews, I believe it's still a weak spot in our collective technical skills. This doesn't seem to keep it from popping up, and I suspect the interview question isn't going away anytime soon. In the next paragraphs I'd like to offer my best attempt at a simple explanation so that you can capably answer or evaluate this interview question, and more importantly so that you can be confident in preventing or responding to such an emergency if it happens to your exhibit.

To refresh some fundamentals, let's quickly revisit a couple of gas laws that help to understand saturation. The first is Henry's law, which says that at higher pressure, more gas is soluble in liquid (think of a soda can or beer keg, where pressure allows gas to be dissolved at higher levels). Henry's law also states that as temperature goes up, gas solubility goes down. The second is Dalton's law, which says that gasses dissolve proportionally to their partial pressures. You won't need these principles for the interview question, but they help to understand what's happening with gas saturation in our aquariums. In practical terms, we should remember that more gas will go into solution in the parts of our exhibits that have higher pressure, e.g. pressurized pipes or areas of significant water depth.

Further, let's consider dissolved gas in aquariums specifically. We measure dissolved oxygen most frequently, but there are other gases dissolving into our systems as well. Almost all LSS systems depend on atmospheric air to oxygenate the water, but that atmospheric air is only 21% oxygen. The remaining 79% is almost entirely nitrogen, which has its own solubility threshold in water. There are negligible amounts of other gases too, but they are minor enough amounts that we can ignore those for purposes of this discussion. The nitrogen in atmospheric air dissolves proportionally into water alongside the oxygen, and the total of these gases is referred to either as Total Dissolved Gas (TDG), sometimes translated to Total Gas Pressure (TGP). When the total dissolved gas in water is at perfect equilibrium with the air above it, the water is said to be at 100% saturation. Any more than that, and the water is said to be supersaturated. Barometric pressure fluctuates, and so TDG/TGP measurements are most useful when represented as a percentage value of the air above it.

Gas dissolves into the bloodstream of fish passively across the gill membrane, which means whatever is dissolved in the water will find its way into our animals' bloodstream. While we often use dissolved oxygen as an indicator to identify a gas supersaturation event, it isn't the oxygen itself that causes the health risk. Indeed, those that have measured the dissolved oxygen content of a fish bag packed with pure oxygen know that a concentration of 20mg/L (often 300%) is not uncommon upon arrival. Thinking about DO then is not the same as understanding TGP, because it doesn't account for the nitrogen component of air.

If you're a diver, you already know the risks of having too much nitrogen dissolved in the bloodstream. High levels of dissolved nitrogen become dangerous if pressure fluctuates, as it bubbles out of solution and causes embolisms (the "bends"). When nitrogen becomes supersaturated in the blood of fish, it poses the same physiological risks. Referred to as Gas Bubble Disease, it is often rapidly lethal. Gas Bubble Disease manifests as gill embolisms, exophthalmia, disorientation, vomiting, and death. Fish affected by a nitrogen saturation issue will often dive toward the bottom of the exhibit, instinctively trying to reach areas of higher pressure. It is likely that your institution has a protocol for how to identify this issue, and it is useful to think about which systems and animals in your collection may be most at risk. Most aquaculture sources suggest a baseline TGP value should be below 103%, and that acute issues begin around 110-115%. It may be that these tolerances are more nuanced and species-specific, and some animals (e.g syngnathids) seem especially intolerant to elevated nitrogen concentration.

Since we've established that higher pressure can increase the nitrogen in solution, and that too much nitrogen in solution can cause animal health issues, we should look at which parts of our systems create pressure and pose the biggest risks. The pressurized parts of our systems are typically either the plumbing and filtration components, or areas of significant water depth. While very deep exhibits or aggressively cascading waterfalls or overflow boxes can create pressure, these are typically static elements of a system and TGP issues will manifest at startup. However, filtration is getting serviced and adjusted constantly, and this is the biggest risk for causing a supersaturation event. Aquarium-scale filtration can run up to 50psi, which would be the same pressure as 110 ft of water depth. Pressure that high can dramatically increase the solubility of nitrogen, and it is these areas that create the biggest dangers. If air gets into the suction side of a pump, it will be pulverized into small bubbles with increased surface area just before going into the pressurized discharge side where it is very soluble. If you've worked with aquariums for a while, you know that it's not out of the question for air to find its way into filtration. For example, a sump level may fall low enough that the pump sucks air, or a plumbing fitting may get bumped or vibrate its way loose. Additionally, the mechanical seals in aquarium pumps are designed to last a long time but not forever. When they eventually fail, they can sometimes fail in a way that causes venturi effect, drawing air into the impeller cavity and sending it into the pressurized line. If not identified immediately, this is a recipe for a rapid increase in dissolved nitrogen. For this reason, suction lines and pump seals should be inspected and serviced on a regular basis.

Just like dissolved oxygen, TGP must be measured with a specific meter. Unlike DO however, TGP probes don't offer fast or efficient readings, and they need tedious calibration before using them. Until recently, even the best TGP meters on the market take 60 to 90 minutes to give a definitive reading, which is simply too long in an actual saturation emergency. There are newer products available (e.g. ProOceanus Solu-Blu TGP probe) which are made for long-term field deployment and provide longer periods between calibration and faster data collection. However, these are not mainstream yet and may be cost prohibitive for many institutions. If there is a TGP meter in your water quality lab, it is useful to occasionally practice using it and ensure that it can be calibrated and trusted when the necessity arrives.

If your system experiences a supersaturation emergency, the best way to intervene is to identify the pump/pressurized line causing the emergency and shut it down. If that isn't practical to do quickly, shutting all of the pumps down is likely a better choice than trying to do a lengthy investigation. Once this is complete, it is useful to deploy pure oxygen directly into the exhibit where the animals are. This will allow the exhibit to maintain adequate DO for the animals' respiration, and it will also change the partial pressure of oxygen and help any extra nitrogen in the animals' bloodstream to diffuse back out safely. This can triage the animal health concerns and allow you time to troubleshoot filtration and to call for help. Deploying oxygen like this is similar to how you might respond to a human in a diving emergency, and thinking about that parallel can be a useful way to understand and practice these skills. A supersaturation event is never easy, but quick action can prevent a bad situation from becoming catastrophic.

Like most aquarium emergencies, we should take steps to prevent supersaturation from occurring. This includes servicing pump seals and filtration as mentioned above, and proactively testing TGP occasionally. Another important component, especially in larger systems, is degas/deaeration towers. While we often think about these elements as useful for biological filtration and oxygenation, a key function of this technology is allowing dissolved nitrogen to off-gas and leave solution before it reaches our animals. If you're designing new filtration or taking over a new system, it is worth thinking about your system's capability for deaeration.

If I were to try to summarize this information into a quick concise statement (for example to answer an interview question about it), I might suggest something like this:

"Supersaturation refers to a situation where air is forced into solution in the aquarium water. Usually this is from a filtration failure, like air getting into a pump suction or a failed mechanical seal. The air contains not just oxygen but nitrogen, and that nitrogen can reach a saturation point in an animal's bloodstream that makes it a risk for embolisms and Gas Bubble Disease. The dissolved oxygen value in the water can be an indicator that this is happening, but may not tell the whole story, so it's best to confirm it with a TGP meter. If a supersaturation emergency happens, it would be best to shut down the suspect filtration and add pure oxygen to the water- sort of like you would in a dive emergency."

This article is a summary of a talk I gave at RAW 2024 in Tacoma, WA. A recording of that is available at animalprofessional.com, along with several other talks that are useful in further understanding this subject. Specifically, I recommend the talk by Ying Zhang of Hong Kong Ocean Park from AALSO 2018, a case study which illustrated the importance of adequate degassing as well as the benefits of supplemental oxygen. At that same AALSO conference, John Negrey of Monterey Bay Aquarium did a useful talk about dissolved gas in a natural seawater intake that is especially relevant for facilities pulling in water on the coast. Finally, Andy Aiken of National Aquarium in Baltimore offered some good details in a RAW presentation (talk from RAW 2016) describing optimal degas tower design and construction.

I consider TGP and supersaturation preparedness to be an advanced fundamental skill that is critical in rare but high-stakes situations. While we historically don't teach this very well in the aquarium world, my hope is that it is a skill that we collectively improve upon rapidly in the coming years. Maybe one day it won't even be such a ubiquitous interview question. In the meantime, the time you take to prepare and refresh these skills will make you a better and more prepared aquarist. It may even help you land your next role!

November 12-15, 2024
Phillip and Patricia Frost Museum of Science, Miami, FL.

This was the second annual ReeFlorida Symposium. Our mission was to connect researchers, educators, conservationists and managers who have an impact on reef health to strengthen scientific collaboration and conservation efforts. Over 200 individuals attended the event, resulting in 49 oral presentations, 12 poster presentations and 6 workshops.

-Shannon Jones, Frost Science Senior Director of Conservation
Contact for ReeFL 2025, dates TBD: sjones@frostscience.org

How DEP's Reef Injury Prevention and Response Program is Actively Protecting Florida's Coral Reef

Megan Miller[1]
[1]Florida Department of Environmental Protection

Since the implementation of the Florida Coral Reef Protection Act (CRPA) in 2009, Florida Department of Environmental Protection has served as the state's lead trustee for protecting, restoring, and educating the public about Florida's coral reef resources. The goal of the CRPA is to reduce coral reef impacts through increased legal authority by making it illegal to anchor on and/or damage a coral reef in state waters and giving DEP the authority to enforce such violations and collect damages and penalties from responsible parties. Within DEP, the Reef Injury Prevention and Response (RIPR) Program is responsible for the development and implementation of management actions that prevent coral reef injuries associated with commercial and recreational vessels, as well as the response, restoration and/or mitigation when injuries do occur. The RIPR Program also works directly with the Southeast Florida Action Network (SEAFAN), a citizen reporting and response system designed so that anybody can report marine incidents such as vessel groundings and anchor damage, marine debris, invasive species, harmful algal blooms, fish disease and fish kills, and coral disease and bleaching. The RIPR Program is responsible for responding to all SEAFAN reports of vessel groundings or anchor damage by assessing the damage following an injury event, performing restoration or mitigation if needed, and sending outreach materials to the responsible parties to reduce the likelihood of a repeat occurrence. One of the primary goals of the RIPR Program is to educate the public about coral reef resources and conservation actions that individuals can take to minimize impacts and protect Florida's Coral Reef. By promoting public awareness of the CRPA and providing resources such as mooring buoy maps and the Southeast Florida Coral Reef Locator map, the RIPR Program advocates for the protection of Florida's Coral Reef through education and outreach.

Teaching About Threats to Florida's Coral Reef Through Civic Action Projects

Analisa Duran[1], Mikaela Arena[1], Megan Ennes[2]
[1]Phillip and Patricia Frost Museum of Science, [2]Florida Museum of Natural History

Youth are concerned about their environment and are making a difference in their communities. Many are interested in becoming civically engaged to help their communities become more sustainable. In this session, we will share how participants can use CAPE (Community Action Projects for the Environment) to engage youth in civic action for the environment. We will walk through the importance of civic engagement and how it differs from service-learning projects. Then we will share the 8-module curriculum designed to help formal and informal educators facilitate community action projects with middle and high school aged audiences. Based on the Earth Force Model, this curriculum includes tested activities to help support the process of civic engagement. It is designed to support youth from all backgrounds by engaging them in local issues through a curriculum that is youth driven. We will share research behind the curriculum, and our experiences facilitating it in an informal learning environment. We will share the online materials which includes all of the leader guides, youth guides, printable versions of the worksheets, pre/post evaluation surveys, and additional training resources. Lastly, we will prompt session attendees to think through example community action projects focused on Florida's Coral Reef and how they may use aspects of the curriculum in their work.

Coral Protection and Restoration: Innovative Solutions for the Florida Reef Tract

Rachel Silverstein[1]
[1]Miami Waterkeeper

The expansion of ports along the eastern seaboard, including PortMiami, by the Army Corps of Engineers has had significant ecological consequences, particularly for the Florida Reef Tract. Between 2013-2015, dredging activities at PortMiami led to the millions of corals likely being smothered and impacted over 278 acres of critical reef habitat buried, far exceeding initial predictions. Despite the passage of seven years since the project's completion and five years since the last environmental monitoring report, a comprehensive impact assessment and mitigation remain pending. Future projects at PortMiami and Port Everglades will need to mitigate for expected damage to millions of corals, but current restoration infrastructure is inadequate to supply sufficient numbers of corals. A proposed solution involves establishing a large-scale coral restoration center in Miami, guided by scientific experts and using innovative restoration techniques. By finding synergy with resiliency initiatives such as the Back Bay study and the regional Climate TechHub grant, this initiative aims to restore damaged reefs, build capacity for large-scale mitigation and storm surge protection, and set a precedent for future coral conservation efforts, transforming the past damage into a positive future for Miami's reefs.

From Science to Policy: Collaborative Strategies for Coral Reef Resilience

Sara Thanner[1], Rebecca Ross[1], Mike Greenemeier[1], Austin Schlenz[1],
Laura Eldredge[1], Loren Parra[1]
[1]Miami-Dade County

Florida's Coral Reef is often said to be suffering a death by a thousand cuts from poor water quality to overfishing to physical impacts and everything in between. As the local steward, Miami-Dade County collaborates across departments and partners to protect, research, and advocate for our unique, yet stressed ecosystem. For almost fifty years, the County's Division of Environmental Resources Management (DERM), under the Department of Regulatory and Economic Resources, has continually worked to address both disease and physical impacts on local reefs. In response to Stony Coral Tissue Loss Disease (SCTLD), DERM biologists formed a Coral Disease Strike Team conducting reconnaissance dives to identify and treat coral colonies exhibiting signs of the SCTLD and respond to reports from the public or researchers/restoration practitioners. The offshore Mooring Buoy Program minimizes physical threats to the reef from boat anchor impacts and in 2023 the Program successfully expanded by 20%. Under the leadership of Mayor Daniella Levine Cava, multiple departments are now working to increase awareness and restore our coral reefs. The County parks department now exhibits interactive and interpretive programs to educate visitors on the importance of Florida's coral reefs, the biodiversity they support, the threats they face, and the important conservation actions that individuals can take to protect them. The Office of Resilience is working to incorporate nature-based solutions across County infrastructure projects, including wave-attenuating hybrid reefs as part of DERM's coastal risk assessment program, habitat monitoring and restoration program, and regulatory analysis. The County's forthcoming Biscayne Bay Reasonable Assurance Plan, spearheaded by DERM, will achieve the reduction of harmful nutrient loads that degrade our reefs. In partnership with Miami-Dade Police Department and community partners, the administration is prioritizing water safety and boating education that successfully protects both residents and our natural resources.

Benthic Community Dynamics and Demographics Barriers to Coral Recovery In Southeast Florida

Nicholas Jones[1], David Gilliam[1]
[1]Nova Southeastern University

The resilience of many coral reef communities has been diminished in the Anthropocene. Nowhere is this more evident than in Florida, where coral cover rarely recovers following disturbance. Understanding community dynamics and the demographic mechanisms of populations which underpin them, may provide insight into the barriers to coral recovery and the future for coral reef community structure. We quantified long-term changes in benthic community structure, and coral and octocoral recruitment and size structure in the marginal reef system off southeast Florida. We analyzed these in relation to disturbances and local environmental conditions to elucidate the drivers of change and assess the resilience of benthic taxa. Significant changes in benthic community structure coincided with major disturbances, which impacted the region on average once every 3 years. Repeated heat stress and disease from 2014-2017 caused mass mortality of many reef-building coral species, reducing coral cover by up to 85%. These species showed limited recovery subsequently, but overall coral density increased significantly at some sites, fueled by the substantial recruitment of weedy, non-reef building species. Spatial variation in recruitment was strongly influenced by the local temperature regime, with nutrient enrichment and sediment further reducing coral recovery potential by increasing macroalgal cover. Most colonies that did recruit remained small (5 cm) coral density (>200%), while mean coral size nearly doubled and coral cover exceeded that of reference reefs. Results from this study indicate that substrate stabilization should occur immediately after grounding events, as unconsolidated rubble showed limited recovery through the study. Baseline data collected after grounding events, coupled with a consistent monitoring regime are essential for tracking intervention success and community development. Additional action such as biological restoration may jump start stony coral recovery. This data gives insight to recovery timelines and provides resource managers with a framework to effectively respond to future grounding events.

Miami Beach Marine Park

David Grieser[1], Sam Van Leer[1], Patrick Breshike[1]
[1]Urban Paradise Guild

A largely unknown coral reef exists just 600 feet off of Lummus Park, the busiest beach in the USA. This near shore reef, full of endangered species and rare hard corals, holds great promise to drive education in our community. The difficulty of accessing reefs can be a limiting factor in our community's understanding and passion for Florida's coral ecosystems. What makes this site special is its short distance from the beach which is uncommon in Miami Dade County and South through the rest of the Florida Reef Tract. This provides great opportunity for both shore diving and shore snorkeling. This presentation seeks to explore the education, advocacy, and citizen science potential of a protected marine park designed to facilitate this unique shore access. We would discuss the biodiversity of the site and take attendees on a "virtual tour" of this near shore coral community. We would discuss protection possibilities at the local, State, and Federal levels and how these protections would help preserve the ecosystem and encourage responsible access. We would examine the benefits of a local municipality having a "front yard" reef to serve as a focus point for both education and advocacy for its residents and visitors. Most residents and visitors to Miami have never seen a coral reef. This park could have the potential to build a better, more informed, and passionate ocean advocacy community.

Coral Observer.com: How A Progressive Web Application Is Supporting the Collaborative, Caribbean Coral Spawning Database

Jennifer Mallon[1], Valerie Chamberland[2], Anastazia Banaszak[3], Hannah Ditzler[4], Rusty Leigh[5], Lynnette Roth Roth[6], Patricia Kramer[6]
[1]National Coral Reef Institute NCRI, Nova Southeastern University, [2]SECORE International/CARAMBI Marine Research Station, [3]CORALIUM Laboratory, National Autonomous University of Mexico, [4]SECORE International, [5]Quantumweb, [6]Atlantic and Gulf Rapid Reef Assessment (AGRRA)

Assisted fertilization of coral gametes can support sexual reproduction on contemporary coral reefs and enhance genetic diversity in restoration populations. Coral gametes are fertilized in the lab or field at low cost with high yield of coral larvae. The first step in this process is observing coral spawning to understand when and where gametes can be collected. However, in-situ coral spawning monitoring is labor-intensive, costly, and highly time sensitive. Many ecologically important Caribbean corals release spawn just one or two nights per year, but the estimation window for spawning can span many days or even weeks. While approximate time and date ranges can be estimated based on the lunar cycle, coral spawning windows vary geographically, and the most reliable way to predict when coral spawning will take place is to look at observation data from previous years at local sites. To streamline collaborative sharing of coral spawning data in the Caribbean, we developed Coral Observer, a progressive web application that can be used by anyone: researchers, restoration practitioners, citizen scientists, divers, and conservation volunteers, to collate useful data for scientists to plan gamete collection. Coral Observer can be used on cell phones, laptops, or any internet-supporting device. Data entered into Coral Observer enhances the Caribbean Coral Spawning Database to help with accurate spawning predictions and identification of geographical trends in coral spawning. In this talk, we demonstrate how the app works, discuss how to use it, and encourage future participation with Coral Observer.

Lost in Translation: The Role of Coral Reefs in Shoreline Protection in South Florida

William Precht[1], Chandler Precht[2], Alex Modys[3]
[1]Bio-Tech Consulting, [2]Sustainabity Science Program, Columbia University, [3]Coral Reef Consultant

Coral reefs protect coasts from erosion and flooding by attenuating wave energy. Recent meta-analyses have shown that a healthy coral reef that grows to sea level with active coral growth on its seaward facing slope can reduce wave energy by up to 97 %. In these analyses it was shown that reef crests were found to dissipate 86 % of the total incident wave energy, while reef flats dissipated ~65 % of the remaining energy. Under optimum conditions they protect shorelines by dissipating incoming wave energy, mainly by breaking waves in the ‘surf zone’ and through bottom friction as the waves move across the highly rugose living reef community. The above narrative is the accepted paradigm for reefs the world over including those in the Florida Keys and southeast Florida. But is this view correct? Unfortunately, not all reefs are created equal in their ability to dissipate waves. Critically, the depth of water above the reef; its cross-shelf profile; width of the reef flat; and the surface roughness associated with the living coral community on its seaward face determine the amount of wave attenuation. The transmission of wave energy from

the offshore wave regime to the shoreline varies significantly across reefs with differing geometries, geologic histories, and physical oceanographic settings. On the reefs in southeastern Florida, the inner reef terrace lies approximately 1.5-2.0 km from shore in water depths ranging from 6-11 meters with the outer reef being found seaward of the inner reefs in water depths of about 16 meters. The depth of these structures and their distance from shore provide little wave attenuation and minimal shoreline protection. This natural reef morphology has rendered the most densely populated areas (and most expensive real estate) of south Florida essentially defenseless against the onslaught of tropical storms and hurricanes.

Scouts and School Groups Visit Sea Base for All-Inclusive, Educational Experiences in the Florida Keys, Bahamas, and U.S. Virgin Islands

Abigail Clark[1], Mary DiLalla[1]
[1]Boy Scouts of America, Sea Base

Sea Base offers immersive, experiential learning opportunities to young people ages 12 and older through its numerous Scouting and non-Scouting programs. Sea Base has locations in the Florida Keys, Bahamas, and U.S. Virgin Islands that serve over 16,000 participants every year. Scouts participate in a variety of aquatics programs and learn fundamentals in sailing, fishing, scuba diving, ocean conservation, and much more. At Sea Base in Islamorada, FL, Scouts in the Scuba Advanced Marine Exploration Program have unique opportunities to help restore Florida's Coral Reef by outplanting corals and assisting in the maintenance of in-water coral nurseries. At the Sea Base Brinton Environmental Center (BEC) in Summerland Key, FL, every Scout visits Sea Base's very own land-based coral nursery. Introduced in 2019, the BEC coral nursery currently houses over 15,000 corals across eight species, including threatened and endangered species. Over 3,000 Scouts visit the coral nursery annually and learn about the role they can play in restoring Florida's Coral Reef. Of these 3,000 individuals, more than 300 youths work with Sea Base STEM staff in the coral nursery as part of the Marine Eco Expedition Program. As such, they participate in a variety of hands-on activities, including water quality testing and microfragmentation. In addition to coral husbandry and restoration, Scouts complete a variety of citizen science and service projects, including coral health assessments, shark tagging, fish surveys, and marine debris removal. These opportunities are also available to visiting school groups. From October to April, Sea Base is opened to school groups and to the general public, including conferences and workshops. Sea Base regularly receives visitors from middle schools, high schools, as well as colleges and universities, because of the educational programs and amenities that Sea Base offers, making it an ideal destination for school field trips and for researchers.

Upwelling Events on the Southeast Florida Shelf

Alexande Soloviev[1], Brian Ettinger[1], Terry Thompson[1]
[1]Nova Southeastern University

The coral benthic communities on Southeast Florida Shelf are occasionally exposed to upwellings. The cause and frequency of upwellings on Southeast Florida Shelf, however, are not fully understood. The classical wind induced coastal upwelling is not typical for western boundary current regions like the Straits of Florida; it has been observed only during hurricanes, which are relatively rare events. Internal wave solitons breaking on the continental slope are another cause of upwellings, though this mechanism is effective only in localized areas, like Conch Reef (Leihter et al., 1995; Miller 2023). A year-long series of glider transects on the Southeast Florida Shelf between Ft. Lauderdale and Jupiter has revealed the previously unknown upwelling mechanism associated with the southward jet attached to the continental slope and influenced by or coupled with submesoscale eddies (Soloviev et al., 2017; Quezada, 2023; Soloviev et al., 2023). This upwelling mechanism is forced by the southward jet lifting the cold deep water towards the coast due to the Coriolis effect. Here we expand the year-long glider observations of upwellings with the data from ADCP moorings deployed and maintained on the Southeast Florida Shelf by Nova Southeastern University from June 1999 to April 2024. This is a long and large data set with analysis that is still ongoing. The first results, however, indicate that the new mechanism is an important cause of upwellings. Notably, the upwelling events bring cold and nutrient-rich water to the shelf and thus may alter, suppress, or even damage coral reef benthic communities (Lirman et al., 2011).

Combined Restoration Efforts Improve Broward County's *Acropora Palmata* Population Viability

Michelle Mair[1], Casey Harris[2], David Gilliam[1]
[1]Nova Southeastern University, [2]Cummins Cederberg - Coastal & Marine Engineering

Florida's Coral Reef experienced an unprecedented die-off of *Acropora palmata* due to a severe heatwave in 2023. However, Broward County, Florida (the northern extent of this species' range) did not experience extreme heating, highlighting the potential for this area to act as a refuge for *A. palmata*. Restoration efforts have been employed to monitor all known existing colonies, preserve unique genotypes, and outplant additional genotypes to increase diversity. Since 2011, 16 sites with wild *A. palmata* parent colonies were tri-annually monitored to track growth, health, and fragmentation. Fragments found during monitoring periods were reattached to the substrate to increase survival and overall population abundance. As of May 2024, seven parent colonies remained, and reattached fragments had a survival of 62% one-year post attachment. Due to the progressive decline of Broward County's unique population, we sought to increase the redundancy of the remaining genotypes by clipping fragments from each genotype and placing them in our offshore nursery. Our gene bank housed a total of 50 fragments with a 76% survival. To further increase genetic diversity and test the restoration potential of Broward County, 23 genotypes from the Florida Keys were outplanted on the reef in January 2023. The overall survival was 54% one-year post outplant, yet the average percent increase in volume of live tissue area was 527%. Considering the loss of only one genotype, this effort quadrupled the genetic diversity of Broward County's population. While this region is not exempt from stressors, the relative success of *A. palmata* colonies in their northern extent reveals the restoration potential of this area. Our work still needs improvement, as our wild colonies and outplants experienced some mortality from disease, thermal stress, predation, and dislodgment during storms. Nevertheless, these combined efforts can be applied to restore other *A. palmata* populations throughout the Caribbean.

The Effects of Recurrent Disturbances on Coral Traits Over Time in Florida's Coral Reef

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Coral reefs provide a multitude of ecological, economic, and social benefits (i.e., ecosystem services) to nearly one billion people worldwide. However, coral reefs are put at risk of reconfiguration by the increasing extent and duration of anthropogenic disturbances worldwide. Examining changes to trait composition and diversity on already reconfigured reefs can provide insight into the potential future of coral reefs, as climate change continues to worsen. Here, we study how trait composition, diversity, and redundancy change in response to disturbance over eleven years on a high-latitude reconfigured reef ecosystem: Florida's Coral Reef. Long-term coral monitoring data, globally estimated coral species trait data, and disturbance data were combined to assess how trait composition, trait diversity (functional richness and Rao's quadratic equilibrium), and trait redundancy changed in response to disturbance over time, and what traits are defining these changes and explaining genera's response to disturbance. We found that trait composition changed over time in response to the duration and extent of cold stress events as well as the duration of heat stress events, but not in response to hurricanes or coral disease. Additionally, while heat and cold events impacted trait diversity and redundancy, trait diversity and redundancy did not change much over time, potentially indicating declines in trait diversity when coral communities declined in the 1970's, decades prior to this study. However, our results suggest these declines do not appear to drive communities towards resilient traits. Overall, our results indicate that the reconfigured Florida's Coral Reef is in a heavily trait-degraded state, but still responds to disturbance.

Searching for Survivors: Learning from the 2023 Coral Bleaching Event to Inform Resilient Restoration Strategies for Florida's Acropora Species

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[1]Mote Marine Laboratory

Acroporid populations on Florida's Coral Reef (FCR) have been decimated by disease outbreaks and bleaching events, motivating a strong restoration response. Since 2008, Mote Marine Laboratory has conducted effective large-scale coral outplanting on FCR, integrating corals that are resilient to intensifying environmental stressors. Coral survival, the number of outplanted fragments alive, is tracked at one month, one year, and three years post-outplanting. In response to the severe coral bleaching event in 2023, Mote monitored 365 unique *Acropora* spp. outplanting events on 51 reefs in the Lower and Middle Keys. 136 of those outplanting events were last monitored between October 2022 and July 2023, the period of time between the end of summer temperatures in 2022 and the start of bleaching alert level 1 in 2023. We used this subset, which included corals outplanted between April 2021 and June 2023, to assess the impact of the 2023 marine heatwave on Mote's restored Acroporid populations. *A. cervicornis* outplant survival before the 2023 bleaching event was ~72% and ~2% afterwards. Surviving *A. cervicornis* outplants included 14 'founding' genets that had been asexually propagated in-situ, several of which were previously experimentally determined as resistant to heat stress and/or disease. Over 90% of the *A. cervicornis* survivors were from two cohorts of selectively bred crosses of known disease resistant or susceptible parents, representing over 20 unique families. *A. palmata* outplant survival before the 2023 bleaching event was ~78% and ~0.2% afterwards. 36 genotypes of *A. palmata* survived, of which the majority were sexual recruits that had been integrated into Mote's restoration pipeline for several years. Although Mote's Acropora species' outplant survival after the 2023 bleaching event was only ~1%, the surviving corals support continued resilience research to inform assisted sexual reproduction efforts and promote long term restoration success and ecosystem recovery.

A Rehabilitation Framework for Effective Stony Coral Recovery at Ship Grounding Sites On Florida's Coral Reef

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Ship groundings are acute disturbances that cause substantial damage to the benthic community and underlying framework of coral reefs. Although rigorous management practices and technological advancements have reduced the likelihood of ship groundings, increases in maritime transport and boat traffic persist as threats towards Florida's coral reef. Therefore, resource managers need to understand stony coral recovery at previous grounding sites to properly respond to future grounding events. Using nearly two decades of data from ship grounding sites on Florida's coral reef, we developed a rehabilitation framework for stony coral recovery. Study sites included two ship grounding sites and four undisturbed reference reef sites nearby. Both groundings occurred in 2006 and their bow scars were stabilized using limestone boulders in 2015. Belt transects for stony coral demographic data and photo transects for benthic community cover were collected yearly, from 2016 to 2024. After 7 years of monitoring, stony coral recruit (5 cm) coral density (>200%), while mean coral size nearly doubled and coral cover exceeded that of reference reefs. Results from this study indicate that substrate stabilization should occur immediately after grounding events, as unconsolidated rubble showed limited recovery through the study. Baseline data collected after grounding events, coupled with a consistent monitoring regime are essential for tracking intervention success and community development. Additional action such as biological restoration may jump start stony coral recovery. This data gives insight to recovery timelines and provides resource managers with a framework to effectively respond to future grounding events.

Long Sediment-Laden Algal Turf, An Underappreciated Detractor of Florida's Coral Reef Resilience

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Coral reefs in the Florida Keys challenge a common paradigm describing the resilience of western Atlantic reefs. Coral abundance has declined over several decades driven by disease, bleaching, and storm damage. However, despite the high biomass of large herbivorous fishes, relatively low macroalgal cover, and availability of coral larvae, populations of corals have failed to recover on Florida reefs, suggesting that other factors may compromise the recruitment, post-settlement survival, and growth of small corals. We conducted field surveys and lab experiments to evaluate the potential effects of long sediment-laden algal turf (LSAT), a common yet poorly studied benthic group in Florida, on juvenile corals. The benthic assemblages of the upper section of Florida's Coral Reef (Fort Lauderdale to Key Largo) were evaluated seasonally between summer 2023 and spring 2024. LSAT comprised approximately 40% of the reef's benthic cover, with site-specific fluctuations in abundance and sediment load. Our field surveys found a 50% decline in the likelihood of juvenile coral presence as a function of sediment depth trapped within LSAT (5mm), but only during summer. In addition, we conducted experimental studies that assessed the response of larval settlement and recruit survival to the presence of sediments and substrate burial. The burial of suitable substrate significantly decreased the settlement probability for all species tested, with just 2 mm of sediment decreasing settlement probability to 25% or less and 4 mm suppressing settlement entirely. Similarly, burial of coral recruits under 4 mm of sediment decreased survival probability to 0-31% within ten days. Our results highlight the importance of improving habitat quality for conservation or restoration programs and identify a likely significant driver underpinning the coral recruitment crisis on Florida's Coral Reef.

Microbial Gene Expression Response to SCTLD Transmission

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Stony coral tissue loss disease (SCTLD) impacts over 22 species of reef-building Caribbean coral and is characterized by rapid tissue loss. Notably, Acropora cervicornis and *Porites astreoides* exhibit resilience to SCTLD, while *Montastraea cavernosa* and *Orbicella faveolata* show relatively higher susceptibility. Previous work has shown that microbial communities are important in the progression of SCTLD, however, the functional contributions of the microbiome in response to SCTLD exposure have not been explored. In this study, we conducted a controlled SCTLD transmission experiment involving these four coral species, selected for their diverse SCTLD susceptibility, ecological contributions, and priority in restoration practices. We characterized the microbial community (16S rRNA gene abundance, n=102), and functional profiles (metatranscriptome, n=77) from the host, algal symbiont, and microbiome of all four species. Here, our results will focus on the gene expression profiles of the coral microbiome. We found microbial genes were associated with transmission outcomes and coral susceptibility to SCTLD. This study sheds light on the differential susceptibility of coral species to SCTLD, highlighting the resilience of *Acropora cervicornis* and *Porites astreoides*. Moreover, our findings reveal novel insights into the functional role of the microbiome in response to SCTLD transmission, expanding our understanding of coral disease dynamics and producing reliable biomarkers of survival ideal for restoration decision making.

Transmissibility of Stony Coral Tissue Loss Disease (SCTLD) to Pacific Coral Species *Pavona clavus* and *Pocillopora* sp.

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Stony coral tissue loss disease (SCTLD) is a devastating coral disease first observed in 2014 near Virginia Key in Miami. It has since spread to 30 Caribbean countries and U.S. territories. However, it has yet to be observed in the Pacific. Prior studies have demonstrated the transmissibility of SCTLD via simulated ship ballast water, and the Panama Canal represents a potential avenue by which the disease could spread into the Pacific. It is therefore imperative to determine whether Pacific coral species are susceptible to SCTLD, and if so, to develop disease diagnostics. We conducted an ex-situ waterborne disease experiment to test the susceptibility of the common eastern Pacific coral species, *Pavona clavus* and *Pocillopora* sp., to SCTLD. Additionally, Orbicella faveolata was used as a SCTLD-susceptible Caribbean control species (Atlantic) to compare disease signs in Pacific species. Treatments included disease-exposed water (waterborne transmission), disease adjacent (near-contact transmission), and healthy coral-exposed water. Transmission data collected suggested that *P. clavus* and *Pocillopora* sp. are not immune to SCTLD, as some corals developed rapid tissue loss under near-contact and waterborne transmission. A survivorship analysis revealed that the susceptibilities of *P. clavus* and *Pocillipora* sp. to SCTLD are not significantly different from *O. faveolata*, a moderately-susceptible Caribbean species. Histological examination of coral lesions will corroborate the presence of SCTLD, while tissue samples will be analyzed for 16S microbial community variation and presence of SCTLD indicator taxa. Combined, these data provide a cellular and molecular diagnosis of SCTLD in P. clavus and *Pocillopora* sp., allowing the development of in-situ monitoring tools to evaluate the spread of disease in the Pacific Ocean. This information is critical for the management and prevention of SCTLD in coral reefs, providing further insight to the potential microbial origin of SCTLD, and developing SCTLD mitigation strategies across ocean basins.

A Coral's Journey: SECORE and Frost Science's Coral Conservation Collaboration

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In this presentation, we will explore the collaborative efforts between SECORE international and the Phillip and Patricia Frost Museum of Science to advance best husbandry practices for newly settled corals in their first year of life. Our presentation will begin with an introduction to SECORE international and their mission. We will then follow the life history of a cohort of corals that were successfully settled by SECORE using an ex-situ version of their proven CRIB larval settlement units. Detailed insights into the methods and challenges faced during this early stage will be shared, highlighting what was learned from the techniques employed. The narrative will continue as the corals were transferred to the Frost Science Coral Conservation Wet

Lab. Here, the focus shifts to the growout phase. We will present a comprehensive overview of the progress observed, supported by photo documentation and data collected, and discuss key milestones achieved. We will then dive into the implications of this collaborative effort, emphasizing how the experience gained can be instrumental in future coral conservation endeavors. We will explore the potential for scaling these practices to enhance our efforts. This presentation aims to offer insights for professionals in the marine conservation field on the importance of cross organizational collaboration by providing a detailed account of a concentrated effort between SECORE international and the Phillip and Patricia Frost Museum of Science.

Informed Selective Breeding for Increased Resiliency in *Acropora cervicornis* and *A. palmata*

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In response to the decline of natural *Acropora palmata* and *Acropora cervicornis* populations throughout Florida's Coral Reef, scientists are utilizing assisted sexual reproduction (ASR), a form of managed breeding, to increase the genetic diversity and adaptive potential of restored reef ecosystems. Mote Marine Laboratory houses a diverse inventory of *A. cervicornis* and *A. palmata* genotypes, both as a result of decades of wild coral collections and Mote's ASR efforts. Mote's science-based restoration strategy and managed breeding program are informed by seven years of resilience experiments testing restoration coral response to environmental stressors and disease, outplant survivorship data, in-situ nursery survival, and life history. This information also includes survival data associated with the 2023 marine heatwave. From this broad collection of data, we identified specific families and individuals that were more tolerant to stressors such as disease, high ocean temperatures, ocean acidification, and/or were more likely to host heat tolerant algal symbionts. This information is now being used to create a strategic approach that maximizes these resilient traits in the next generation of acroporid coral recruits by prioritizing specific crosses during upcoming annual coral spawning events. This resilience-focused selective breeding model will be used for immediate fertilization and larval rearing, as well as the potential use of cryopreserved *A. cervicornis* and *A. palmata* sperm for future utilization. This informed approach to selective breeding has already proven to be effective within small-scale outplanting events and we hope to continue developing our methodology with this model. Our approach will showcase the utility of this model for Florida's acroporids ultimately resulting in more effective restoration throughout Florida's reefs.

Predation Impacts on Restored *Acropora cervicornis*: Does Predator Culling Improve Coral Survivorship?

Mason Fitzgerald[1]
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Coral restoration can be effective at recovering lost coal cover rapidly. However, restoration practitioners are finding that outplanted corals are often exposed to the same threats as their wild counterparts, with predation by *Hermodice carunculata* (Bearded Fireworm) and *Coralliophila abbreviata* (Lamarck snail) identified as a major source of tissue mortality for restored Acropora colonies. This study evaluated the effectiveness of predator culling using baited *H.carunculata* traps and *C. abbreviata* hand removal from a restoration site established with 468 *A. cervicornis* colonies of different sizes to represent different states of restoration. Predators were collected and removed from half of the restoration plots every 2 weeks and all corals were surveyed for predation impacts for up to 4 months to evaluate the susceptibility of *A. cervicornis* to snail and fireworm predation based on colony size and predator culling. This information will help develop Acropora outplanting and maintenance strategies to improve coral survivorship and growth under intense predation.

Triggers, Cascades, & Endpoints: Connecting the Dots of Coral Bleaching Mechanisms

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Coral reefs, among the most diverse ecosystems on Earth, owe their success to the intricate symbiosis between corals and dinoflagellates. However, environmental stressors leading to coral bleaching and the subsequent loss of these symbionts are causing widespread reef degradation. Understanding the cellular mechanisms underlying coral bleaching is crucial for developing strategies to mitigate this crisis. In this presentation, I will introduce novel models that integrate the mechanisms of coral bleaching within a unified framework. These models categorize the bleaching process into three components: triggers (bleaching initiators; e.g., heat, hypoxia, light stress, cold), cascades (molecular pathways; e.g., nitric oxide, unfolded protein response, photoinhibition), and endpoints (symbiont loss mechanisms; e.g., necrosis, vomocytosis, apoptosis). Supported by direct evidence from cnidarian systems and comparative evolutionary analyses from non-cnidarian systems, these models reveal new mechanisms within and between cascades initiated by different bleaching triggers. Notably, our models shed light on the poorly understood connections between bleaching cascades and endpoints, highlighting a newly identified mechanism of symbiont loss, termed 'symbiolysosomal digestion,' distinct from symbiophagy. This comprehensive approach provides a detailed atlas of bleaching mechanisms, making the complex physiology of coral bleaching more accessible to both specialists and non-specialists. In the latter part of the talk, I will address major knowledge gaps and discuss how future research can enhance our understanding of the diverse cellular pathways leading to symbiont loss. By mapping these pathways, we aim to identify potential intervention points to prevent or reduce the impact of bleaching on coral reefs. This presentation aims to provide new insights and stimulate discussions on the cellular physiology of coral bleaching, ultimately contributing to the development of solutions to preserve these vital ecosystems.

Enhancing Resilience through Adaptive Management in Reef Restoration Programs

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[1]Coral Restoration Foundation

The Coral Restoration Foundation (CRF) has been actively restoring Florida's Coral Reef for over 16 years. During this period, CRF has continuously evolved its restoration approach by adapting to predictable and unforeseen challenges. Adaptive management is vital in coral reef restoration, enhancing resilience against disturbances and ensuring continuity in restoration efforts. Here, we discuss multiple instances where CRF has implemented adaptive management techniques at various stages of the restoration process. Within in-situ nursery settings, CRF has made multiple adaptations to the original Coral Tree structure to increase coral capacity without adding more structures to the nursery and while limiting biofouling. Additionally, the introduction of new species through partnerships, coral swaps, and collections from corals of opportunity (COOs) and manmade structures enhances genetic diversity in restoration without compromising native wild coral colonies. Most recently, CRF has incorporated ex-situ genetic banking to complement the genetic diversity within in-situ nurseries, building redundancy in preparation for future disturbance events. CRF has embraced knowledge from other practitioners and gained insights from firsthand experiences, such as the 2023 mass bleaching event. Lessons learned from this event have been translated into new practices, with targets adjusted accordingly. Current and future management and outplanting of coral stock are re-evaluated after the loss of coral nursery stock to determine how to continue raising abundant corals for restoration efforts. Lastly, CRF is collaborating with researchers to develop and deploy new outplanting strategies based on multiple species interactions on the reef. This new design of outplanting has sparked ideas that may change future restoration practices. This presentation will share how adaptive management, characterized by flexibility, ongoing learning, and the integration of scientific research, is crucial in reef restoration. Successful recovery in coral restoration efforts following significant disturbance events offers hope for continuing to assist the recovery of Florida's coral reef.

Reef Arches: Nature-Based Solution for Shorelines & Reefs

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Reef Arches offers an innovative solution to enhance the effectiveness of existing coastal infrastructure by reducing wave energy and supporting shoreline preservation and restoration. This system provides essential infrastructure for promoting coral growth, fostering a harmonious balance between engineered and natural elements. Unlike traditional wave break methods, Reef Arches utilizes a "flow-through design" that prevents the destructive channelization of water commonly associated with rip-rap and similar methods. The weight requirements of Reef Arches are dictated by wave energy, offering a range of sizes suitable for various sites (50 pounds, 1200 pounds, 7200 pounds). This adaptability ensures that Reef Arches can be effectively deployed in diverse environments, from small-scale installations to large coastal projects. The deployment of Reef Arches is designed to be low-impact and safe for barge deployments. Reef Arches serves as a nature-based solution ideal for applications like coral growth, particularly with its novel integration of special inserts designed to support coral attachment and development. The open flow-through design allows for light penetration, creating an environment conducive to the growth of multiple coral types within the complex structure. This integration not only supports the proliferation of corals but also contributes to the overall health of the coastal ecosystem. A unique aspect of Reef Arches is their stackable design, allowing for efficient use of space and ease of installation. The high surface area to weight ratio (120 sq ft per ton) maximizes the structural benefits while minimizing material usage. The efficient design also enables the use of high-grade CSA concrete at scale. By combining structural integrity with ecological benefits, Reef Arches represents a forward-thinking approach to coral restoration, inshore reef systems, promoting sustainable development and the preservation of marine habitats.

Octocoral Community Dynamics Over a Decade on the Florida Reef Tract

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Caribbean octocorals have shown remarkable resilience, maintaining steady populations despite coral disease and ocean warming challenges affecting many scleractinian populations. These foundational species, known for their high diversity and vertical structures, have consistently played a crucial role on Caribbean reefs. Notably, recent decades have witnessed an increase in the abundance of gorgonian octocorals, indicating their potential to flourish on reefs once dominated by scleractinians. This study examines octocoral population dynamics using data collected from 45 sites across Florida coral reef ecosystems between 2013 and 2023. We analyzed trends in octocoral abundance, biomass, and cover during periods of extreme weather events and major scleractinian degradation episodes, employing mixed-effects models to test for spatial and vertical effects. Our findings reveal an increase in octocoral abundance at most sites, while octocoral cover remained stable. Events like Hurricane Irma in 2017 had region-wide impacts; however, octocoral populations quickly rebounded to pre-storm densities, even surpassing them in some areas. Different reef habitats across Florida significantly influenced octocoral population dynamics, possibly suggesting that ecological niches and habitat suitability will play a vital role in the future of these communities. This study enhances our understanding of underexplored benthic fauna on Florida reefs and correspond with observations from other locations across the Caribbean, indicating that octocorals are more resilient to stressors compared to scleractinians.

Brick by Brick: The Efficacy and Efficiency of Keeping Corals Alive Through Disease Intervention

Karen Neely[1] , Kevin Macaulay[1] , Michelle Dobler[1] , Sydney Gallagher[1] , Arelys Chaparro[1] , Kathryn Toth[1]
[1]Nova Southeastern University

The majority of global and local reef stressors cause coral mortality that is unstoppable except through long-term, multi-stakeholder solutions. Mortality due to the highly lethal stony coral tissue loss disease is an exception, as an in-water medicine applied directly to lesions is highly effective at immediately halting disease and drastically reducing mortality. Within the

Florida Keys between 2019 and 2024, we treated over 5000 SCTLD-affected corals with a topical amoxicillin paste and subsequently conducted semi-monthly monitoring. Over 90% of treated lesions halted, and 94% of treated colonies survived. We estimate that these in-water treatments prevented the SCTLD-related loss of over 9700 square meters of coral tissue, equivalent to approximately 3.8 million coral outplants in the Florida Keys. Lesion treatments were localized and not prophylactic, but 36% of corals treated once did not develop lesions within the next year, and an additional 22% treated for new lesions 1-2 months after the initial treatment also remained disease free for at least the next year. While regular monitoring and follow-up treatments if necessary can reduce SCTLD-related mortality on target colonies to almost 0%, even one-time site visits to treat affected colonies can save large numbers of corals. For example, during just 16 days of targeted intervention cruises in Dry Tortugas National Park, we conducted one-time treatments on over 12,500 corals. Even if only 36% of these remained disease-free, the amount of tissue saved is estimated at 268 square meters, or the equivalent of over 151,000 outplants. Preventing the loss of corals through SCTLD in-water interventions is a time- and cost-effective way to maintain reefs. Additionally, these corals represent some of the largest, oldest animals on Earth and provide reproductive capacity and ecosystem services that would take decades to centuries to replace through other methods.

Too Hot to Handle? The Impact of the 2023 Hyperthermal Event on Florida Keys Corals

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The summer of 2023 was the hottest on record for the Florida Keys, with sea surface temperatures and cumulative heat stress exceeding all prior hyperthermal events. Semi-monthly monitoring of over 5000 boulder and brain corals across 9 reef sites documented total bleaching, but vastly different outcomes in coral survival. At offshore reefs, there was no bleaching-related mortality, although some of the largest boulder corals developed unusual lesions as temperatures subsided. At some inshore sites, bleaching-related mortality was similarly low. But at other inshore sites, total mortality of over 25% of colonies occurred as a direct result of bleaching. At one site, substantial mortality occurred before cumulative thermal stress reached critical levels, suggesting that in this instance, death was the result of direct high water temperatures. Within the two most heavily impacted sites, partial and total mortality from bleaching varied significantly among species, with brain corals exhibiting greater losses than boulder corals. Though the vast majority of the boulder and brain corals survived the severe 2023 summer temperatures, hyperthermal events are expected to become increasingly common and severe. Assessments of how corals responded in 2023 can inform future predictions as well as management best practices.

The Influence of Light Intensity and Water Movement on Growth and Photobiology of *Acropora palmata* in an Ex-Situ Nursery

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Land-based coral nurseries are vital tools for preserving genetic diversity and producing corals for restoration; however, the current body of knowledge for keeping, propagating, and growing corals ex situ is largely anecdotal and focuses primarily on Indo-Pacific "hobby" species. This lack of scientifically supported guidance on the care of Atlantic corals can manifest as slow growth and high mortality rates, limiting the effectiveness of land-based nurseries. As warming oceans continue to push more corals into human care, the need to optimize coral husbandry guidelines has never been greater. The branching coral Acropora palmata, historically a dominant species on shallow Caribbean reefs, can exhibit a range of growth rates and morphologies in human care; however, little has been done to understand why these differences occur. Here, we report on a controlled laboratory experiment to evaluate the combined effects of light intensity and water movement on the growth and health of A. palmata. To do this, we cultured 1-2 cm A. palmata fragments across gradients of light intensity and water movement for 9 months and characterized their dimensional growth rates (horizontal and vertical), calcification rate, and photosynthetic efficiency. Results are forthcoming; however, the findings of this study will provide valuable insight into the conditions and infrastructure needed to maximize the growth and health of this critically endangered species as it nears functional extinction throughout its range.

Toxicity of Arsenate and Arsenite to *Acropora cervicornis* and *Orbicella faveolata*

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Port Everglades is a large seaport in Fort Lauderdale, Florida, located adjacent to the coral communities at the northernmost end of the Florida Reef Tract. There are questions regarding how resuspended sediments from the planned expansion of the port could impact nearby coral reefs. Previously, threshold effect levels (TELs) and probable effects levels (PELs) have been derived for nine metals in Florida coastal waters. A recent study found concentrations of arsenic above TEL (7.24 µg/g) and PEL (41.6 µg/g) values in the port's sediments. Arsenic enters coastal waterways through anthropogenic activities and natural sedimentary processes. In corals, exposure to arsenic-contaminated sediments or solubilized arsenic may disrupt vital biological functions and symbiotic relationships, leading to coral bleaching and mortality. To assess the possible effects of soluble arsenic exposure on adjacent reef systems, the acute toxicity of arsenic species arsenate (As(V)) and arsenite (As(III)) were tested with coral species *Acropora cervicornis* and *Orbicella faveolata* using 96-hour static renewal assays. Each exposure assay included six treatments, consisting of five concentrations and a negative control, with six replicate beakers per treatment. Effects were evaluated based on coral mortality (LC50), coral condition (EC50), and the photosynthetic efficiency of the dinoflagellate symbiont (IC50). Arsenic concentrations were analytically verified. During the exposure assays, arsenate and arsenite were found to induce polyp discoloration and polyp retraction. The three highest concentrations of As(V) solutions resulted in 100% mortality after a 24-hour period, while the highest concentration of As(III) led to 100%

mortality after 48 hours. Arsenite, despite being tested at lower concentrations and within a narrower range, exhibited greater toxicity than As(V). This observation is consistent with prior research conducted on other marine organisms. The results of these experiments provide new data to support management decisions relating to the testing and disposal of arsenic-contaminated sediments in tropical coastal environments.

A Systems Approach to Caribbean Octocoral Symbiosis Networks

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Rising oceanic temperatures and other stressors have placed Caribbean hard corals under immense stress and have restructured reefs so that octocorals and sponges are now the predominant habitat providing organisms. Octocorals provide habitat for reef fish and invertebrates and aid in the cycling of nutrients throughout the water column. Their success is dependent on their symbiotic Zooxanthellae, however, our understanding of their resilience relies primarily on examination of a few species. For this reason, we set out to create a symbiosis network of Caribbean gorgonians and the Symbiodineacae that inhabit them to explore their symbiosis through a systems approach. This host-symbiont frequency-weighted interaction network will map species traits such as: host and symbiont thermal tolerance, transmission mode, and host morphology. These traits will be analyzed in a phylogenetic framework to assess patterns detected in observations and reductionist experiments on octocorals to search for emergent properties. This information can assist restoration efforts by offering guidance towards vital species.

Developing a Propagation Strategy for Rescued Corals for the Recovery of Florida's Coral Reef

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Since 2014, stony coral tissue loss disease (SCTLD) has caused the mortality of millions of colonies from >20 coral species on Florida's Coral Reef (FCR), including primary reef builders and species listed under the Endangered Species Act. A multi-agency Coral Rescue and Propagation Team (CRPT) was developed to design and implement a coral collection plan for SCTLD-susceptible species, preserve genetic diversity of Rescue corals in land-based holding, scale-up propagation, and plan for the restoration and introduction of Rescue coral offspring to the wild. Since 2018, the CRPT has collected over 2500 broodstock corals across 20 species now cared for via partnerships with 24 facilities across 13 states. Now that SCTLD prevalence has declined to background levels along FCR, propagation of these Rescue broodstock is paramount to creating sexual offspring which will be outplanted to assist in the recovery of coral populations on FCR. The CRPT has calculated the number of corals that need to be outplanted to restore 1% of the population that was lost due to SCTLD. Also, Florida's Coral Reef Restoration and Recovery Initiative (FCR3) uses a tiered approach to strategize long-term reef restoration and has created "Tier One Neighborhoods" areas to serve as priority reef restoration sites along FCR. The CRPT's restoration estimates have been extrapolated to estimate the number of corals needed to restore the "Tier One Neighborhoods" over time, thus allowing to estimate spacing needs for propagation and infrastructure/facility costs. Understanding the number of corals, the amount of propagation space, and the number of experienced staff necessary to successfully create the number of corals necessary to restore these state-designated priority neighborhoods over time is a crucial step in promoting and meeting reef-wide restoration needs.

Exploring the Potential of Native Sea Urchins as Ex-Situ Coral Propagation Allies

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Caribbean coral reefs are experiencing drastic declines due to various anthropogenic and environmental stressors, prompting the development of conservation and active restoration strategies. Among these efforts, ex-situ sexual propagation of corals is a critical component of active restoration, helping to maintain genetic diversity and increase population resilience. This study explores the efficacy of utilizing captive-reared sea urchin herbivory to control benthic algal proliferation and improve coral growth in land-based systems. For biosecurity considerations, any organism employed in co-culture with corals intended for reintroduction must share a similar origin. Therefore, we selected three native urchin species—Lytechinus variegatus, *Tripneustes ventricosus*, and *Diadema antillarum* - to evaluate their ability to control algal proliferation, enhance growth, and alter benthic algal communities with the brain coral *Pseudodiploria strigosa*. Juveniles of each urchin species were co-cultured with six-month-old sexually propagated *P. strigosa* colonies over a 105-day experiment. Results indicated that all urchin treatments significantly reduced algal cover compared to controls. The *T. ventricosus* treatment conferred the highest coral growth rate, though coral survival was consistently high across all treatments. Benthic community analysis revealed shifts in algal composition, with *D. antillarum* grazing associated with an increase in crustose coralline algae coverage. Overgrazing by *D. antillarum* may have resulted in mild peripheral tissue damage to some corals. Urchin survival remained high, suggesting potential for downstream utilization in restoration, such as stocking to augment herbivory on reefs. This study highlights the potential of native urchins as biocontrol agents in ex-situ coral propagation, emphasizing the importance of species-specific interactions in promoting coral resilience.

Fostering Equity in Marine Science: The Impact of the Your Shores Program

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[1]Frost Science

Your Shores is a collaborative project at Frost Science, integrating efforts from Museum Volunteers for the Environment (MUVE), Upward Bound Math and Science (UBMS) and the museum's Marine Conservation department. This coastal restoration program aims to foster equity and inclusion in marine and coastal science by engaging students from under-resourced areas and encouraging their continued education in STEM fields while enhancing various coastal ecosystems in northern Miami-Dade County. By removing financial and practical obstacles, the program makes marine science more accessible to underserved populations. Participants receive stipends and gain practical skills, research experience, service hours, certifications, and other resume-building experiences; collectively supporting their academic pursuits and opening pathways to careers in STEM. As part of the program, students are trained in scuba diving, coastal restoration

techniques, and biodiversity monitoring. The first cohort of seven students achieved notable accomplishments, gaining immersive educational experiences; completing eleven scuba dives and enhancing ecosystems at Haulover Beach Park by planting over 1,000 native plants and removing more than 200 gallons of nuisance and invasive species from endangered plant habitats. A majority of these students are now pursuing higher education degrees in marine and environmental science. The Your Shores program exemplifies how volunteer-based restoration, coupled with youth access to marine science resources, strengthens the social and economic resilience of the community and the future of conservation in South Florida.

Rescue to Reef: A Model for Hope

Leneita Fix[1]
[1]The Reef Institute

The Reef Institute (TRI) implements a strategy they call "Rescue to Reef," which involves using closed-loop systems indoors on land to scale up coral restoration to meet the urgent needs of Florida's coral reef. This targeted approach addresses the increasing threats facing Florida's coral reef through proactive measures. The process involves rescuing corals to bring them on land for long-term care in response to emergencies. Subsequently, the corals undergo sexual and asexual propagation, assisted fertilization, and larval settlement in systems designed to enhance juvenile settlement. By allowing for the control of variables and disease corals can be adapted for ongoing changes in ocean. The final stage includes transferring all juveniles back to the reef. Additionally, TRI offers training in coral husbandry for volunteers of all ages, from high school students to retirees, to assist in coral maintenance. A specialized training program for undergraduate students, regardless of background, aims to expand the coral husbandry workforce. This model provides for anyone's training and growth in coral husbandry and directed coral work. The goal is to create a sustainable model of coral restoration that allows for a pipeline of corals and those trained to continue with restoration efforts. This presentation will outline how this methodology can create a scalable approach to long-term care and restoration of Florida's coral reef.

Corals from Urbanized Habitats in Southeast Florida Are a Priority For Conservation and Restoration

Michael Studivan[1,2], Ashley Rossin[1,2,3], Lorelei Ing[1,4], Allyson DeMerlis[1,5], Nash Soderberg[1,2], Ben Chomitz[1,2], Albert Boyd[1,2], Keir Macartney[1,6], Ewelina Rubin[1,2], Rich Karp[1,2,5], Nicole Besemer[1], Sophia Ippolito[7], Taylor Gill[1,2], Patrick Kiel1,[5], Graham Kolodziej[1,2], Ashley Stevens[1,2], Mia Silverberg[1,2], Morgan Coleman[3], Gillian Coleman[3], Andrew Baker[5], Daniel Holstein[3], Mark Ladd[7], Ian Enochs[1]
[1]NOAA AOML, [2]University of Miami CIMAS, [3]Louisiana State University, [4]Smith College, [5]University of Miami Rosenstiel, [6]NOAA CCME, [7]NOAA SEFSC

Coral populations in southeast Florida have been marred by decades of coastal development and urbanization, disease outbreaks, land-based pollution, and thermal stress events. Yet, some of the most resilient corals in the region can be found in the most unexpected places, such as highly urbanized, artificial substrates in the Port of Miami. We have studied these ‘urban coral’ habitats for the past 6 years, focusing on 1) environmental and benthic community characterization, 2) lab-based climate change and disease experimentation, 3) molecular mechanisms of resilience, 4) algal symbiont assemblages, 5) isotopic signatures of energy sources, 6) field-based stress hardening, 7) population genetics, and 8) spawning and fecundity assessments. Not only are urban corals in the Port of Miami more resilient to thermal stress, ocean acidification, and disease, they exhibit molecular signatures of acclimatization to climate change-associated stressors. Further, these populations maintain species diversity of corals most affected by the stony coral tissue loss disease outbreak, and may be contributing to population persistence through spawning. Restoration efforts are now leveraging an abundance of urban corals in the region to increase production of broodstock for outplanting and maintaining genetic diversity on local reefs, as well as using urban coral sites for field-based stress hardening. However, the same unique circumstances that appear to have contributed to the observed resilience of these corals - continued coastal development and urbanization - threatens their very existence and survival. Conservation strategies are therefore critically needed to protect these unusual, yet valuable, ecosystems.

Elevated Temperature Decreases Stony Coral Tissue Loss Disease (SCTLD) Transmission Rate on *Orbicella faveolata*

Ana Palacio[1,2], Nash Soderberg[1,2], Zachary Zagon[3], Kenzie Cooke[1,2], Michael Studivan[1,2], Taylor Gill[1,2], Chris Kelble[2,4], Tyler Christian[1,2], Ian Enochs[2,4]
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Stony coral tissue loss disease (SCTLD) has caused extensive coral die-offs throughout the Western Atlantic. Although disease dynamics are influenced by environmental stressors, uncovering the environments that increase SCTLD activity has been elusive. We utilized a novel robotic multi-stressor system to investigate the effects of elevated temperature and nutrients on SCTLD transmission. *Orbicella faveolata* fragments were preconditioned for 16 days to two temperature treatments (28°C and 31°C) and two nutrient levels (with and without ammonium dosing) in a fully factorial design, before exposing them to waterborne SCTLD. Prior to the disease challenge, elevated temperature marginally decreased in Fv /Fm and favored algal symbiont communities dominated by *Durusdinium*. Ammonium dosing reduced coral calcification while slightly increasing algal symbiont abundance and photosynthetic efficiency (Fv /Fm). During the disease challenge, SCTLD transmission was lower at 31°C (17% of the fragments) compared to 28°C (70%) with no effects of nutrients. Our results indicate that elevated temperature reduces SCTLD transmission, offering potential insights for disease management. This is particularly relevant in anticipating a decrease in disease incidence during the summer months when elevated temperatures can provide protection against SCTLD. Acute heat stress and bleaching may still exacerbate disease once temperatures decline.

Optimizing Coral Sexual Propagation Ex Situ: Synergistic Effects of Multiple Cues on the Larval Settlement Rate of *Diploria labyrinthiformis*

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For coral restoration to be effective at the ecosystem scale, ex situ coral propagation needs to be optimized and cost-effective. One of the major bottlenecks to the sexual propagation of corals ex situ is low larval settlement rates. At nurseries, coral larvae settlement is typically induced by the presence of crustose coralline algae (CCA) and microbial films on ceramic tiles. However, coral larval settlement is known to also be enhanced by colored substrates, reef sounds, and presence of nutrients. Specifically, coral larvae have been observed to favor red and purple substrate, swim towards healthy reef sounds, and display higher settlement when fed. This study is assessing the potential synergistic effects of colored tiles, reef sounds, and food, along with the commonly used settlement cues (CCA and microbial films) on the settlement rates of coral larvae. To test this, *Diploria labyrinthiformis* larvae were exposed to tiles covered in CCA and microbial films with one or a combination of three additional settlement cues (purple tile, reef sounds, and food), and their settlement was assessed. Each of the eight treatments were performed in 8 replicate jars with 10 larvae each. We expect these cues will act synergically to boost larval settlement, allowing for ex situ coral sexual propagation to be further optimized.

Elevating Alkalinity as a Tool to Boost Production Rates of Coral Outplants In Inland Facilities

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As climate change threatens coral reefs globally and mass mortality events are becoming more frequent, scaling coral restoration efforts is crucial. A critical step in scaling is the accelerated production of biomass, which is necessary not just for producing large numbers of outplants, but also for increasing efficiency and reducing generation times. Preliminary evidence from aquarists, as well as lab and field studies that have strictly focused on calcification, suggest that this enhanced seawater alkalinity could be operationalized to grow corals at scale. To date, however, it has been unclear whether this benefit manifests strictly in higher skeletal density or in linear extension as well. Here, we use a sequential-treatment application robot (STAR-system) and 3D scanning to investigate the effect of elevated alkalinity on total calcification and linear extension in the critically endangered Caribbean coral, *Acropora cervicornis*. Using a sodium bicarbonate/sodium carbonate solution, corals (n=40) were exposed to one of four treatments for 33 days. The average total calcification (mg cm^{-2} day^{-1}) increased by as much as 24% under the highest alkaline treatment at around 1.8 times ambient seawater alkalinity (linear model: $p < 0.0001$, slope = 0.2). The average linear extension (mm day-1) increased by about 89% under the same treatment, although with higher variability (linear model: $p < 0.05$, slope = 0.02). These results indicate that using simple and inexpensive methods to artificially elevate alkalinity in land-based grow-out facilities may accelerate coral production, thereby helping to scale restoration efforts through greater biomass production and potentially shorter generation times.

Rebuilding Restoration Projects Post-Disaster: CRF's Resilient Response to Mortality Events in the Lower Keys

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Coral Restoration Foundation (CRF) is one of the largest coral restoration efforts in the world. In total, CRF nurseries hold nearly 1,000 coral trees and have the capacity to produce 40,000 reef ready corals every year. Since 2007, over 250,000 corals have been returned to the Florida's Coral Reef. However, these numbers were severely impacted in 2023 due to mass bleaching seen throughout the Caribbean. The 2023 mass bleaching event in the Florida Keys, while not unexpected, was unprecedented in three areas: its early arrival, its extreme temperatures, and its duration. Two of CRF's four main production nurseries, Looe Key and Key West, were hit the hardest, where Acroporid coral stock losses totaled 99.5%. The 2023 bleaching event was not the first time CRF had to rebuild a nursery from the ground up. Mass mortality events ranging from a cold snap bleaching in 2010 to Hurricane Irma in 2017 have impacted CRF's restoration efforts in the past, providing a blueprint in lessons learned and how to rebuild moving forward. Re-establishing these coral stocks is vital to CRF's program moving forward as they provide thousands of corals to Mission: Iconic Reef sites in the Lower Keys. Here we will discuss the current state of these two nurseries, our shift to incorporating species and genotypic diversity, the emphasis on non-acroporid propagation, and exploring deeper water nursery sites as temporary holding sites, among other methods novel to CRF.

Habitat, Not Genotype, Drives Chemical Profiles in Cryptic Lineages of *Montastraea Cavernosa*, the Great Star Coral

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A major consequence of coral decline is the reduction of genetic diversity within populations. Reduced genetic diversity may hamper populations' ability to adapt to changing environmental variables (e.g., rapid warming, pathogens, etc.). Because of this, reef practitioners and restoration organizations have aimed to preserve and/or generate genetic diversity by protecting particular reefs or habitats and cultivating diverse genotypes in coral nurseries for restoration. However, the recent discovery of cryptic genetic lineages within some species challenges these efforts. In the great star coral, *Montastraea cavernosa*, previous research has found at least six cryptic lineages across the Caribbean driven primarily by depth. Here, we performed a reciprocal transplantation experiment on the two shallowest of these cryptic lineages, MC4 and MC7, in the Florida Keys to help disentangle genotype x environment (GxE) interaction effects within these cryptic lineages. We hypothesized that fragments placed in their native environments would have increased fitness compared to their clones placed in their non-native habitats and that chemical profiles would be driven by lineage assignment rather than habitat of origin or transplantation. Contrary to our expectations, we found a strong effect of transplantation habitat on growth proxies and metabolomic profiles. This suggests that the local environment the coral is placed in has a greater influence on the fitness and chemical fingerprint than the lineage of the coral. This has strong implications for coral restoration practices, as the cultivation of certain genotypes may not matter as much as the health of the habitat that the coral is outplanted in.

Fish in Seagrass Habitats: Seascape Connectivity Across Protected Ecosystems (FISHSCAPE)

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[1]Florida International University

Seagrass habitats are important for supporting biodiversity and providing ecosystem services. Despite their importance, seagrass beds are often under-represented in management strategies and planning. For example, in the Florida Keys seagrasses comprise a small portion of protected habitats within Sanctuary Preserve Areas. Our multi-disciplinary project aims to identify the seagrass area needed to support foraging reef fishes. We characterize seascapes, resource availability, predation risk, fish foraging behaviors, and the energetic needs of fishes throughout the Keys. First, we mapped focal seascapes via training points and the classification of satellite imagery. Next, we surveyed prey resources in seagrass habitats of varying quality, allowing us to characterize the availability and accessibility of invertebrate prey across seascapes. We then assessed relative predator and prey abundances using baited remote underwater videos (BRUVs). BRUV data provides a metric of risk via predator encounter rates and behavioral responses to predator presence. We used acoustic telemetry to track fine and large-scale movements of four reef-associated species (white grunt, yellowtail snapper, mutton snapper, and barracuda). Fish movements were used to identify which seagrass habitats are used for foraging. Stable isotope analyses identified trends of shared resources between focal fish species, however additional data from sulfur isotopic content reveals partitioning in resource use and different reliance on seagrass prey. Finally, laboratory experiments quantified metabolic demands for two focal fish species using lab data along with acceleration values from tagged fishes in the field. Ultimately, field metabolic rates will be used to model energetic demands of fish and the consumption necessary to meet these demands across varying seascapes. Data generated from this project will be combined with long-term seagrass monitoring to predict seagrass areas necessary to support healthy fish populations under current and future habitat states. Consequently, FISHSCAPE aims to aid management decisions in the Florida Keys and beyond.

Developing a Restoration Strategy and Plans for Florida's Coral Reef

Caitlin Lustic[1], Kathleen Freeman[1], Laura Geselbracht[1], Chris Bergh[1]
[1]The Nature Conservancy

Florida’s Coral Reef forms the basis of our economy and way of life; and yet it faces both human-induced and natural threats that have caused a significant decline in the health of this critical ecosystem. Over the past two decades, scientists and practitioners have developed and refined coral reef restoration techniques as one tool to help reverse the decline. In an effort to better direct resources as restoration efforts scale up, the state of Florida identified a need for comprehensive restoration planning at both the state and regional level. Florida’s Tier 1 Strategy focuses on ecological goals to restore ecosystem structure and function and recommends places along Florida's Coral Reef where restoration is likely to have more impact based on long-term monitoring data and larval connectivity modeling. A more detailed plan for the Kristen Jacobs Coral Reef Ecosystem Conservation Area builds on the Strategy by including ecosystem service-related goals, and further narrowing potential restoration areas in support of those goals. These planning efforts will be used to guide state investments in restoration efforts and can be used by other reef managers and restoration practitioners to help prioritize reefs for restoration. Reef

Relief: Marine Science for All

Dora DeMaria[1], Alicia Manfroy[1], Tara McCracken[1]
[1]Reef Relief

Reef Relief is a non-profit located in Key West, Florida. Established in 1986, Reef Relief has spent decades educating the public about coral reef conservation. Their various programs have successfully engaged the public in marine science programs. Their most popular program to date has been their Discover Coral Reefs School program, that reached over 15,500 students in just the 2023-2024 school year alone. These programs are offered free of charge in their efforts to make quality marine science education free and accessible for all. During this presentation, Reef Relief will highlight their accomplishments as well as provide advice and tools to successfully communicate conservation science to a broad range of audience members. Participants will also gain access to a digital packet, accessing Reef Relief's educational resources to bring to their own classroom or facility.

Maximizing Coral Tissue Production: The Role of Fragment Size and Grow- Out Environment

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As Florida's Coral Reef experiences unprecedented declines from local and global stressors such as disease and thermal stress, practitioners are increasingly incorporating species with massive morphologies such as boulder and brain corals into the reef restoration toolbox. However, guidelines for the optimal propagation and outplanting of massive species are still in their infancy. A slow growth rate and high propensity for predation have limited the use of corals with massive morphologies within restoration. Here, we conducted a paired in-situ (nursery) and ex-situ (lab) experiment to investigate the effects of fragment size and grow-out location on the survivorship and growth of six coral species with multiple genotypes (*Orbicella faveolata*, *Pseudodiploria strigosa*, *P. clivosa*, *Montastraea cavernosa*, *Dichocoenia stokesii*, *Solenastrea buornoni*). Corals were fragmented into three size classes (1cm^2, 4cm^2, 9cm^2) and monitored monthly for changes in surface area. Preliminary analysis indicates that certain species favor smaller fragment sizes like *P. clivosa*, which showed a 150% increase in surface area while other species showed opposite with *O. faveolata* losing 20-60% of tissue surface area. After ~6 months, fragments have now been out planted onto a Miami reef to quantify the role of the main factors of the study (species, genotype, size, grow-out environment) on fish predation patterns. We expect to see a trade-off between the role of fragment size on growth and predation impacts (smaller fragments will have faster growth rates, higher predation mortality) influenced by species and genotype. The findings of this study will be used to inform on the optimal husbandry and use of massive corals to expand reef restoration efforts in the face of the two important bottlenecks: slow growth and predation.

Sequential Treatment Application Robot (STAR) for Coral Restoration Research

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The global issues of coral bleaching and reef degradation necessitate intervention on a scale that we have yet to achieve. This principle applies to various aspects of restoration, from coral cultivation, to stock maintenance, performance testing, genotype selection, reproduction, and ultimately outplanting. Despite significant progress in these areas, efforts have been hampered by a heavy reliance on manual labor, which is repetitive, time-consuming, and costly. Robotics and automation offer a promising solution. We have developed the Sequential Treatment Application Robot (STAR) system to enhance coral performance testing and support multi-stressor research. The system features a six-axis robotic arm mounted on a linear track, enabling it to move across multiple aquarium systems. A custom dosing system with syringe and peristaltic pumps delivers precise volumes of solutions via a series of tubes to an end effector, allowing the robot to apply specific treatment combinations to various aquaria and corals. Controlled by an intuitive graphical interface, STAR has proven effective in maintaining coral viability during multiple experiments. It is an open-source platform, with software, design files, and build instructions freely available online, making it easily modifiable for further technological advancements. Ongoing development includes capabilities for sample collection, specimen manipulation, feeding, and aquarium maintenance, with potential applications in aquaculture and land-based coral nurseries.

The Complexity of Complexity: The Importance of Structure to Fishes On Florida's Coral Reef

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The importance of complexity to reef fishes is well established. However, important questions remain as we consider the future of Florida's Coral Reef where flattening is an inevitable consequence of on-going coral loss. For example, fisheries management will be more effective if we understand the importance of structure to fish abundance compared to other biophysical drivers, which species will be particularly affected by flattening, and what aspects of complexity are particularly important to fish behavior. We firstly built comprehensive models of fish biomass in relation to fishing impact and 18 other biophysical variables. These models showed the importance of fishing on the snapper-grouper complex, but complexity was the strongest predictor for all other fish groups. Consequently, of the individual management scenarios tested, adding structure had the largest impact on predicted fish biomass. A more detailed species-level analysis also demonstrated the positive correlation between complexity and the presence of large-bodied parrotfishes that are functionally critical grazers. The importance of complexity to parrotfishes is consistent with a trait-based analysis of the characteristics of 109 species and their relationship to structure. This work shows that 53% of species will be 'losers' and become less abundant on low-complexity reefs, and the loss of structure appears more critical than loss of coral cover. Smaller, streamlined, habitat and trophic generalists are more likely 'winners' (increased abundance) on flattened reefs and large-bodied predators, among other taxa, are likely losers of reef flattening. Finally, we used structure-from-motion technology to examine which specific metrics of complexity affect the fine-scale movement of graysby. Space use was best predicted by the height of cavity-providing carbonate structures. These results suggest that conservation strategies aimed at protecting and increasing structural reef complexity should be a critical consideration in fish conservation and management discussions because of its impact on species' abundance, ecology and behavior.

The Potential for Species Interaction Targets, Based on Behavior, For Restoration Of Coral Reef Fish Communities

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Aldo Leopold advised that "[t]he first rule of intelligent tinkering is to keep all the pieces." As we collectively design and implement approaches for the restoration of coral reefs, we need to consider all the interacting elements that comprise the ecosystems around those reefs, notably fish communities and the diversity of interactions between species. Here we leverage a historic dataset of pair-wise fish species interactions from mixed-species foraging groups on Florida Keys reefs to ascertain behavioral relationships at species and trophic guild levels (based on diver surveys at the Aquarius undersea laboratory in 2010). Patterns of dominance (or lack thereof) within the resulting behavioral interaction webs reveal important positive species associations and functional roles indicative of community status (e.g., recovered, degraded) over space and time. In the specific case of the Florida Reef, these types of quantitative approaches can directly support assessments of restoration and recovery efforts.

Community Perceptions of the Florida Keys National Marine Sanctuary

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[1]NOAA, [2]WVU

Community perceptions of 459 individuals were collected regarding the Florida Keys National Marine Sanctuary (FKNMS) and the condition of its coral reefs. The primary activities that motivate people to visit the FKMNS are beach recreation (38%), fishing (34%) social event/interaction (5%), snorkeling (5%), general boating (5%) and kayaking/paddle boarding (2%). The proportion of respondents surveyed who were residents versus tourists was 86.2% and 13.8% respectively. Out of the surveyed individuals, 44.2% had heard about the Florida Keys National Marine Sanctuary. When asked about their satisfaction with their recreational experience, 66% reported being moderately satisfied, 33% were somewhat satisfied, and 1% were not satisfied at all. Next, respondents were asked about the factors that influenced their satisfaction. The most important factors mentioned were water quality/clarity (M=4.3, SD=1.0), seeing healthy reefs (M=4.3, SD=1.0), getting away from their normal routine (M=4.1, SD=1.1), seeing/catching

wildlife or sea life (M=3.7, SD=1.2), experiencing adventure (M=3.6, SD=1.2), learning about the ocean (M=3.5, SD=1.2), improving their skills (M=3.2, SD=1.4), and avoiding crowds (M=3.2, SD=1.4). Respondents were asked if they were familiar with coral reef restoration, with 47% indicating that they were not at all familiar, 26.6% slightly familiar, 18.3% moderately familiar, and 8.1% very familiar. Similarly, respondents were asked whether they were familiar with the Mission Iconic Reefs project, with 83% reporting that they were not at all familiar, 9.5% slightly familiar, 5% moderately familiar, 2% very familiar, and 1% extremely familiar. Based on our research, it is recommended that further outreach and educational programs involving the community that visits the FKNMS should be strengthened, as well as promoting greater community involvement in coral reef restoration efforts.

The Secret Life of Corallivorous Reef Fish: Understanding Coral Susceptibility to Enhance Restoration

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[1]University of Miami, [2]Lirman Lab of Benthic Ecology & Coral Restoration, [3]Rescue a Reef

The widespread impact of Stony Coral Tissue Loss Disease (SCTLD) on massive colony morphology coral populations in Florida's Coral Reef has necessitated their integration into propagation and restoration efforts. While massive coral propagation has successfully been demonstrated in both in situ and ex situ environments, predation by corallivorous fish (mainly by parrotfish and butterflyfish) can significantly affect these corals in the weeks after outplanting. Newly outplanted massive corals typically experience intense predation in the initial week to month after outplanting which gradually tapers off over time. However, the drivers of fish behavior and interactions with coral outplants remain poorly understood. To better understand these predator prey dynamics, fragments of nine species of coral were deployed, and their susceptibility to predation was monitored. Revealing a susceptibility hierarchy where PPOR, PSTR, PCLI and PAST are highly susceptible, MCAV and OFAV are moderately susceptible, and DLAB exhibited minimal susceptibly to predation. This study also tested the feasibility of stress hardening corals to predation in hopes of inducing a chemical defense response. Corals exposed to sublethal predation prior to outplanting experienced significantly less predation prevalence than those exposed to simulated predation or no predation. Furthermore, we developed a Coral- Baited Underwater Video system (C-BRUV) that was "baited" with a variety of coral species to observe fish behavior in the absence of divers. We identified Redband parrotfish, Foureye butterflyfish, and Stoplight parrotfish to be the most prevalent predators with *Pseudodiploria clivosa* being the most preferred prey species.

Art for Impact (Marine Habitat and Restoration)

Shelby Thomas[1]
[1]M.S scientist and founder of ORAI The Ocean Rescue

Alliance International (ORAI) is a marine conservation and restoration nonprofit organization that implements innovative techniques to restore our marine environments. ORAI creates artistic artificial reefs that are designed to increase fish biodiversity, enhance coral restoration, and provide a unique diving location. Our ability to connect people to the ocean is more important now than ever before. As reefs are degrading there is an immediate need for supplemental complex fish habitat to support fisheries and marine life. Through the use of artistic and complex reef structure ORAI aims to change the publics' relationship with the ocean and our coral reefs but more importantly create biodiverse habitat space. Facilitating a more personal connection with people and their marine environments. Art gives us the ability to connect people and cultures, designing unique dive sites which draw tourism, aiding in natural reef relief. Culturally impactful reefs connect and engage our local communities, creating a social responsibility to conserve and protect our reefs. Each reef integrates a habitat base with micro and macro habitat to target fish biodiversity. Each reef module has Coral Loks, a device that enhances coral out planting, embedded to provide an opportunity to out plant coral. ORAI integrates restoration technologies to scale reef artificial reefs. ORAI targets a community approach to sustainable restoration through incorporating art and memorials, our goal is to strengthen societies relationship our marine environments. Our citizen science and coral rangers program engages our local communities and youth in marine conservation, coral restoration, and reef monitoring efforts. Through habitat creation, restoration, research, and education ORAI seeks to conserve our marine ecosystems aiding in saving our oceans one reef at a time.

Steelhead, Bruce Koike

WHY AREN'T WE CULTURING OUR CLEANING CREW? A BRIEF REVIEW OF CULTURE METHODS FOR GASTROPODS IN THE ORDER TROCHIDA

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Akron Zoological Park, Editor: Drum and Croaker

Small gastropods are extremely popular for controlling algal growth in brightly illuminated marine aquariums and are some of the most commonly collected species in the live specimen trade. Many of these species are from the order Trochida, and have: 1) reproduceable spawning triggers; 2) very short planktonic stages that don't need to be supported with algal cultures (i.e., lecithotrophic veligers); 3) young juveniles that feed on diatoms or other biofilms; and 4) later dietary preferences for turf or macroalgae that we can accommodate.

Among the most reported invertebrate species in AZA collections in 2024 (Nelson, et al. 2025), snails from the genera *Turbo*, *Tegula*, *Trochus*, *Astrea*, *Lithopoma*, *Cerithium* and *Nassarius* lead the list. Although species ID or current genus names on this list may not all be current, all but the last two are members of the order Trochida. Related species are already aquacultured for food and shell production, including the green snail, *Turbo marmoratus*, and the commercial top shell, *Rochia* (previously *Trochus*) *nilotica* (Kitutani and Yamakawa 1999). Larval development and experimental culture have been reported for others, such as the wavy turban snail, *Megastrea* (previously *Lithopoma, Trochus, Astrea) undosa* (*undosum*), the gold-mouth turban, *Turbo chrysostomus* and the locally extinct or threatened, but IUCN and CITES "not evaluated," West Indian top shell, *Cittarium pica.*

While not a member of the same order, *Cerithium* spp. also may have a short, non-feeding larval stage. They lay egg masses and are not broadcast spawners.

In 2008, 2009 and 2011 the most commonly imported snails (to the USA) for the aquarium trade were reported to be: *Trochus maculatus*, *Tectus fenestratus*, *T. pyramis*, and two *Nassarius* spp. (Rhyne et al. 2017). Between 1994 and 2007 "cleaning crew" collection in Florida jumped markedly, with grazing snail harvest increasing 3-6-fold. This has led to concerns about sustainability (Rhyne et al. 2009), already an issue with larger related species worldwide. Most of the snails reported in each study were Trochida species. Life history studies on two Florida species, the American star snail *Lithopoma americanum*, and the chestnut turban *Turbo castanea,* reveal rapid growth to maximum size that may offset collection pressure somewhat. *L. americanum* reaches maximum size in 2 years, while *T. castanea* can achieve this in a year (Herbert et al. 2023). Rapid growth may also make these and similar species good candidates for aquarium culture, reducing take from the wild.

The following sections describe some of the known attributes of cultured Trochida species, and should provide a starting point for anyone considering propagating "cleaning crew" gastropods. This does not represent an exhaustive literature search, but is offered as a starting point for those interested in exploring snail culture.

Spawning Triggers

Much like stony corals, lunar and thermal cues can be important determinants of the onset of spawning. *Trochus maculatus* has been observed spawning in the field three days after a full moon, on a rising tide at 29.5°C. Sperm release preceded egg release by five minutes (Maboloc and Mingoa-Licuanan 2013). Spawning can also occur during a new moon (Chunhabundit 1993).

Cittarium pica also spawned in association with a new moon and rising tides, and at 25-28°C (Bell 1992, Velasco and Barros 2018). Bell also noted that settlement was induced by the presence of microbial/algal biofilms.

Rochia niloticus spawning begins after the snails move to a high spot in the aquarium at night, a few days before or after the new or full moon (Kitutani, and Yamakawa 1999). This corresponds to high spring tides, and local fisherman report that this is the time when trochus are most visible on the reef top (Dolorosa 2011). In this study males spawned about an hour before females. In the lab, this (and other) species seem to respond favorably to UV-treated water. UV-treated seawater kills microbes (Hijnen et al. 2006) leading to higher hatch rates. Lee (1997) moved specimens into water that was 2-3°C higher than normal for 2 hours, repeating this up to 3 times.

Guzman et al. (2003) induced spawning in *Megastrea undosa* by moving animals from 19°C to 28°C water, then back to the cooler bath. This was done twice for durations of 1.5 hours in each temperature regime. Actual spawning did not occur for up to six days after the temperature treatments. Salas-Garza et al. (2009) used a 4°C change for 30-60 minutes to stimulate spawning. Males always spawned 30-60 minutes before females.

Tegula funebralis spawned after a sea table water change resulting in a sudden temperature drop (Moran 1997).

Kudo et al. (1994) induced spawning in *Tectus pyramis* using temperature increases (25-27°C to 30-31°C) and 35% hydrogen peroxide (0.01 mg/L). During successful spawns, males spawned first at 25-37 minutes, and females followed 10-28 minutes later.

I observed *Lithopoma* sp. spawning in a sea table at Keys Marine Laboratory (Florida, USA) while monitoring some pillar coral fragments. This was several days after the full moon in August and water flow to the table was off or reduced to facilitate observation.

Soundscapes (healthy vs degraded) may play a role in determining settlement. *Turbo castanea* had a higher settlement response to degraded hardbottom soundscapes, while other gastropods responded more to healthy hardbottom soundscapes (Anderson et al. 2021). This may have implications related to "environmental" sounds in LSS spaces.

Larval Development

Trochus maculatus larvae settle within 24 hours and morph to a creeping stage in seven days (Chunhabundit 1993).

Cittarium pica larvae settled in 3.5-4.5 days (Bell 1992).

Turbo marmoratus hatch in 12-22 hours depending on temperature, and settle on the 4th day (Yamaguchi 1997). *Turbo chrysostomus* larvae do best at 26.5–27.5°C and a salinity of 31.5–35.5 g/L (Hamzah et al. 2021).

Rochia niloticus hatch in 10-12 hours, eventually move towards the surface, and ultimately settle in 3-4 days (Kitutani, and Yamakawa 1999).

Guzman et al. (2003) notes that *Megastrea undosa* larvae settle by day 5. Settlement may be enhanced using a 20°C cool water treatment for 24 hours (Guete-Salazar et al. 2021).

Tegula funebralis eggs hatched at 40 hours and settlement occurred by 6.7 days (Moran 1997).

Tectus pyramis settled to creeping stage only at temperatures above 22°C, varying from 61 hours at this lower temperature to 37 hours at 29-29°C.

Juvenile Diet

Navicula spp (benthic diatoms) are consumed by juvenile *Trochus maculatus* (Chunhabundit 1993) and *T. niloticus* (Dolorosa 2011). Murakoshi et al. (1993) describe *Navicula* culture. *Navicula* grow best at NO^{3-} and $PO^{4\ 3-}$ concentrations of 3.6 mg/L and 0.18 mg/L, respectively (Xiaobo et al. 2014).

Month-old *Rochia niloticus* grew well on a diet of the sessile diatom *Nitzschia* sp. that was cultured in f/2 medium before being inoculated on natural substrates (coral rock and shell rubble) (Gimin and Lee 1996).

Turbo marmoratus postlarvae and juveniles feed on diatoms, while older juveniles and adults consume red algae, preferring *Gelidium* turfs in one study (Yamaguchi 1995, Kitutani, and Yamakawa 1999).

Guzman et al. (2003) note that while benthic diatoms are frequently used to rear larvae of *Megastrea undosa*, they successfully fed two planktonic microalgae, *Nanochloropsis aculata* and *Phaeodactylum tricornotum.* However, Salas-Garza et al. (2009) used *Navicula* sp., the benthic diatom mentioned above.

Cittarium pica juveniles grew better when fed macroalgae (*Laurencia obtusa* and *Padina gymnospora*), than some biofilms (multi-specific vs the diatom, *Cylindroteca* sp.). However, biofilms established on mucus trails of congeners were also a successful medium for early juveniles (Velasco and Barros 2018).

Later Diets

An appropriate diet for older juveniles and adults is critical for survival. For example, Watson et al. (2018) fed three common aquarium grazers (*Turbo bruneus*, *Tectus fenestratus*, and *Tegula eiseni*) on a sole diet of *Ulva lactuca*. After 53 days all *T. bruneus* survived, but the majority of *T. fenestratus* were dead.

Two-month-old *Trochus maculatus* can be fed *Enteromorpha* spp. (Chunhabundit 1993).

Turbo chrysostomus were offered *Gracilaria* sp., *Ulva* spp. and *Kappaphycus alvarezii* (red, green, and brown algae, respectively), but in this case *Gracilaria* was the only medium that produced growth (Ridwanudin et al. 2016). Gut contents from wild-collected *Turbo marmoratus* contained a wide variety of green, brown and red algae (Kikutani et al. 2002). As noted above, lab reared specimens preferred red algae.

Older *Rochia niloticus* juveniles (1.5 cm) fed on the red macroalgae *Acamhophora muscoides* (Lambrinidis et al. 1997). Alternate diets may be an option. Indonesian fishermen maintain captive trochus on a diet of papaya or banana stems and animal skins (Burhanuddin 1997).

Megastraea undosa, a California native, prefers kelps especially *Macrocystis*, but eats a variety of macroalgae and may actually grow more efficiently on red algae (Cox and Murray 2006).

Growth

At 4-5 months of age, *Trochus maculatus* are 2.5-3.0 cm in diameter (Chunhabundit 1993).

Older *Rochia niloticus* juveniles (1.5 cm) fed on the red macroalgae *Acamhophora muscoides* (Lambrinidis et al. 1997). Those propagating Indo-Pacific corals will be interested to note that 2.6-cm individuals have been used to keep coral culture substrates and giant clams clear of turf algae (Villanueva et al. 2013, Clarke et al. 2003). They have also been co-cultured with red snapper (*Lutjanus argenticulatus*), and grew well on a diet of fish wastes and uneaten fish feed.

Turbo marmoratus reach 2-3 cm at a year of age, and mature at 3-4 years (Yamaguchi 1989 cited in Kitutani, and Yamakawa 1999, but attribution may contain a typo).

Juvenile *Cittarium pica* reached 3.4 mm at 6 months of age (Velasco and Barros 2018).

Planning for Culture

A few of the steps in evaluating methods and facilities for culture are listed below. More research is needed on individual target species.

1. Properly identify the species to be cultured. It is assumed that some identifications for collection planning purposes are based on the supplier's ID, which may not be correct in all cases.
2. Determine the appropriate trigger for spawning. Manipulating photoperiods, lunar cycles, tidal regimes and/or temperatures can be important. An oxidized water supply seems to be a common trigger, usually via UV-treated water, but in at least one case, the addition of hydrogen peroxide. Expect males to release gametes first.
3. Do larvae need a static or stirred environment during their brief planktonic stage?
4. Settlement cues should be considered. The presence of biofilms for initial feeding and proper temperatures can be important.
5. Establish food sources for settled larvae/early juveniles and growing snails. Diatom or other biofilm cultures are required for newly settled larvae of many Trochida species.

Larger juveniles and adults typically have food preferences for particular turfs or macroalgae. Providing the correct diet to breeding stock will condition them for spawning.

Final Words

We clearly have the ability to produce "cleaning crew" gastropods in our facilities. Small scale cultures by individual aquarists will prove the concept. Is it economical? Hard to say. Aquaculture has associated increased costs and many benefits including reducing take from the wild and the production of aquarium-adapted individuals. We are already very good at growing unwanted diatoms and turf algae. Some Trochida have already been used to keep newly settled and growing coral free of competing algae (Villanueva et al. 2013, Neil, et al. 2021), which will be important for coral spawning projects. Why not co-culture the cleaning crew?

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OBSERVATIONS OF AND CARE NOTES FOR THREE SPECIES OF LARGE MARINE GASTROPODS IN THE FAMILY FASCIOLARIIDAE FROM COASTAL WESTERN ATLANTIC WATERS

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Introduction

The family Fasciolariidae, commonly called the spindle shells, is comprised of large, carnivorous marine snails. Included in this family is the Horse Conch (*Triplofusus giganteus*), the second largest marine gastropod in the world, and the largest shelled gastropod in the United States. Tulip snails also belong to this family, several species of which can be found in the shallow waters of the coastal Western Atlantic Ocean. The Banded Tulip (*Cinctura hunteria*) and the True Tulip (*Fasciolaria tulipa*) are two such species. The relatively large size of even the smallest of these species, as well as the ease of collection of all three species make them great options for education and ambassador animals.

The following information was learned over nine years of keeping and displaying these animals at The Bailey-Matthews National Shell Museum and Aquarium in Sanibel, Florida. All photos were taken by Rebecca Mensch at The Bailey-Matthews National Shell Museum and Aquarium.

Horse Conch, *Triplofusus giganteus* (Kiener, 1840)

The Horse Conch (Figure 1A) is the second largest shelled gastropod in the world, and the largest in United States waters and the Atlantic Ocean. The world record shell specimen measures 23.9in and is housed at The Bailey-Matthews National Shell Museum and Aquarium. It is also the State Shell of Florida. Horse Conchs are found in the shallow waters of the Western Atlantic, ranging from North Carolina in the north down to Yucatan, Mexico in the south (Abbott, 1974). They are opportunistic predators and obligate carnivores. Despite its range and impressive size, relatively little else is published about this enigmatic species. It was only in 2022 that the first data was published regarding growth and age (Herbert et al., 2022).

Horse Conchs can be collected by hand year-round either by wading or diving in the shallow coastal waters of Florida (Geiger et al., 2020; Stephenson et al., 2013). Viable egg cases are found during winter and spring (D'Asaro, 1970), but spent cases can sometimes be found long into the summer which can be dried and used for education. Water temperatures of the Horse Conch's natural habitat are variable by region. Even in Southwest Florida, the Gulf of Mexico water temperatures vacillate from 60ºF to 90ºF throughout the year. Though there is no data on the amount of stress these extremes may or may not cause for the animals, Horse Conchs were always kept in the Museum between 72-78ºF.

Figure 1. A) Live Horse Conch specimen viewed from side. B) Horse Conch escaping enclosure. C) Horse Conch feces.

Horse Conchs should be kept in saltwater aquariums appropriate for their size. Length and width of the enclosure are of more importance than depth or overall volume. Enclosures must have a locking or heavily weighted lid in place while unsupervised. The animals are surprisingly strong and are not deterred by a few inches of dry acrylic (Figure 1B). Standard saltwater aquarium life support systems are necessary, including a protein skimmer. Horse Conchs can produce a prodigious amount of waste (Figure 1C) which is not always taken care of by the cleanup crew. Regular gravel vacuuming the day after feeding is strongly recommended.

Horse Conchs are usually not very active and will spend several days sitting in one spot but can put on quite a burst of speed when in pursuit of prey. Unless food has just been introduced, they seemed to be most active when no one was around. The two main hypotheses on this are that it is a result of bright lighting during the day or movement of guests and staff around the enclosure, which the animals are unable to discern from the movement of a large predator swimming nearby. Due to infrequent activity, guests have a more impactful experience with these animals at exhibits that have a docent. These animals do well in supervised touch pools with the standard "2-finger touch" rule, except when an animal is eating.

Sexing these animals is very easy but does require patience. Gently turn the animal on its "back" with the shell aperture facing up. If the animal resists being picked up, do not try pulling harder; instead, try sliding the animal sideways, or gently running your finger around the margin of the foot. Once lifted the animal will quickly withdraw into its shell, using its operculum to protect itself. Do not disturb the animal again. After roughly one to ten minutes, the animal will stretch out its foot, grasp the substrate, and quickly flip itself back over. While the animal has its foot out, but before flipping, observe the soft body of the animal as far up into the shell as possible. The female animals will appear smooth, while the males exhibit a very large, conspicuous, coiled penis (Figure 2).


Figure 2. Horse Conch flipping over, making its large, coiled penis observable.

Horse Conchs are voracious predators of other gastropods (Figure 3A), including smaller conspecifics (Dietl, 2003). Captive breeding was not attempted due to cannibalism concerns. Horse Conchs should not be housed with other gastropods that are not intended to be food, unless the other gastropod is significantly larger than the Horse Conch (Dietl, 2003). This author once observed an 8in Horse Conch consuming an 8in Lightning Whelk (*Sinistrofulgur sinistrum*) kept in the same enclosure. The Horse Conch did not eat again for six weeks, even though live and frozen food were consistently offered. Horse Conchs most likely have a wider variety of prey in the wild as they will readily eat frozen bivalves under human care and have even been observed scavenging dead fish in the wild (J Rader, Personal Communication, 2018), but certainly prefer live gastropods when given a choice. Horse Conchs kept at the Museum were fed once a week, primarily frozen bivalves (Figure 3B). Six-inch-long Horse Conchs consistently consumed three frozen or live clams or mussels once a week. Twelve-inch-long Horse Conchs consumed four to six frozen or live clams or mussels once a week. These numbers are roughly in line with Paine's observations (1963) of wild Horse Conchs eating about one gastropod every four days, or 3% of their own volume in prey per day.

Figure 3. A) Adult Horse Conch eating a Crown Conch (*Melongena corona*). B) Adult Horse Conch eating a frozen mussel.

While the world record Horse Conch shell is nearly 2ft long, most adult specimens collected today are not larger than 12in. Horse Conchs less than 3in long were not consistently successful in surviving more than one year under human care. Animals longer than 6in were consistently successful, with one specimen surviving more than five years under human care at the Museum. Long-term survival and growth studies were routinely stymied by tropical storms and hurricanes. This author recommends a minimum size for exhibit of 6in long.

Viable egg cases from Horse Conchs may be collected from the beach during winter months and add significant contributions to educational opportunities when displayed with or near adults. On April 8, 2017, a viable egg case was legally collected from a beach on Sanibel and placed in a 90gal saltwater aquarium next to an aquarium displaying adult Horse Conchs. Several hatchlings were first noticed on April 21, 2017. Several hundred hatchlings were observed on May 8, 2017. All hatchlings emerged from their egg capsules with entirely white shells and white soft bodies, a sharp contrast to the stunning orange of the adults of the species. By May 28, 2017, a few hatchlings started to grow orange shells, and their soft bodies had begun to turn orange, about one month after the first hatchlings were observed. The white protoconchs were still intact. On June 22, 2017, multiple 0.25in long orange specimens were observed eating smaller white specimens. Soon after, the egg case was removed from the system due to a red nematode infestation within it. Many capsules were unhatched, but it was unclear if the embryos inside were still viable or not. In the end of June 2017, one "albino" hatchling was observed. The specimen was about 0.5in long, a size at which all other hatchlings had long since turned orange. The hatchlings were observed eating a frozen mussel in August 2017, while still being observed cannibalizing. By December 2017 and January 2018 only two live hatchlings remained at a size of about 0.75in. At that time, they were moved to the main program tank in the Fighting Conch (*Strombus pugilis*) section due to display changes, where they were eventually observed consuming some of their tankmates (Figure 4A & B). It was unclear if the animals being consumed had already died before the Horse Conchs began consuming them. The last observation was on April 27, 2018, with at least one hatchling still alive but showing no significant growth.

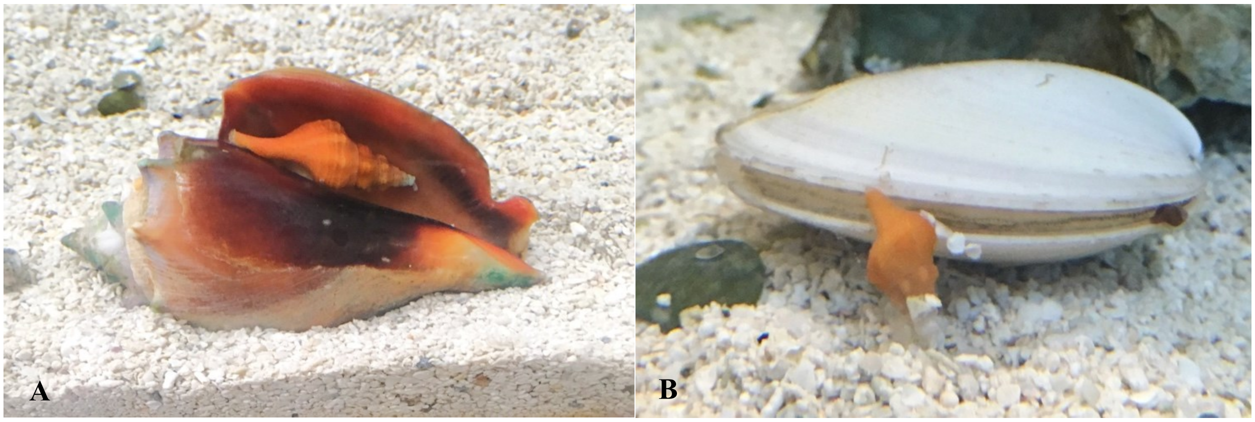

Figure 4. A) Horse Conch hatchling eating a Fighting Conch (*Strombus pugilis*). B) Horse Conch hatchling eating a Disk Dosinia (*Dosinia discus*).

Banded Tulip, *Cinctura hunteria* (Perry, 1811)
True Tulip, *Fasciolaria tulipa* (Linnaeus, 1758)

The Banded Tulip (Figure 5A) and True Tulip (Figure 5B) are both large, marine, obligate carnivore gastropods. They may both be found from North Carolina to Brazil (Abbot, 1974; WoRMS Editorial Board, 2024). Banded Tulip and True Tulip care notes are treated here together, as they require no significant differences in care. Aquarium water parameters and life support systems may be treated the same as Horse Conchs. Both Banded Tulips and True Tulips can be collected by hand from shore year-round in the shallow coastal waters of Florida, with Banded Tulips being by far the more common species of the two in Southwest Florida waters (Geiger et al., 2020; Stephenson et al., 2013). Egg cases from both species may be collected during winter, with True Tulip spawning lasting as late as August (D'Asaro, 1970).

Both species are opportunistic predators of other gastropods and bivalves (Durham, 2012; Stephenson et al., 2013), and will easily eat purchased mussels and clams, either frozen or live. Banded Tulips will sometimes scavenge recently deceased tankmates. One True Tulip specimen was observed on several occasions crawling up and over a flow-through acrylic tank divider to eat the adjacent live Fighting Conchs. The animal had to entirely exit the water to do so, a feat reminiscent of many octopus urban legends.

Figure 5. Live Banded Tulip and True Tulip specimens. A) Banded Tulip viewed from the side crawling up an acrylic divider in a display aquarium. B) Two True Tulips viewed from above, consuming a frozen clam. Specimens showing diversity of coloration within the species.

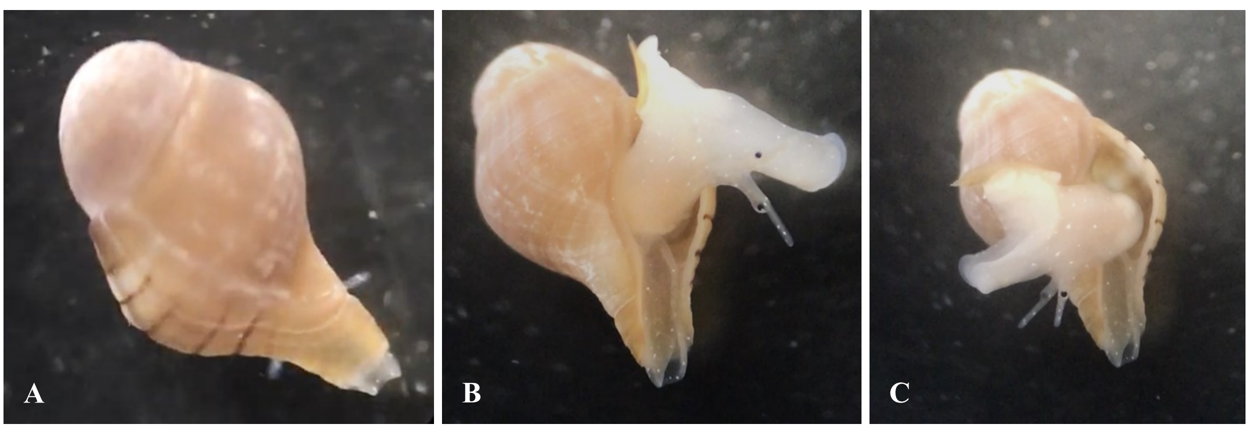

Figure 6. Live Banded Tulip hatchling. A) After hatching, new shell growth with stripes begins immediately. B) Hatchlings do not have pigmented soft tissue, but white spots seen in adults are already present. C) Hatchling with penis observable.

Banded Tulips were generally collected at 2in shell length and survived about 1 year on exhibit. For reference, the world record Banded Tulip shell is about 3in long, also on display at The Bailey-Matthews National Shell Museum and Aquarium. True Tulips tended to last more than 1 year on exhibit when collected at 2-3in shell length. This species may reach a shell length of more than 10in, but more regularly not more than about 6in.

Banded Tulips would frequently mate and lay viable egg cases on exhibit year-round, rather than seasonally like their wild counterparts. This author successfully raised tank-bred Banded

Tulips through F2 generation to 2 years old, though with much greater time and effort than simply going to the beach and hand collecting adults for display. Their fecundity makes this species a great educational asset. Viable egg capsules laid in exhibits may be peeled from their lodging. Be sure to handle by the peduncle so as not to damage the capsules or embryos. When placed in a hanging mesh fish breeder, guests can view the developing embryos inside the capsules, as well as the newly hatched baby snails (Figure 6A, B & C). Generally, dozens of babies hatch from one fertilized egg cluster (~10 capsules with ~12 viable embryos per capsule), though success is short lived after hatching and cannibalism is rampant. The hatchlings will eat most meats offered, including various mussels and clams. Detailed True Tulip hatching and growth notes may be found in the December 2022 publication of American Conchologist (Mensch, 2022).

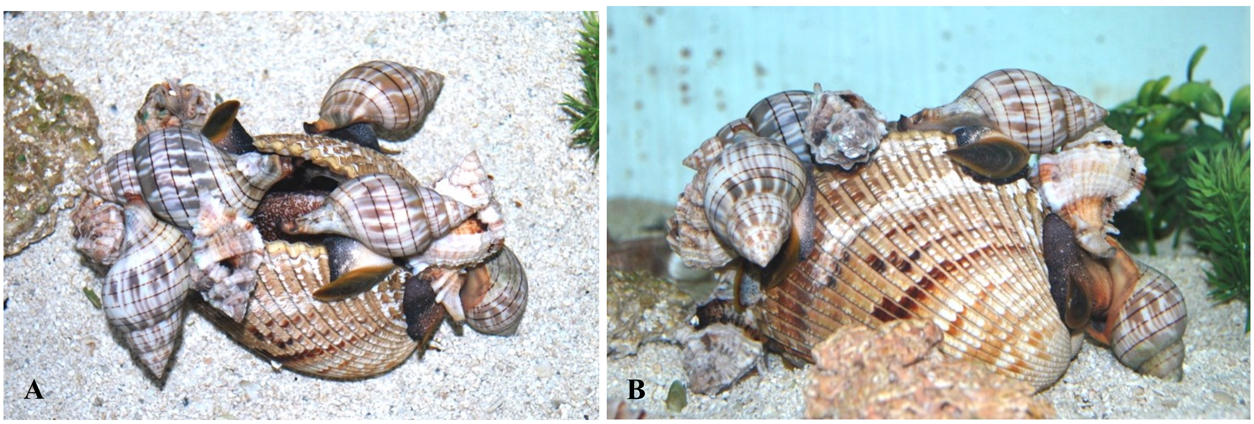

Figure 7. Banded Tulips and Apple Murexes (*Phyllonotus pomum*) eating an Atlantic Giant Cockle (*Dinocardium robustum*). A) Viewed from above. B) Viewed from the side.

Adult Banded and True Tulips were fed frozen bivalves weekly. They were generally offered one mussel or clam each, if the bivalves were about the same size as the snails. This was usually more food than Paine calculated for Horse Conchs (1972). Individual consumption was hard to accurately quantify due to frequent communal feeding (Figure 7A & B). These captivating feeding behaviors, when considered along with their continuous successful mating and relatively abundant wild populations and ease of collection, make the Banded Tulip a particularly appealing addition to a properly staffed touch pool.

Acknowledgements

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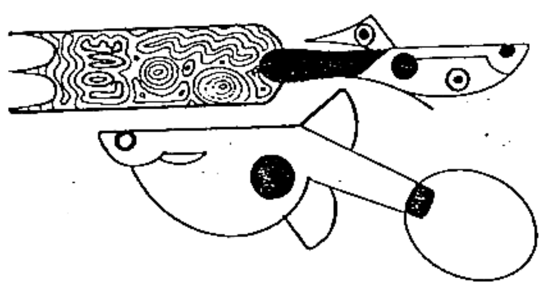

<u>A BRIEF GUIDE TO AUTHORS</u>

Updated 2025

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The approximate deadline for submissions is December 21st.

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- Use justified, single-spaced, Times New Roman 12-point font throughout (except for the title section, and figure and table legends as noted below).
- A4 "paper" users please reformat to 8 ½ x 11-inch documents (North American "letter" size).
- Keep the resolution of photographs as LOW as practical. High resolution photos make the final PDF file huge and I always compress them anyway.
- **Format the title section with the <u>line spacing set on 1.5 lines</u> (not another method) and using centered, boldface font. Only the title should be CAPITALIZED (except italicized *Scientific namesii*)**. When using MS Word, go to the "Home" tab, open the detail on the "Paragraph" section, and choose "1.5 lines" under spacing and make sure the before and after spacing settings are at "zero." In order to preserve single line spacing in a title section (name of paper, multiple authors, multiple institutions) add an "enter" (carriage return) at the end of each line. Turn on the ¶ tool, highlight the symbol at the end of the line of text and choose the line spacing needed. For some additional help with these settings, see "Other Things I Whine About" below.
- Double-space after your "institution name" to begin the body of your text. When correct, the title and headings formatting should look like this:

Sample Below

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Jill Fishhead, Senior Aquarist jfishhead@fishland.com

Fishland of South Dakota, 1 Stinking Desert Highway, Badlands, SD, USA

Text and Heading Format

Headings and text should look like the above heading and this paragraph. Use single spacing with 1" (2.54 cm) margins on ALL sides. Please indent/tab 0.5 inch (1.3 cm) at the beginning of each paragraph (not using the space bar!) and leave a single space between paragraphs. Justify the text margins (see toolbar options and note how pretty the right margin of this paragraph lines up!). Section headings should be in bold (as above) at the left margin.

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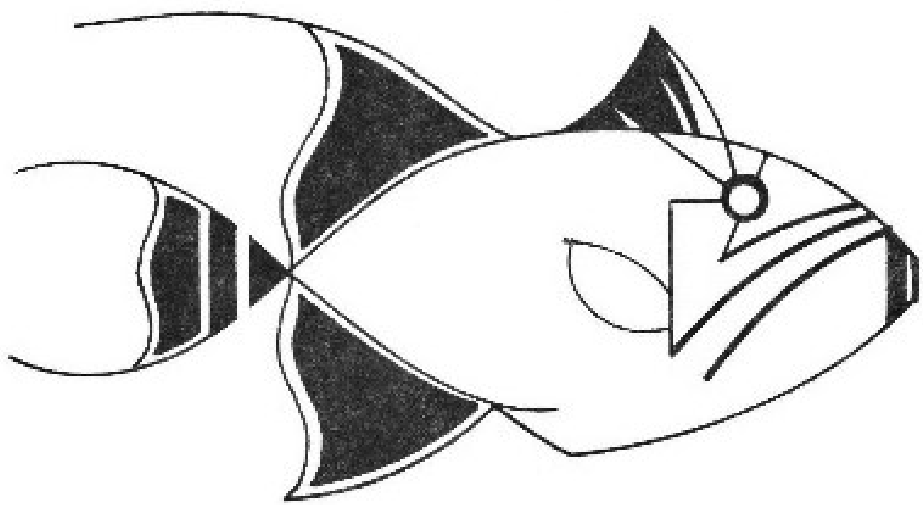

Figure 1. Legends should appear under the photo (such as this drawing by Craig Phillips) or graph in this format in 10-point font, aligned with the sides of the image or figure (center or justify). Very short legends can be centered. Photographs should be pasted into the document in the proper location by the author. I may reduce the size (appearance on the page) of figures and photographs to save space. Photos, tables, and figures not referred to in the text may be omitted for the same reason.

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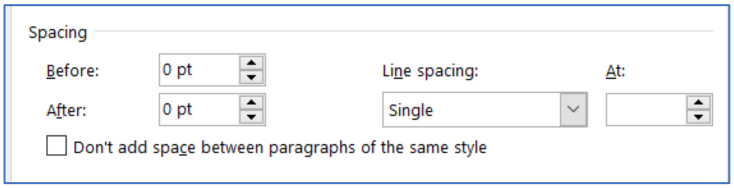
Table legends go above the table. Otherwise, formatting is as above for figures.

Other Things I Whine About

- Again, please don't use Paragraph formatting to add spacing above or below lines. I have to remove all of these. Start with a single-spaced Word template, with NO before or after spacing. You will likely need to select this from the paragraph section on the home tab of Word **(See Below!)** as you start the document, as the normal default templates may contain unwanted 'before' or 'after' spacing.



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These include any articles, observations, or points of interest that are less than a page in length. A brief bold faced and capitalized title should be centered, the body text should be formatted as above, and **author and affiliation should be placed at the end of the piece** with the left end of each bolded line right of the center of the page. Reformatting that must be done by the editor may reduce a shorter "main" article to a note, or may bump a note up to main article status.

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Literature Cited

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