DRUM *and* CROAKER

A Highly Irregular Journal for the Public Aquarist

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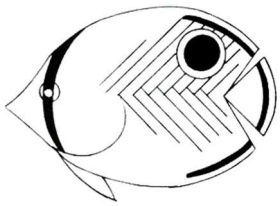

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Interior Line Art: Craig Phillips, D&C Archives

Letter from the Editor – January 2026

SOME RAW UPDATES AND THANK-YOUS

Pete Mohan, *D&C* Editor and RAW Secretary

The Regional Aquatics Workshop (RAW) continues to organize itself after achieving 501(c)(6) non-profit status. This qualifies us as a "membership organization," rather than a (c)(3) "charitable organization." Membership is awarded and limited to regular conference attendees as part of your registration, and is in effect from the beginning of that particular conference to the last day prior to the next conference. Our focus continues to be solely on the annual conference and we anticipate increased involvement in future planning. We've hired someone to build a snazzy new, permanent website (thanks to Matt Seguin for his past volunteer efforts), and are currently navigating taxes, committee organization and logo design.

Drum and Croaker is not directly associated with RAW, but I relaunched this dormant journal in the early 1990s with a lot of moral support from the 21 attendees at RAW #6 (then a record crowd). The Columbus Zoo and Aquarium continues to support the *D&C* website, and I hope to meet with them soon about possible updates. We all agree that while the current site is functional, it is very dated (same main page for 20+ years). Many thanks to the folks at Columbus, especially Kevin Bonifas and Doug Warmolts.

The officers and other board members (RAW BOD) are currently assisting the South Carolina Aquarium with its preparations for "CaRAWlina" in April. See the announcement in this issue. During the 2025 Business Meeting, attendees voted for the location for RAW 2027. The successful bidder was the Kansas City (MO) Zoo and Aquarium. SeaLife Kansas City will also be involved.

For more information about the annual conferences: https://www.regionalaquaticsworkshop.org/

Barrett Christie and Steve Bailey continue to serve as part of my editing team and have helped expand our content. Thanks to them both!

Barrett authors the "Novus Aquas" column and continues to provide other technical content as well as communications with AALSO, who started to provide their conference abstracts to us last year. He also sourced the abstracts from this year's "Jelly Camp."

"Bailey" assumed the "historian" role a couple of years back, assembling the "Drum and Croaker 50 Years Ago" column. He's also been instrumental in acquiring abstracts from the European Union of Aquarium Curators (EUAC), ReeFlorida, and the 4th International Seadragon Husbandry Symposium.

DRUM & CROAKER 61-YEAR RETROSPECTIVE (FROM 1965, ISSUES 9 & 10)

Steven L. Bailey

The Year 1965 produced two Drum & Croaker editions of impressive aquariology! The traditional "Rick Segedi 50-year retrospective" had to be modified this year to a 61-year retrospective, given the 1975 & 1976 volumes having recently been reviewed.

Those (2) issues of D&C are: March'65 & December'65, Vols 9 & 10, aka 65(1) & 65(2), aka Vols 7(1) & 7(2) by the current system. The numbering system at that time was still exploring a definitive nomenclature.

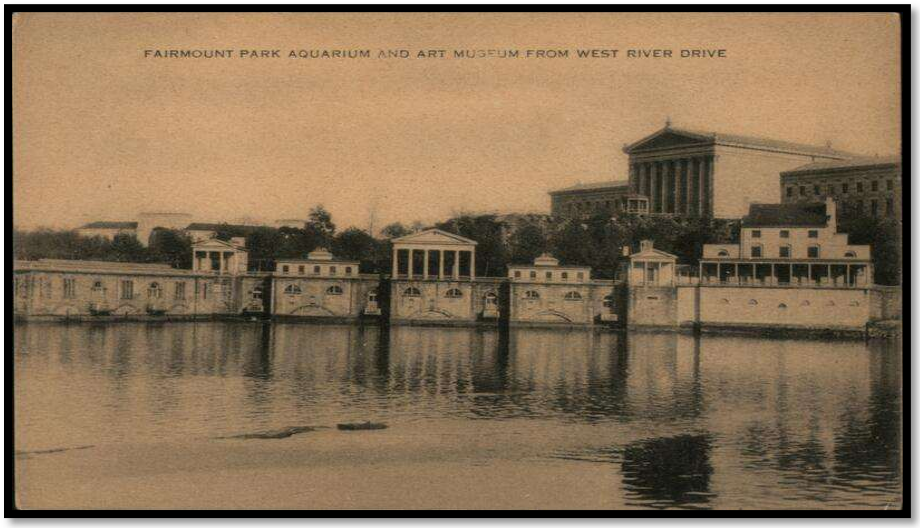
This revisiting of the Drum & Croaker archives will reflect on some of that six decades-ago work being done by our industry's pioneers, *and* a now lost-to-time aquarist.

So, let's jump in.

Of the many submissions, topics spanning the spectrum include: groundbreaking "plastic plumbing" aka PVC pipe and fittings being used, Vancouver Aquarium's first-known industry exhibition of Orca, the "new Boston Aquarium's" (the 4th since 1859) water-filtration construction plan defined, adrenocortical hormone stress studies in recently-introduced exhibit fishes, the celebration (alcohol consumption was specifically scheduled on the meeting's agenda) of a well-attended and content-heavy Aquarium Symposium[1] hosted by the Shedd Aquarium (sounds a lot like an early RAW meeting of the 1990s!), Marine Life Park Hawai'i President Taylor Pryor taking on a side-hustle (that of Hawai'i State Senator), and the endorsement of quinaldine use for successful specimen collecting.

The authors list of those contributions contains a real who's who of industry innovators and shepherds e.g. Earl Herald, D.W. Wilkie, John Prescott, Dan Moreno, David Powell, James Atz, and U. Eric "Freese" (sic) Friese [appears that an early spell-check software was installed on that typewriter<g>]. Several international submissions made journal appearances, as apparently word had made its way beyond the borders regarding this new-ish, semi-rigorous (non-reviewed in the typical academic fashion) publication.

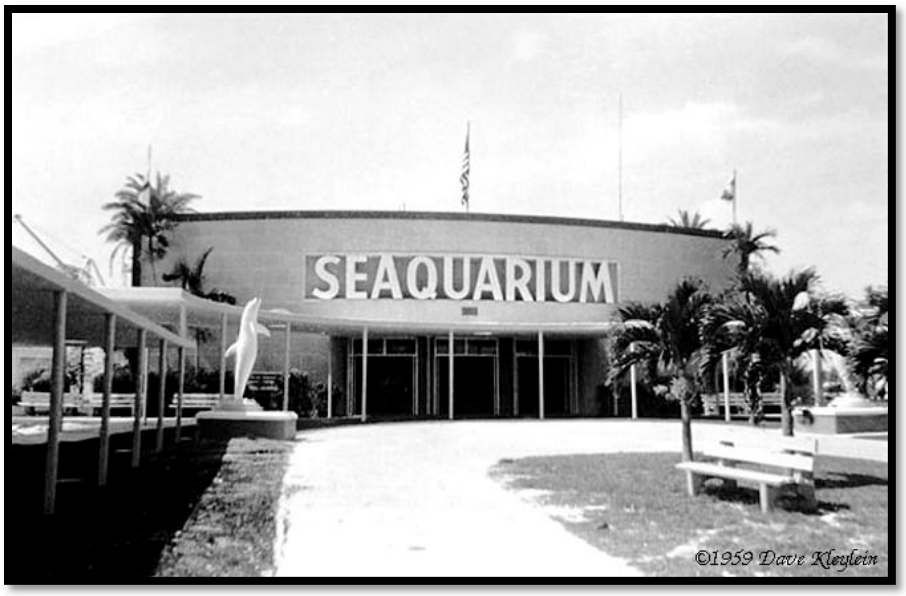
D&C's 1965 authors represented a significant proportion of existing institutions, given the 1960's smaller total number of U.S. public aquaria. With the passage of time, many are now longer functioning public aquariums; mentioning a few – Fairmount Park Aquarium (Philadelphia), and its successor - Philadelphia Aquarama aka Theatre of the Sea, Seattle Marine Aquarium, Marineland of the Pacific, and the Miami Seaquarium. *(see some images below)*



Fairmount Park Aquarium 1911 - 1962
Postcard produced by the Ruth Murray Miller Co.

Philadelphia Aquarama aka Theatre of the Sea 1962 - 1969
Postcard produced by Jack Freeman Inc.

Seattle Public Aquarium 1962 - 1977
Postcard produced by Ellis Postcard Co.



Miami Seaquarium 1955 - 2025
Postcard produced by Florida Natural Color Inc.

Marineland of the Pacific 1954-1987
Postcard produced by Plastichrome Colorpictures, Boston, MA

1965 D&C Submissions Worth Revisiting:

Notes On the Fresh-water Goby from a Bayou Off Davis Bay (*Eleotris pisonis* (Gmelin))
Laine M. Dimmick, Aquarist, Ocean Springs, MS

An interesting read here submitted by an 11yr-old aquarist. Some connections had clearly been made with local marine lab staffers (Gulf Coast Research Laboratory, Univ. Southern Mississippi) that compelled this aspiring industry professional to file a report with D&C on a multi-species agonistic behavior investigation. Under that guidance, an honest and frank recounting of successes and mistakes were submitted. The collecting techniques outlined sound largely unchanged during the subsequent six decades and would no doubt be a framework for an Aquarist I's first field exhibit collecting trip in 2026.

L.M. Dimmick must surely be the youngest D&C contributor to date! Some internet searches could not reveal any evidence of an inspired Aquarist Dimmick making the transition from hobbyist to public aquarium professional. Our work encourages those who will succeed us – let us all take the time to share, guide, and advocate!

Spinecheek sleeper *Eleotris pisonis*
Photo by Ethan Currens, from iNaturalist (CC BY-NC)

Capture of the Lemon Shark (*Negaprion brevirostrus*) and its Maintenance at Philadelphia (a closed system inland aquarium)

Donald W. Wilkie, Curator, Philadelphia Aquarama aka Theatre of the Sea

An impressive account of groundbreaking Lemon Shark husbandry work. Curator Wilkie's paper includes descriptions of the collection in Marathon Florida and a 1,300-mile transport over 48hrs via tractor trailer truck to the City of Brotherly Love. At the time of publication, 3 of 4 specimens had been on exhibit for nine months. The transport description includes details of temperature swings between 85 and 68dF during that trek north. Persistence paid off as the sharks would not accept food for three weeks upon exhibit introduction but rebounded and did quite well, including minimal wall-walking once settled in.

[1] *For sixteen years (1955-1970), the North American public aquarium community held their annual "Aquarium Symposium" in conjunction with the annual meeting of ASIH. For more information, see the 2021, 2022 and 2023 issues of Drum and Croaker. 35 individuals from 25 institutions were reported to have attended the 1964 meeting at the New York Aquarium. Mysteriously, the 1965 ASIH meeting was reported to be held in Kansas and no record of an Aquarium Symposium was found in the annual report. However, the second 1965 issue of D&C, indicates that the aquarium occurred in Chicago.*

NOVUS AQUAS (NEW WATERS)

Barrett L. Christie, enteroctopusdofleini@yahoo.com

One defining characteristic of those who work in aquariums is that we are nothing if not resourceful. All of us, whether we be aquarists, LSS operators, veterinarians, divers, or other specialty have been, by necessity, a 'jack of all trades' to pursue these intertwined professions. To grow in this field is still very much to undertake an apprenticeship, and those who are most successful tend to be life-long learners. Husbandry to this day persists as a hybrid of art and science, and an insatiable curiosity is a trait that helps the most versatile aquarists to see new angles of a problem, envision unorthodox solutions, and refine husbandry practices overall.

Toward this end, when it comes to our niche profession, I reject the assertion, often espoused by psychologists and other charlatans, that all it takes to master something is 10,000 hours of practice. This may prove true by happenstance for eastern European fiddle players, but ask any accomplished person in the aquarium world if they consider themselves a master of this craft. The reply is likely to be a resounding 'no'. After all, 10,000 hours is just under five years of full-time work, to say nothing of the years of formal education, volunteer positions, internships, and other experience it takes just to get one's foot in the door at an aquarium. Think back, at five years in this field, would you consider yourself to have 'mastered' husbandry?

Perhaps this is due to the fact that working in an aquarium requires one to be at least proficient, if not downright accomplished at not one skill, but hundreds. Perhaps it is not that our profession is an outlier to the rules of mastery, it may just be orders of magnitude more complex than the skills upon which the model is based. As our profession has increased in complexity it is natural that we have seen some specialization, allowing for efficiencies, and more importantly, allowing us to be collectively better positioned to absorb and assimilate the increasingly enormous amount of information available to us.

This underscores the reality that the amount of new information increases every year, and we must specialize to a degree to meaningfully keep pace with these developments. It is a good thing that nowadays the curator is not the one to diagnose a disease, though they must still know enough to recognize the common ailments. It is similarly great that an aquarist need not always be the one to plumb in and rewire a pump, but having the skill to do so makes them more prepared to be a teammate, and eventually to be a leader.

Specialization in our field is not necessarily to be feared, but we must guard against specializing to the degree where aquarists become mere technicians, whose job it is to scrub algae and dispense food prepared and provided by someone else. As life support systems and other technologies become ever more complicated, it is important to at least understand how (and why) they work, even if one did not design or install them. The ability to see the forest for the trees, and envision solutions to complex problems has not changed, and is required for new techniques and practices to evolve.

Recently a colleague (B. Nelson) introduced me to the writings of science fiction author Robert A. Heinlein, who once opined on the importance of versatility, writing:

"A human being should be able to change a diaper, plan an invasion, butcher a hog, conn a ship, design a building, write a sonnet, balance accounts, build a wall, set a bone, comfort the dying, take orders, give orders, cooperate, act alone, solve equations, analyze a new problem, pitch manure, program a computer, cook a tasty meal, fight efficiently, die gallantly. Specialization is for insects."

The well-rounded aquarist can lead with empathy, and balance workloads equitably. They can delegate a task but also step in to lighten the workload of a colleague. Knowing the resources required to write a sonnet or build a wall allows one to coordinate the work of those tasked to lay bricks as well as those laying down verse. Interpreting Heinlein's words to make the abstract practical, what attributes might we ascribe to our profession? What are the most valuable skills to acquire over the course of one's career to make us well-rounded? What should a 'master' of aquatic husbandry be able do, if committing a description to paper? After speaking with a handful of colleagues on this topic, bemoaning the skills lost over time as our industry changes, and ideating upon the myriad niche skills we value in ourselves or others, I submit for your consideration this modification of the Heinlein list:

An aquarist should be able to plumb, filet a fish, helm a boat, rig fishing tackle, SCUBA dive, analyze a new problem, glean new insights from old literature, wire a pump, use a dichotomous key, use a hole saw, give an injection, read a tape measure, perform a skin scrape (and identify what lies therein), know (and accurately spell) the scientific names of the species in your care, change a tire, use a microscope, tie a line to a cleat, read a blueprint or P&ID, and analyze water chemistry. Moreover, they should be able to both euthanize an animal and support a colleague as their animal is put down, act effectively alone and as part of a team, be both a carpenter and a naturalist, be both a student and a mentor…specialization is for nudibranchs.

Fundamentally we should be *versatile*, we should be always be students, for our subject is immense, and our time is finite. Your own personal list of skills may vary, what do you consider missing from this list? What would you omit?

One may ask, what if my facility does not offer the opportunity to learn, let alone practice, some of these skills? Reach out to those in other departments, or even other organizations nearby and express an interest in learning. The responsibility for our professional growth lies as much (or more) with ourselves as with our employers. By constantly collecting new skills and new knowledge we make ourselves more versatile, and by extension more likely to have a novel perspective.

Perspective is often the key to seeing the pattern that others do not, or considering a solution others would have ignored. It is often said that if your only tool is a hammer every problem will look like a nail; the sheer immensity of diverse aquatic life we seek to keep in little glass boxes of water demands a wide variety of metaphorical tools. Furthermore, to advance husbandry we must envision paths untaken, and in doing so forge new tools not yet known to aquarists.

What tools will you add to your toolbox in 2026?

THE 1975 STEINHART AQUARIUM COELACANTH EXPEDITION

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Introduction

When Marjorie Courtenay-Latimer discovered a living coelacanth in South Africa in December 1938, the scientific community was turned on its head. The revelation that these fish, which were only known from the fossil record and presumed to be extinct for seventy million years, still swam in the murky depths, captivated the public. The retrieval of a second specimen by J. L. B. Smith in 1952 solidified the importance of the fish to the study of ichthyology and evolution, secured it a place in our popular culture, and identified the Comoros Islands as the true home of the coelacanth. Thus began an elusive quest, attempted by many, but to date unsuccessful, to obtain a living specimen for aquarium display and observation. Fifty years ago, Steinhart Aquarium Director Dr. John McCosker and colleagues conducted an expedition to the Comoros Islands with the goal of collecting a living coelacanth. The team was a remarkable group of women and men who went on to make impressive contributions in their fields. Although they were unsuccessful in capturing a living coelacanth, the 1975 expedition documented the culture of the local coelacanth fishers, expanded our scientific knowledge of coelacanth biology, physiology, and taxonomy, and discovered several new shore fishes in the Western Indian Ocean. Incidentally, it also resulted in the first successful aquarium display of living bioluminescent fishes.

Old Four Legs

In her account, Marjorie Courtnay-Latimer credits woman's intuition for what is almost certainly the greatest ichthyological discovery of the twentieth century (Courtnay-Latimer, 1979). With a budding career as a curator of a small museum, she was pursuing a childhood dream of spending time on Bird Island, off the coast of her home in South Africa. On that day, she happened to go down to the wharf to "wish the men Happy Christmas," and saw the coelacanth beneath an otherwise uninspiring pile of starfish, sharks, and rays (Courtnay-Latimer, 1979). Although she attempted preservation, most of the specimen was discarded, and only the outer casing, skull, and bony tongue was saved (Nulens, Scott and Herbin, 2011). However, her general description and drawing of the specimen was enough to convince her colleague and mentor, J. L. B. Smith, that the fish was a living coelacanth: a member of a group of fishes presumed to be extinct for seventy million years. She and Smith revealed this discovery in the press, and it became front-page news all over the world. A one-day public viewing of the specimen was arranged at the museum, and a reported 20,000 people came to see it (Courtnay-Latimer, 1979).

Smith immediately began the search for a second specimen, which he hoped could be properly preserved for study. He and his wife and academic partner, Margaret Smith, conducted several expeditions along the East Africa coast, collecting and cataloging reef fishes and searching for coelacanths. Smith believed, correctly, that because of its shape and coloration, the coelacanth was a deep reef fish, and not from the bathypelagic. Alas, the arrival of the second world war in 1939 impacted their ability to continue this work, and progress stalled for several years.

Following the conclusion of the war, the search resumed. A Danish team launched a global deep-sea expedition looking for coelacanths. Although they collected a wealth of material, they did not find a coelacanth- probably because they were fishing at too great a depth (Smith, 1979). Starting in 1947, J. L. B. and Margaret Smith traveled up the East Africa coast all the way to Kenya, documenting reef fishes of the Western Indian Ocean, and searching for the coelacanth. They plastered posters up and down the coast, offering a cash reward for an intact coelacanth specimen (Nulens, Scott and Herbin, 2011). Captain Eric E. Hunt, who ran a trading schooner between mainland Africa and the islands of the far Western Indian Ocean, distributed Smith's wanted ads (Thomson, 1999). The presence of these posters in the Comoros led local fishers to recognize the fish as "Gombessa," which they occasionally (and unintentionally) caught while fishing for oilfish (Thomson, 1973).

In 1952, some 14 years after the discovery of the first specimen, J. L. B. Smith received the call he had been waiting for. A coelacanth specimen was caught on hook and line by fisherman Achmed Hussein Bourou, south of Domoni (Anjouan) in the Comoros, and secured by Captain Hunt (Nulens, Scott and Herbin, 2011). Due to the known scientific importance, the French authorities refused to release the specimen unless Smith claimed it in-person, not expecting him to be able to do so (Smith, 1979). Somehow, he managed to convince the South African government to loan him a plane to fly to the Comoros and quickly retrieve it. This second coelacanth specimen validated Smith's claim, and provided the first opportunity to examine a nearly-intact specimen. Smith planned a second expedition, intending to collect a living specimen, but he was unable to secure funding.

Almost immediately after Smith procured the second coelacanth, the French colonial government shut down all work by non-nationals, took control of the fishery, and began to send all specimens to Dr. Jacques Millot (an arachnologist) and Dr. Jean Anthony (an anthropologist) at the Paris Museum of Natural History (Thomson, 1999). Several dozen coelacanth specimens were preserved, catalogued, and warehoused in Paris over the ensuing years. This situation persisted through the early 1960s, greatly impacting coelacanth research by all scientists outside of France. It wasn't until 1965 that the first coelacanth arrived in the United States (Nulens, Scott and Herbin, 2011). A subsequent, frozen, specimen was purchased by the Yale Peabody Museum in 1966, allowing American scientists to study a fish that had not been preserved with formalin for the first time (Thomson, 1999). Analysis of fresh tissues finally allowed scientists to begin to study coelacanth physiology and biochemistry, revealing that coelacanth blood was isotonic with seawater, and retains significant quantities of urea, like elasmobranchs (McAllister, 1971).

A Coelacanth Display at the Steinhart Aquarium

In 1948, Dr. Earl Stannard Herald took the reins of Steinhart Aquarium as its Superintendent and Curator. Herald was an ichthyologist by training, was charismatic and driven, and had a goal of making Steinhart Aquarium the leading institution of its kind in the United States. He hosted a weekly live television program, "Science In Action," one of the earliest television shows dedicated to scientific content. This made him a household name in the San Francisco region and beyond. Herald attempted to travel to the Comoros in the mid-1950s to collect a coelacanth, but was unable to secure permission from the French authorities (Thomson, 1992). In the early 1960s, Herald led the Steinhart Aquarium through a city bond initiative to rebuild and modernize the aging facility, which was closing in on 40 years of operations. This renovation, which cost

$1.77 million, included the modernization of the life support systems, incorporating plastic piping, ultraviolet sterilization, and the construction of larger aquarium tanks intended to house aquatic mammals and other novel species (McCosker, 1998). One of these, Tank 11, was specifically designed to house a living coelacanth– to be displayed for the first time in a public aquarium. This tank was located at the center of the main corridor of the newly designed Steinhart Aquarium, a prominent location worthy of such an iconic species. Herald had a fiberglass model of a coelacanth constructed, which he used to promote this project with donors and in the press (Figure 1).

Figure 1. Dr. Earl S. Herald, Superintendent of Steinhart Aquarium, with his fiberglass coelacanth model. Behind him, smiling, is Phyllis Ensrud, the aquarium secretary. The identity of the woman in the foreground is unknown.

Herald was collaborating with Dr. Malcom Gordon from UCLA, and Dr. Rolf Bolin of the Hopkins Marine Laboratory, on a multi-year deep-sea research expedition on the Stanford University research vessel Te Vega. In a 1963 newspaper article, Herald laments that a South African scientist "let the cat out of the bag" and revealed his plans, which were not intended to be announced until the following spring. This project, "Marine Physiological Expedition to Madagascar and Iles Comores," was funded by the National Science Foundation, and included plans to fish for coelacanths at depths of 600 feet or more in the Comoros. Ultimately, they did not capture any coelacanths. During this time, Herald was on the board of the Society for the Protection of Old Fishes (SPOOF), a group of scientists (clearly with a wonderful sense of humor) collaborating to fundraise for and conduct an expedition to collect a living coelacanth. Correspondences between Steinhart and SPOOF reveal that some funding had been secured, and

that a long list of scientists and research project proposals had been compiled in preparation for work with both living and preserved specimens once they arrived at the Steinhart.

From the mid-1960s through the early 1970s, several groups, including Jacques Cousteau and the Calypso, attempted to film the fishes in their natural environment. However, none were successful. In 1970, Earl Herald did manage to secure a preserved coelacanth for the ichthyology collection at the California Academy of Sciences (Figure 2). This specimen (CAS-24862) was caught on 1 January 1970 on the West Coast of Grand Comoro by Oussoufa M'Latamou (Nudens, Scott and Herbin, 2011). It was purchased by Herald, arrived at the Academy on 23 June 1970, and is still in the collections today.

Figure 2. Steinhart Aquarium Superintendent and Curator, Dr. Earl S. Herald, observes a preserved coelacanth (CAS-24862) acquired in 1970 for the California Academy's ichthyology collections.

Michal Lagios, a medical doctor and consulting pathologist for Steinhart Aquarium, participated in the joint Franco-Anglo-American coelacanth collecting expedition to the Comoros Islands in early 1972 that was funded by the British Royal Society. In his unpublished trip report, Lagios (1972) describes numerous obstacles to this expedition's success, including delayed shipments of essential fishing and boating gear, and a non-functional outboard motor on the Royal Society's 18' boat. Comically, there was no place to test the motor while they attempted to repair it, so they had to repeatedly carry the vessel to the ocean and then back to land again to continue

the repairs. That same year, Dr. Murray Newman led an expedition to the Comoros to collect a living coelacanth to display at the Vancouver Aquarium. Despite offering a paid trip to Mecca in addition to the portioned share of the "official" French governmental prize of $200 for any fisher able to land a coelacanth, he also was unsuccessful and did not secure a living fish (Lagios, 1972). They did, however, return with a preserved specimen, which was later exhibited in the MacMillan Tropical Gallery at the Vancouver Aquarium.

Lagios (1972) also described the local fishery and fishing methods employed to catch coelacanths at that time. By his account, the native fishing effort for coelacanths was largely due to the $200 offered by the French government. However, even this "princely prize" didn't stimulate a large fishing effort. Only three species of edible fishes are taken at the depths where coelacanths are caught: the coelacanth, the Roudi escolar *(Promethichthys prometheus* Cuvier 1832), and the oilfish (*Ruvettus pretiosus* Cocco 1833), a species of special significance to Islamic culture due to purported antimalarial properties (McCosker, 1979). Fishing occurs during moonless portions of the night, and is said to be best during a period of dead calm following rains. Fishers were observed to venture out only during the moonless hours, returning at moonrise. According to Lagios' local contacts, coelacanths will take many different fish baits, but the most commonly employed was *P. prometheus*. The long-lines employed to catch coelacanths are expensive to replace, and not every fisherman has such a line. They were made of twisted cotton, coated with a thin resin to deter rot, and had a single hook placed terminally. The line was stored in loose loops on a spindle, which sat astride the gunwales of the fishing boat. After baiting the hook, the fisherman weighted the line by attaching small stones with a slip-knot. The baited rig was then lowered until it hit the bottom, at which point the fisherman gave the line a jerk, releasing the stones. This technique permits fishing at or near the bottom with an unweighted line, which is less likely to become snagged. Because of the depth involved, 300 meters or more of line might be lost if snagged on the bottom. Fishing for such a large target, especially during the heavy monsoonal rains, was risky, and there were reports that men were "lost to sharks" when their boats capsized (McCosker and McCosker, 1976). Outside of the limited and tightly controlled market for scientific specimens, coelacanths were not worth the effort. Fishing for other species by day, in shallower water, was simply more lucrative.

The joint Franco-Anglo-American expedition in which Lagios participated secured two coelacanths, one of which resides at the Paris Natural History Museum. This first specimen lived for nine hours after landing. It was a female, and upon dissection was found to contain 19 mature eggs (Nudens, Scott and Herbin, 2011). The second specimen, which is at the Yale Peabody Museum, was dissected, and tissues and organs were sent to 54 scientists around the world (Nudens, Scott and Herbin, 2011). It also lived for several hours post-capture. It was transferred into a submerged cylindrical cage, where it was observed and filmed until it died (Locket and Griffith, 1972).

McCosker Picks Up the Challenge

In 1973, Earl Herald died while scuba diving on a collecting trip in Baja California, leaving his goal of being the first to display a living coelacanth unattained. In September that year, just in time for the 50th anniversary of the opening of Steinhart Aquarium, Dr. John E. McCosker was hired as Superintendent. Having earned his doctorate from the Scripps Institute of Oceanography studying the evolution of tropical eels, McCosker continued the tradition of an ichthyologist

leading the Steinhart. Upon his arrival, he picked up several projects that Herald had begun, including the design and construction of an innovative circular aquarium intended to display and research pelagic fishes, *The Fish Roundabout*, as well as working with SPOOF on "project coelacanth." To support these efforts, he hired David Powell as Aquarium Curator. Powell had previously worked at the Steinhart, but left to join SeaWorld in San Diego, largely due to the frustration and conflict he experienced working under Herald (Powell, 2003).

Acquiring and transporting a living coelacanth was no small feat. Numerous groups had tried before, but none had been successful. McCosker conducted a preliminary trip in October 1974 to develop relationships with local officials, interview fishers, and plan for other logistical considerations. He was joined by Al Giddings, an underwater filmmaker and technical diver, and Victor Breeden, Jr., a trustee of the Charline Breeden Foundation, the primary benefactor of the planned expedition. McCosker's trip log (1974) describes navigating conversations with both French and Comorian officials. A referendum in Paris, granting the islands independence, was predicted to pass within six months. If this occurred, the French colonial authorities would leave. There was some uncertainty around which faction would be in power the following year, and thus who would control the team's work and any potential fish exports.

McCosker (1974) also describes the arrangements made with the local fishers: the kinds of boats they requested, that they would be working in a team of no more than 20 men, and that they were to be paid a flat fee per night, regardless of whether or not they catch a coelacanth. Following Dr. Murray Newman's lead, McCosker promised that any fisher that did catch a coelacanth would be given an all expenses paid trip to Mecca. Over the course of a week in the Comoros, McCosker, Giddings, and Breeden managed to secure laboratory space and scientific equipment, locate boats capable of hauling their underwater cameras, and even determine that a saltwater pool at a local hotel could serve as a temporary holding tank for a living coelacanth. Air France, which at the time only landed in Los Angeles, secured one-time landing rights in San Francisco to deliver the living coelacanth to the Steinhart (McCosker and McCosker, 1976). McCosker and Giddings conducted several scouting dives to depths of 225 ft (on air!) and noted the presence of several new species of reef fishes. And, perhaps most importantly, they secured permission from both the French and the Comorian scientific and political authorities to collect and export two living coelacanths for display at Steinhart Aquarium.

To The Comoros

The 1975 Steinhart Aquarium coelacanth expedition had three main goals: first, to collect and transport one or two living fishes back to San Francisco, where they would be the first living coelacanths ever displayed in an aquarium; second, to photograph and film living coelacanths in normal natural conditions as much as was practical; and third, to produce and gather materials for a television program, a National Geographic article, ethnic studies, follow-up on prior scientific studies, and for public relations for the California Academy of Sciences. In order to accomplish these goals, McCosker assembled a team of experts, many of whom would go on to have long and successful careers in their chosen avocations. The team consisted of John McCosker, David Powell, Chuck Nicklin, Sandra Smith McCosker, Lester Gunther, Al Giddings, Sylvia Earle, John Breeden, and Michael Lagios (Figure 3). All of the team members, save for Al Giddings, would travel and work under the auspices of the California Academy of Sciences, and all information and

material obtained during the expedition was to be intellectual property of the Academy. Giddings had a separate agreement with National Geographic.

Figure 3. The expedition team. Back Row: John McCosker, David Powell, Chuck Nicklin, Sandra Smith McCosker, Lester Gunther. Front Row: Al Giddings, Sylvia Earle, John Breeden, Michael Lagios.

The majority of the participants were to arrive in Grand Comore in late January, 1975, with Sylvia Earle and David Powell arriving a short time later (Powell, 2003). McCosker was the trip leader; Sandra Smith McCosker was an anthropologist, and fluent in French. She conducted ethnographic studies and served as the expedition's translator. Powell was tasked with collecting fishes and keeping a coelacanth alive from capture through transport back to San Francisco. Les Gunther was a former Academy trustee, and led the "Steinhart Divers," a group of amateur scuba divers who organized live fish collecting trips for the Steinhart starting during Earl Herald's tenure. He, like Powell, had experience catching, handling, and transporting living fishes. Chuck Nicklin and Al Giddings were underwater photographers and cinematographers, and would document the expedition for scientific publications, public engagement, and outreach. Lagios was a pathologist and brought valuable prior experience and relationships from the joint Franco-Anglo-American expedition in 1972. Sylvia Earle was an expert diver and Academy scientist specializing in algae. John Breeden was an electronics technician, and the son of Victor Breeden, who had joined on the scouting trip. He represented the Charline Breeden Foundation, which principally funded the expedition.

By conducting interviews with local fishers, McCosker concluded that the reported depths where coelacanths had been previously caught were being over-estimated. He believed this was due to the fact that the fishers utilized hand-lines, which were suspended in the water column at an oblique angle by the water currents, this greatly over-exaggerating the reported depths of fishing (McCosker, 1979). McCosker validated this theory during the 1975 expedition by scuba diving

next to fishers, and comparing the actual depth of the fishing gear with their reported fishing depths (McCosker, 1979). His targeted fishing depths were actually 150–300 m, which form a narrow band, approximately 1 km wide, around Grand Comore (McCosker, 1979). Analysis of prior catch data also showed that most coelacanths were caught during the months of monsoonal rainfall, January, February, and March– this even with reduced fishing pressure due the rains (McCosker, 1979).

McCosker scheduled his expedition to arrive following the beginning of the monsoonal rainfall. Having observed heavy freshwater outflows at depths of over 100 feet, the team hypothesized that, in moonless nights, following the heavy monsoonal rains, the coelacanths come up to shallower depths to feed in the pockets of cool rainwater percolating through the volcanic rock strata of the islands (McCosker and McCosker, 1976). The team selected a natural deep grotto as a temporary holding space for the fish, fencing it off with chicken wire (McCosker and McCosker, 1976). The plan was to release the fish in the grotto, and observe and film its behavior before transporting it back to San Francisco. Unfortunately, during 1975 and 1976, the Comoros suffered an extended drought, which impacted much of southeastern Africa (McCosker, 1979). Even with the increased fishing efforts due to the presence of western scientists willing to pay a princely reward for a living fish, no coelacanths were captured during this time.

Figure 4. The coelacanth displayed at the California Academy of Sciences, circa 1979.

Despite their setbacks with achieving their elusive goal- capturing, studying, and returning with one or two living coelacanths, the expedition did not leave empty-handed. McCosker managed to secure two specimens that had been collected in 1973 and frozen immediately after capture. The first, CAS-33111, which still resides in the California Academy of Sciences' ichthyology collection, was on display at the Academy for many years (Figure 4). The second specimen was sold to McCosker's alma mater, the Scripps Institute of Oceanography. The 1975 expedition participants also conducted ichthyological surveys of Comorian reefs, collecting 694 lots of marine reef fishes at 40 collecting stations ranging from tidepool depths to approximately 225 feet. These surveys resulted in the discovery of six new species, including the blackcheek moray, *Gymnothorax breedeni* McCosker and Randall 1977, which was named after the

expedition's benefactor, and McCosker's flasher wrasse, *Paracheilinus mccoskeri* Randall and Harmelin-Vivien 1977.

Also worth noting is that the Comorian government issued a postage stamp to commemorate the expedition (Figure 5). It was drawn by Rod Macpherson, a renaissance man who served as an illustrator-in-residence at the Steinhart Aquarium for many decades, beautifully representing the fishes on display in colored pencil and watercolor. Aside from the ichthyological research, the team performed other scientific surveys. Sandra Smith McCosker conducted ethnographic research of the Comorian people, and made more than 100 recordings of 28 genres of traditional music and song (McCosker and McCosker, 1976). Sylvia Earle collected marine algae samples, as well as ferns and flowering plants. Her teammates also recollect that she showed off an extremely large (4.5 lb!) specimen of the nudibranch *Hexabranchus sanguineus*, which she named "Flower" and then returned to where she had found it (Powell, 2003).

Figure 5. The postage stamp commemorating the expedition, drawn by Rod Macpherson.

But perhaps most important to the legacy of the 1975 expedition was David Powell and John McCosker's collection of flashlight fishes, *Photoblepharon steinitzi* Abe and Haneda 1973. These were known by French divers as "Petit Peugeots," due to their resemblance to the headlights of the French automobiles buzzing around the islands. Powell and McCosker saw them on a moonless night at depths ranging from ten to 200 feet, according to the announcement of their arrival in the May 1975 California Academy of Sciences newsletter. Powell recounts in his memoir some detail how he collected these fishes in a shallow, underwater tunnel, so I won't repeat it here (Powell, 2003). Remarkably, despite the exceptionally long flights back to San Francisco (courtesy of Air France), many of these fishes survived. In 1975, Steinhart Aquarium revealed the first public exhibition of living bioluminescent fishes, and we have continuously displayed one or more species of the Anomalopidae ever since.

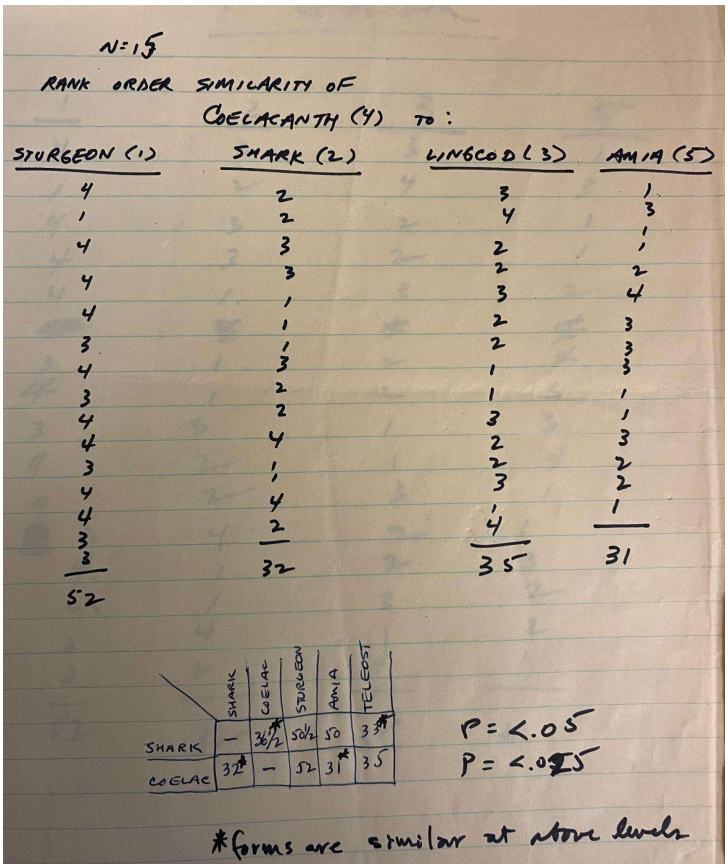

Figure 6. Tabulated tasting scorecards from the May 1975 SPOOF dinner held to celebrate the success of the expedition.

Shortly after the team's return to San Francisco, SPOOF held their annual meeting at the California Academy of Sciences (Powell, 2003). Records in our archives reveal that on 27 May 1975, the Academy hosted a formal dinner celebrating the achievements of the expedition team. Attendees included the McCoskers, David Powell, Michael Lagios and his wife, Mary, San Francisco Chronicle science writer David Pearlman, and several SPOOF board members. The participants dined on a tasting menu of fishes: shark, lingcod, bowfin, sturgeon, and coelacanth. And, in true scientific fashion, they conducted a study where fourteen of the fifteen participants agreed that coelacanth tasted most similar to sturgeon, with statistically significant results (Figure 6).

Tissue samples from the two coelacanth specimens were distributed to some 34 scientists, with the assistance of SPOOF, and a synthesis of this work was presented at a major symposium hosted by the California Academy of Sciences in June of 1977 (McCosker and Lagios, 1979). This symposium included a spirited debate, transcribed in full detail, on the taxonomic placement of the coelacanth, with Lagios advocating for it as a sister-group to the chondrichthyans, countered by Robert W. Griffith, who argued for a less "heretical" placement near the teleosts. The proceedings conclude with McCosker suggesting that they continue the debate with "wine and fillet of coelacanth" (McCosker and Lagios, 1979). Apparently eating your study species was just the way things were done back in the 1970s.

Epilogue

Following the 1975 expedition, the Comoros Islands underwent a dramatic period of political upheaval. On 6 July 1975, the Comorian parliament passed a unilateral resolution declaring independence, and the French colonial administration left. This was followed by a quick succession of local governments. Within one month, the new president, Ahmed Abdallah, was removed from office in an armed coup and replaced by Said Mohamed Jaffar. A few months later, Jaffar was ousted by his Minister of Defense, Ali Soilihi. The Soilihi government closed the country to western expeditionary groups and destroyed all records of coelacanth fishery (McCosker, 1979). Two years later, President Soilihi's government was overthrown with the support of the French, Rhodesian and South African governments, and Abdallah was reinstated. During this time, the Comoros were listed by the United Nations as the poorest country in the world (Powell, 2003). This period of political instability and upheaval prevented further attempts at collections, and no coelacanth specimens left the islands for several years (Nudens, Scott and Herbin, 2011).

Many of the members of the 1975 Steinhart Aquarium coelacanth expedition went on to remarkable accomplishments in their chosen fields. David Powell left Steinhart Aquarium in 1980 to join the Monterey Bay Aquarium as their first Curator, and later Director of Live Exhibit Development. Dave's impact on our profession is remarkable in its breadth and scope, and his memoir, "A Fascination for Fish: Adventures of an Underwater Pioneer" should be required reading for all aquarium biologists. Al Giddings is well known for his underwater directing and shooting on highly acclaimed films such as "The Deep" and the James Bond series "For Your Eyes Only" and "Never Say Never Again." Giddings was also a pioneer in technical diving, and was the first to dive with mixed gases on the Andrea Doria, and the first to discover, dive and penetrate the Japanese I-169 submarine in Truk Lagoon. He received an Academy Award nomination for Outstanding Cinematography for "The Abyss" and served as co-producer and director of underwater photography on "Titanic." Chuck Nicklin also had a storied career in underwater filmmaking. Among his film credits are James Bond movies, "The Abyss," and "The Deep." He founded the San Diego UnderSea Film Exhibition, and was a co-founder of San Diego Underwater Photographic Society. Sylvia Earle, "Her Deepness," was Curator of Phycology at the California Academy of Sciences from 1979–1986. She left the Academy to design, consult, operate, and support piloted and robotic deep ocean exploration with Deep Ocean Engineering, a company that she founded with Graham Hawkes. She became Chief Scientist at NOAA in 1990, and is an internationally renowned and beloved champion of ocean conservation. Michael Lagios, MD, continued to study the physiology and taxonomy of the coelacanth, championing the controversial view that it was more closely related to cartilaginous fishes than to the lobe-finned fishes, based on his histology of the pituitary gland, the presence of a rectal gland, and the retention of urea in the blood. In the early days of mammography (1982), he was the first to suggest that radical mastectomy for small, non-invasive lesions of the breast was not necessary, revolutionizing the treatment of early breast disease, and improving the lives of millions of women, worldwide.

The 1975 Steinhart Aquarium expedition to the Comores Islands to collect a living coelacanth reminds us of the role that public aquariums can play in scientific discovery. The women and men that made this expedition possible each brought a variety of skills and expertise, and worked together as a team under challenging conditions. Although they ultimately did not succeed in collecting and transporting a living coelacanth back to San Francisco, their

achievements are remarkable, especially given the tools, technology, and infrastructure that was available to them at the time. They managed to secure two frozen coelacanths, a large body of biological and anthropological knowledge, important ichthyological voucher specimens, and developed the first public display of living bioluminescent fishes. This type of expedition: an audacious goal that appeals to private philanthropy, tackled by a multi-disciplinary team of animal care experts, research scientists, and media and outreach specialists, is a successful model that can still be replicated, even fifty years later.

Acknowledgements

I am grateful to the staff of the Ichthyology Department at the California Academy of Sciences for their assistance with locating archival materials: David Catania, Jon Fong, Mysi Hoang, and Matt Schmidt. I also am thankful to Rebekah Kim and Seth Cotterell, of the California Academy of Sciences Library and Archives, for their assistance. This paper was an unexpected result of my attempt to share an interesting part of our long and storied history at our annual "Steinhart Day" staff appreciation event. I had no idea that I would find two boxes filled with files, photographs, letters, and newspaper clippings, and that the stories held within would be so fascinating.

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GENDER IDENTIFICATION OF GROUPER SPECIES IN CAPTIVE CARE THROUGH NONLETHAL METHODOLOGY: VITELLOGENIN (VTG)

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Abstract

This paper was inspired by the behavioral shift brought on by the death of our largest goliath grouper, LJ, in a large Caribbean fish and elasmobranch tank. This tank housed 4 goliath groupers for many years and has always had peace within the population. It was after this dramatic shift that we decided to look further into the genders of our goliath grouper to answer perhaps why they may be behaving in such a profoundly different way than before LJ's passing. Using a bioassay of grouper specific vitellogenin; we determined that the remaining 2 adult goliath groupers were a male and a female. The two remaining male goliath groupers have since passed away since the beginning of this experiment. It was visually confirmed upon necropsy that they were male based on the presence of fully developed testes.

Introduction

WoW's largest and what was presumed as our alpha male 'LJ' is what started this entire experiment into grouper gender identification. On a cold winter day, our beloved fish L.J. passed away, and what unfolded after that was behaviorally fascinating. Upon his necropsy, he was obviously a mature male and took samples as dictated by protocol. Very shortly after, I observed a change in the behavior of the remaining goliath grouper population. Two of the remaining groupers began a dramatic shift in behavior. Excessive 'barking', chasing, biting, and showing non-discriminate territorialism. Most notable was the 'barking'. I obviously did not want to euthanize any animals in order to determine their gender, so I looked into alternative methods that only require a blood sample. This is where I decided to investigate the presence of vitellogenin.

Vitellogenin is a protein precursor involved in the formation of egg yolk in female animals. It is produced by the liver and then transported to the ovaries, where it is incorporated into developing eggs. Vitellogenin is found in many species of fish, including the giant or Queensland grouper, *Epinephelus lanceolatus* (*Epinephelinae*), a large marine fish native to the Indo-Pacific (Daud 2016).

Goliath groupers are presumed to be protogynous hermaphrodites. This means that at one point in their lives they could test positive for vitellogenin but many years later could show no signs of the protein. This was seen in a research paper by Murie et al (2023) off the coast of Florida.

In the case of the Giant grouper, vitellogenin plays a crucial role in the reproductive process (Daud 2016). Vitellogenin is produced in response to hormonal signals, specifically estrogen, and is important for the development of healthy eggs (Colin 1994). It is synthesized during the reproductive cycle and deposited in the eggs as yolk, providing the nutrients needed for the embryo's development after fertilization (Prapaporn 1996).

The presence of vitellogenin is often used in studies to monitor reproductive health in fish populations and to investigate the effects of environmental stressors, pollutants, or endocrine-disrupting chemicals. In fish species, including the goliath grouper, vitellogenin levels can be used as an indicator of reproductive condition or environmental contamination (Covens 1987).

Research on vitellogenin in giant groupers could also provide insight into their population dynamics, breeding habits, and overall health (Daud 2016). However, there is limited specific research on the exact mechanisms and implications of vitellogenin production in Goliath groupers, as studies tend to focus on broader ecological and environmental aspects (Mann 2009).

The Goliath grouper is known for producing a variety of vocalizations, primarily as part of its communication during interactions with other groupers, particularly during spawning or in response to threats (Brewster 2023). These sounds are an essential part of their behavioral ecology, particularly for coordinating activities in social aggregations or marking their presence in the environment (Hawkins 1986). The barking from the "Out to Sea" exhibit became an everyday occurrence that drew questions and concerns from observers. This is the same exhibit where the original 4 goliath groupers were housed. We also were curious of the gender of other grouper species that are housed at WoW, and they were included in these trials, as our ELISA test had wells that were available for extra samples. We also sampled a goliath grouper from a different system, a panther grouper and a black grouper to gain further knowledge of our animal population.

Methods

Animal capture

10,000ppm tricaine was used out of large squeeze bottles. The tricaine was mixed with reverse osmosis fresh water (ROFW) and buffered with sodium bicarbonate (NaHCO3) at a 2:1 ratio to tricaine (MS-222). Below you will note a massive undertaking of several departments. Dive operations, medical team and animal husbandry all working together to safely capture all of our groupers to collect a blood sample. This was attempted a few times before we became somewhat confident in our abilities and methods.

Collecting Samples

Blood was taken from all the groupers from the caudal vein (Image5). Blood samples were collected and allowed to clot for two hours at room temperature before centrifugation for 15 minutes at 1,000 ×g. Plasma was collected using heparin as an anticoagulant.

Grouper specific vitellogenin ELISA Preparation

These steps have been taken from the manufacturer of the ELISA test that we used.

- An ELISA for vitellogenin requires specific antibodies that bind to vitellogenin proteins. These can be polyclonal or monoclonal antibodies that have been raised against vitellogenin from the target species or other closely related species.
- If a commercial vitellogenin ELISA kit is being used, the antibodies will typically be pre-coated on the plates or included in the kit.

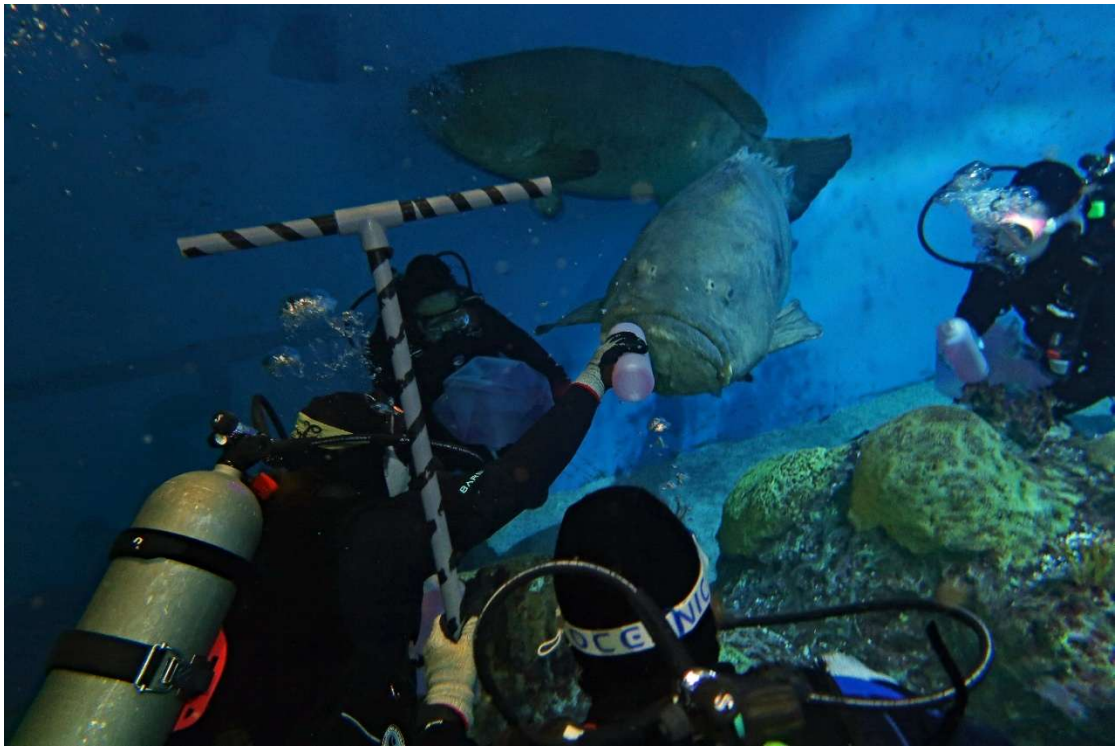

Image 1. Teams working underwater to dose the targeted fish with Tricaine in 20oz squeeze bottles that have food safe red dye added. Stick divers also present to deter other large animals from interacting with the dosing team.

Image 2. A test of the reaction from the groupers dorsal spines allow divers know it is safe to bring him into the med pool.

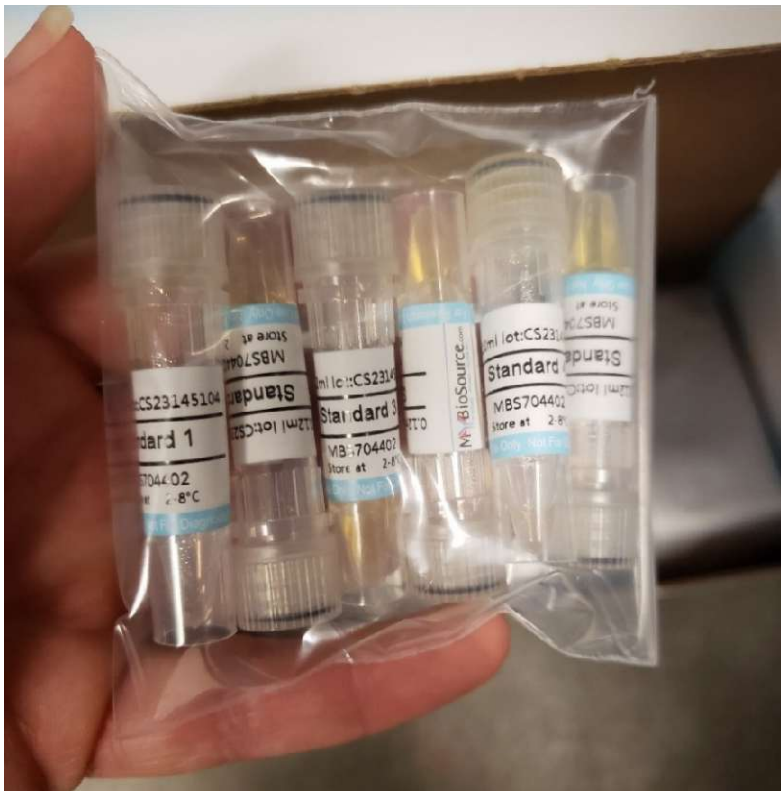

Image 3. Vials hold blood from the grouper. This will be put into the centrifuge.


Image 4. Large squeeze bottles are filled with MS-222, red food color is added to let divers know how much of the medication is being absorbed into the gills.

Image 5. How we collected the blood from each grouper. After the animal is secured, our veterinarian would draw from the caudal vein, located on the underside of the caudal peduncle.

1. *Coating the ELISA Plate*
    - A 26 well format microplate is coated with an anti-vitellogenin antibody, or a capture antibody that specifically binds to vitellogenin.
    - Incubation allows the antibody to adhere to the plate surface.
2. *Sample Application*
    - The collected samples were diluted appropriately and added to the coated wells. Vitellogenin in the sample binds to the capture antibody if present.
3. *Washin***g**
    - The plate is washed to remove any unbound substances (such as other proteins or non-target molecules). We used a lab sink and running city water.
4. *Detection*
    - A secondary antibody, which is conjugated to an enzyme (e.g., horseradish peroxidase, HRP or alkaline phosphatase, AP), is added. This secondary antibody binds to the vitellogenin-bound primary antibody.
    - After washing off any excess secondary antibody, a substrate for the enzyme is added. The enzyme will catalyze a reaction that produces a color change which is proportional to the amount of vitellogenin in the sample.
5. *Quantification*
    - The samples we were observing were all using gross visual examination. We did not use the curve due to lack of the special equipment needed. Having said that the color difference was significant to see where there was a was not any presence of vitellogenin in the sample.

Overall, the vitellogenin ELISA assay is a powerful tool for assessing reproductive status in groupers and other fish species. If you're conducting this assay specifically for a species like the Goliath grouper, it is important to validate the assay with antibodies specific to that species (Covens 1987).

Results

Our facility did not have access to the spectrophotometer needed for a curve determination in this ELISA. What we used for determination of vitellogenin was gross observation. We simply looked at the samples and compared the color change to the blank. See figure 2. It was determined that with three of the groupers tested that there was no presence of vitellogenin due to the distinct color of the serum. Two goliath groupers in the Out to Sea exhibit that were males since this study was initiated, have passed away. Upon necropsy, fully developed testes were found in both. We also were able to test these males for their vitellogenin before they passed and found no presence of vitellogenin.

To explain Figure 2, the blank sample is the S0 which was very yellow and has zero concentration of vitellogenin. So, if we observe samples of a lighter, clearer liquid that was suggest there is presence of the pre-cursor protein found within that animals' serum sample.

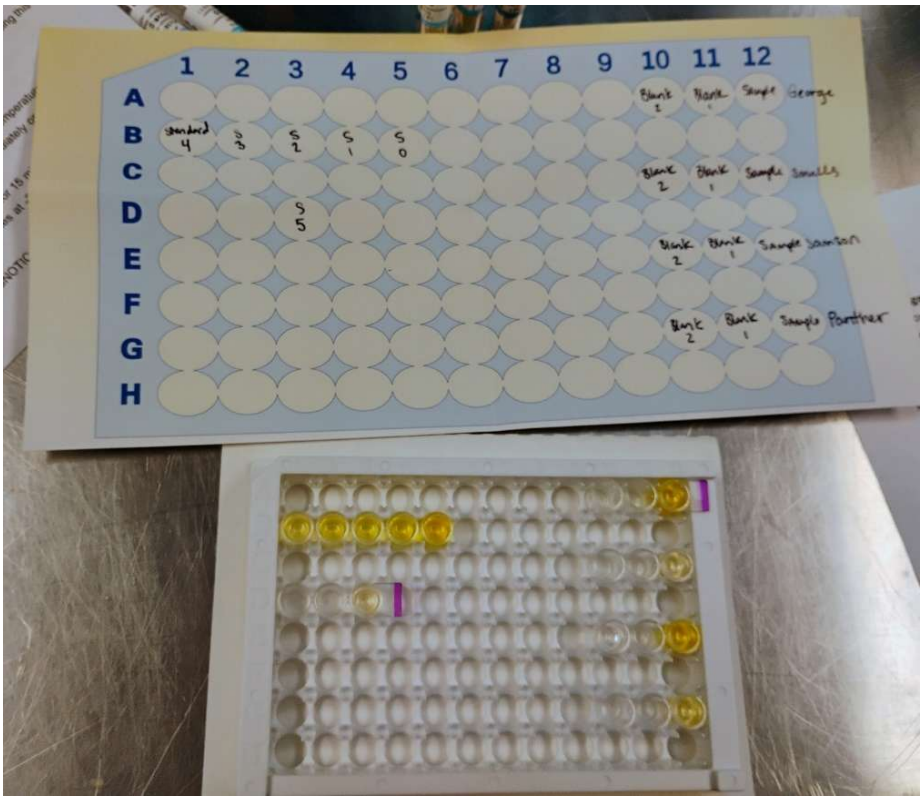

Figure 1. Four groupers tested. Samples show different saturations of the standard solution to determine presence of vitellogenin.

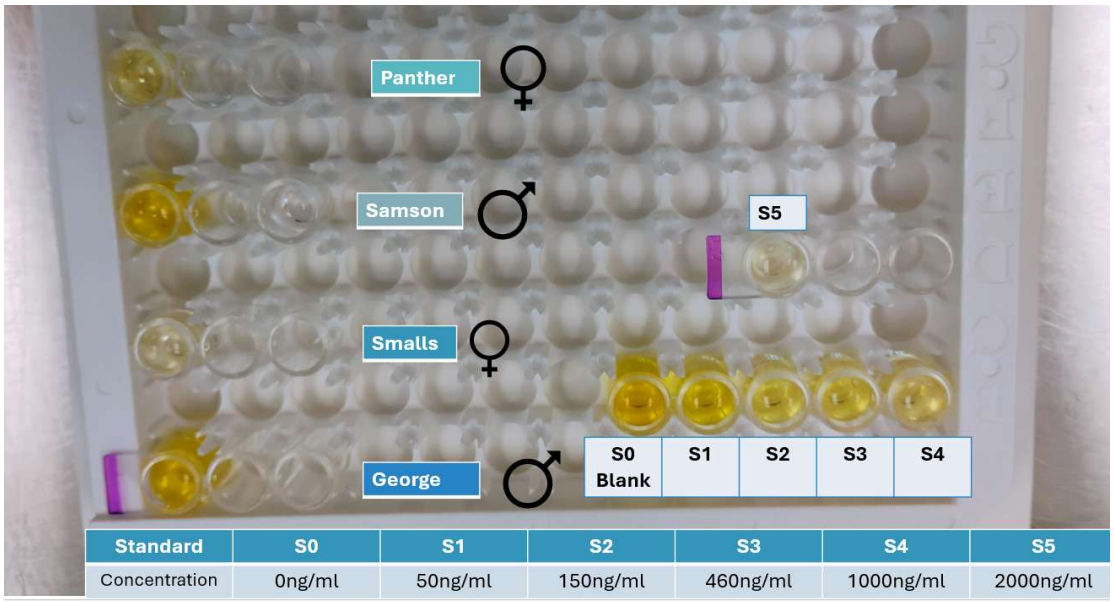

Figure 2. A labeled tray of the ELISA test that shows the color distinction between plasma with and without the presence of vitellogenin.

Conclusion

The results created more questions than answers. It was my hypothesis that one of the goliath groupers was female. In fact, it was true that of the four goliath groupers in the same tank, our remaining grouper "Smalls" did test positive for vitellogenin. We also discovered that the panther grouper in our cylinder tank is female. Our goliath grouper in cylinder is an adult male. The black grouper in our mangrove exhibit is also a male.

I wonder if one of the reasons that 'Smalls" has survived the other groupers was due to gender and lack of aggressive competition with tank mates. It would be worth noting that this may change over time and if this grouper were tested in 5 or 10 years would we still see presence of vitellogenin?

The panther grouper does not have any current health or behavioral concerns and we performed this ELISA on her for the purpose of additional baseline data collection. The large goliath grouper in the cylinder tank and black grouper was also tested for this reason and for pure scientific curiosity, not because of a noted change in behavior like we saw in the groupers together in the Out to Sea exhibit.

Research is limited for groupers in our professional care. We do not know what may trigger a change in gender for these fish, or if the deaths of the two males that passed away after the first one were related to heightened aggression and competition stressors, but these may have been contributing factors. Many questions remain on grouper behaviors and what drives these changes. I was not fortunate enough to capture the results from an earlier round of vitellogenin samples that were taken from the three goliath groupers from Out to Sea. It is expected that these would have looked exactly the same as our second trials featured in this paper. What I am most proud of is that I was able to successfully catch these enormous and fantastic fish many times and got the serum needed to answer the gender mystery without any harm coming to these animals.

Acknowledgments

Thanks to the Life Sciences team and veterinary staff at Wonders of Wildlife for their significant help with running samples and preparing for physicals. It should be noted that the sole author of this paper (myself) is no longer at the facility where this study was done. I am now at the Florida Oceanographic Society. Please reach out to me at epinney@floridaocean.org should you have any questions about this topic. I would be delighted to discuss further details.

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SEAHORSES ON TAP: CREATION OF AN ECONOMICAL HYPERBARIC CHAMBER FOR SMALL FISHES

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Introduction

The use of hyperbaric techniques (recompression/decompression) on fishes have been employed in public aquaria in various forms for many years. The primary use has been recompression following barotrauma (e.g. hyperinflation of the swim bladder and subsequent exopthalmia), but these are also useful for treating other gas-related medical conditions. There are four primary methods which have been employed to employ hyperbaric therapy to fishes:

1) Hydraulic Pressurization: a sealed vessel is completely filled with water and connected to an external source with oxygenation, biofiltration, chilling/heating or other LSS components. Pressure is created by a pump pushing water in to the unit while a backflow regulating valve on the effluent side creates backpressure. For examples see Smiley and Drawbridge (2005); Welsh (2012); and Shepherd et al. (2018).

2) Pneumatic Pressurization: a sealed vessel is partially filled with water and gas is injected into the headspace creating pressure. Because there is no water exchange, accumulation of CO_2 and NH_3 may be problematic depending on the biomass to water ratio. Accounts of this method include this study, Ballard (2008); and Welsh (2012).

3) Hybrid: a sealed vessel is partially filled with water and pressurized with gas as in pneumatic chambers, but at some point, the vessel is connected to an external LSS as is employed with hydraulic chambers allowing pneumatic pressure to be maintained hydraulically while water is exchanged, see Welsh (2012).

4) Commercial Chamber Use: animals and water in an open vessel are placed in a large, commercial hyperbaric chamber, see Schneider and Rollinson (2006) and Anderson and Belhumeur (2024). Very large fishes, including a zebra shark, *Stegastoma tigrinum*, have been treated in this manner.

As described above, most of the aquarium-built chambers have utilized hydraulic pressurization to achieve recompression, though some have used gas. Table 1 below summarizes the specifications of these units which have been described in the literature. These units can absolutely be constructed in-house, but have considerable costs associated with the components, and hydraulic models are reliant on continuous function of both the pump and pressure-regulating valve to avoid catastrophic accidental decompression.

Syngnathid fishes often have issues associated with gas emboli, aquaria have resorted to sinking them to the bottom of their deepest tank and other creative solutions, though hyperbaric

therapy remains a much-understudied tool. When faced with a similar situation at the Dallas Aquarium at Fair Park, the authors (BC, JF) were discussing a medical case with the attending veterinarian, who remarked "*It's too bad you can't run out at lunch and pick up a hyperbaric chamber*" …rather than taking this as a sign to explore other options, it was taken as a challenge.

Knowing that the chambers described by Welsh (2012) were modified pressure vessels, it was surmised that for diminutive fishes such as seahorses, a 20-24h run in a small stainless steel beer keg might work, and was not different in terms of biomass to volume ratio than overnight shipping in sealed bags. The inherent risks identified were accumulation of NH_3/NH_4^+, depression of pH through CO_2 production, and change in temperature through compression and decompression. Strategies to mitigate all of these risks were discussed as would be done in a sealed-bag transport, and in less than a day the first working prototype was constructed. This version was later modified and improved by the authors (SSP, BS, BC) at the Maritime Aquarium to treat similar syngnathid gas emboli, these two chambers are described herein.

Table 1. Specifications of Some Hyperbaric Chambers Utilized by Public Aquaria

Pressurization	**Institution[1]**	**Volume**	**Material**	**Use[2]**	**Working Pressure(s)**			**Decomp. Time**	**Reference**
units		*(L)*			*(fsw)*	*(psi)*	*(atm)*	*(h)*	
Pneumatic	MBA	~15	Steel	Co	231	103	7	72+	Welsh, 2012
	SWD	250	FRP	Co	49	21.8	1.4	6	Ballard, 2008
	SWD	1200	FRP	Co	49	21.8	1.4	6	Ballard, 2008
	DAFP	4	Steel	Tx	33-66	15-30	2-3	20-25	Present Study
	TMA	4	Steel	Tx	33-99	15-45	2-4	25	Present Study
Hydraulic	CAS	6.4	Plastic	Co	197-262	88-118	7-9	17.5-105.5	Shepherd et al., 2018
	HSWI	63	Steel	Co	304	150	10.2	73-150	Smiley & Drawbridge, 2005
	MBA	~24	Plastic	Co	165	73.5	6	72+	Welsh, 2012
	MBA	~80	Plastic	Co	165	73.5	6	72+	Welsh, 2012
	PDZA	160	Plastic	Co	67	30	2	26-48	Foster, unpub. data.
Commercial	TMA	75	-	Tx	60	26.5	2.8	5	Schneider & Rollinson, 2006
	PDZA	3024	-	Tx	16.5	7.4	1.5	0.75	Anderson & Belhumeur, 2024

[1]MBA= Monterey Bay Aquarium, SWD= Sea World Durban, DAFP= Dallas Aquarium at Fair Park, TMA= The Maritime Aquarium at Norwalk, CAS= California Academy of Science/Steinhart Aquarium, HSWI = Hubbs Sea World Institute, PDZA= Point Defiance Zoo and Aquarium

[2]Co = Collecting (relieving barotrauma), Tx = Treatment (therapeutic)

Methods

This hyperbaric chamber design was patterned after Welsh (2012), using a steel vessel rated for up to 125psi of pressure. Instead of using commercial pressure vessels designed for industrial use, a 2 ½ gallon Cornelius keg designed for dispensing beer was utilized. The Cornelius keg has a wide-mouth opening allowing animals to be gently placed by hand in the water, but is limited in size compared to industrial pressure vessels of similar construction. A ball-lock gas fitting was attached to the gas post of the keg, and a copper line was soldered to a manifold with a ball valve, needle valve, and a pressure gauge. In the improved version (Mk. II) later built at the Maritime Aquarium, reinforced beverage tubing (gas impermeable) was substituted for ¼" sweated copper, and the ball valve (used to allow O_2 pressure in) was placed in line with the needle valve to offer redundancy and to prevent rapid decompression should one valve handle be bumped or nudged.

The needle valve allows for very fine control of pressure release during decompression, and the largest pressure gauge available, with the most gradations possible should be used to facilitate the simulated 'ascent' in a slow, controlled fashion. In the Mk. II version, a pressure gauge reading feet of H_2O was substituted for one that read in psi, to be more analogous to published treatment tables and facilitate ease of use. Note that **under no circumstances should an oil-filled pressure gauge be used with compressed oxygen**, as the mineral oil (a hydrocarbon) can combust through adiabatic compression with oxygen. See information below on oxygen cleaning and details on oxygen-safe materials.

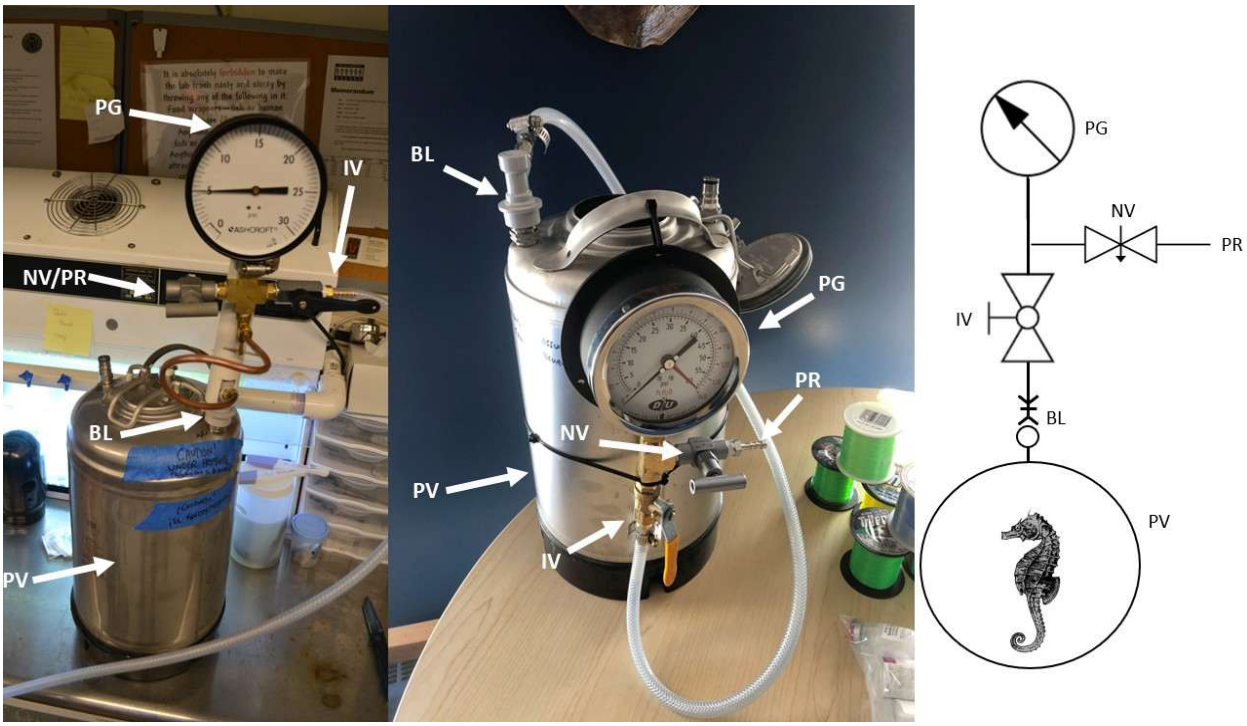

Figure 1. Two variations on a theme, the original unit constructed at the Dallas Aquarium (left) and an improved version (Mk.II) constructed at the Maritime Aquarium (middle). Schematic (P&ID) of key components (right). Figure legends as follows: PG=pressure gauge, BL=ball-lock fitting, NV=needle valve, PR=pressure release opening, IV=isolation valve, PV=pressure vessel. The configuration at middle has two valves in series (ball valve IV and needle valve NV) as a safeguard against unintentional sudden depressurization.

Components

To facilitate replication, the specific components used to construct a hyperbaric chamber using a re-purposed keg are listed below in Table 2. The part number for the suppliers referenced is hyperlinked, though note that while accurate at time of writing (summer 2025) these may change in the future. O-rings required to replace rubber with Viton™ for oxygen safety are listed by their dimensions, including the dash no. for specificity.

Table 2. Parts Required to Build Hyperbaric Chamber from Modified Keg.

Part	Qty	Vendor	Part Number
Pressure Bleed Assembly			
1/4" ID tubing	5'	McMaster Carr	5723N11
Hose Clamps	2	McMaster Carr	5415K32
Oxygen-Safe Lube	1	Dive Gear Express	ASL-PC71-97xx
Brass Tee ¼" FPT	1	McMaster Carr	50785K72
Brass Barb Fittings	2	McMaster Carr	5346K82
Needle Valve	1	McMaster Carr	7833K82
Pressure Gauge (oil-free, oxygen clean)	1	McMaster Carr	9816T12
Ball Valve	1	McMaster Carr	47865K21
Oxygen Tape	1	GetPipe.com	70850
Keg Assembly			
Keg	1	MoreBeer	KEG419
Ball-Lock Fitting	1	MoreBeer	KEG743
Viton™ O-Ring 3/32"-113	2	McMaster Carr	1284N142
Viton™ O-Ring 3/32"-111	2	McMaster Carr	1284N14
Viton™ O-Ring 3/32"-109	2	McMaster Carr	1284N138
Viton™ O-Ring 1/4"-417	1	McMaster Carr	9464K741
Viton™ O-Ring 1/16" -008	2	McMaster Carr	1284N108

**Part numbers hyperlinked to vendor's website, part numbers and links accurate as of 2025, may change over time, double check specifications prior to ordering*

Oxygen Cleaning

Before using plumbing fittings and components with pressurized oxygen they must be appropriately cleaned. Oxygen cleaning involves two or three steps: 1) demineralization (for used parts with calcium or other deposits), 2) removal of hydrocarbons, 3) replacement of gaskets and seals with oxygen compatible Viton™ O-rings and oxygen compatible lubricants (e.g. Christolube™ MCG-111). Threaded NPT fittings should be assembled with oxygen-rated thread tape (e.g. Blue Monster OxyClutch™), not with standard Teflon™/PTFE tape. The step-by-step process of oxygen-cleaning used by the authors employed is described below for educational purposes only, the reader is advised to seek formal instruction if not previously trained in oxygen cleaning procedures and safety:

1) Demineralize by soaking for 24h in 5% acetic acid (this step may be omitted if using new components without potential calcium deposits), rinse and dry. If using new components skip to step 2.

2) Disassemble keg posts and remove all O-rings.
3) Soak all parts (except pressure gauge) to be exposed to pressurized oxygen (including the interior of the chamber and tubing, and new Viton™ O-rings) in hot water and dish soap, scrub with a soft toothbrush or similar, rinse thoroughly with hot water and dry.
4) Place all small parts (including new O-rings to be installed) and tubing in an ultrasonic cleaner with a solution of at least 1:10 Simple Green™ Extreme or Simple Green™ Crystal cleaner at 120-125°F and clean on the highest setting for 30min.
5) Wearing nitrile gloves, rinse with hot distilled water and allow parts to dry in a low-dust environment. Examine with a black light and if any specks of fluorescence on parts are seen repeat steps 3 & 4.
6) Wearing nitrile gloves, replace all rubber O-rings with Viton™ O-rings, and assemble components. Use oxygen-compatible lubricants on O-rings if needed and oxygen compatible thread tape on NPT connections. Note: the only dynamic (moving) O-rings in the system are at the keg poppet, all other O-rings are static and require little to no lubrication.

Note: this process has been employed by the authors to good effect, but ***absolutely no guarantee*** *is given as to the safety or efficacy; if not previously trained in oxygen cleaning procedures and safety seek assistance from qualified individuals. Formal training in oxygen cleaning is available through ASTM, WHA International, and PSI-PCI (the former two being geared towards industrial applications, the latter being aimed at SCUBA diving applications).*

Results and Discussion

Case Study no.1: *Hippocampus erectus* 1.0.0 (DAFP)

In 2014, a group of seahorses, *Hippocampus erectus*, in quarantine presented with gas emboli visible on their fins, and subcutaneous emboli on the tails following shipping to the Dallas Aquarium at Fair Park in 2013. The animals were treated with acetazolamide at 6mg/kg q5d IM and most showed improvement, however one male developed an external lesion and pronounced bubble within the brood pouch adjacent to the site of infection. The gas was aspirated with a surgical catheter, and culture and sensitivity testing revealed a variety of *Vibrio* and other organisms not typically known for gas production. The group began a course of waterborne oxytetracycline treatment at 50mg/L along with 10mg/kg ceftazidime injections q3d.

Within a week the external lesion had healed, and all smaller emboli were resolved, but the brood pouch tissue retained a large gas bubble causing the animal to float upside down (see Figure 4), the gas regenerated despite repeated aspiration, and it was decided to try hyperbaric therapy in addition to continued acetazolamide and antibiotics in an attempt to relieve the brood pouch bubble in addition to antibiotics to treat the underlying infection. In the initial recompression, the specimen was pressurized to an equivalent depth of 33fsw (~15psi, 2atm) for 4h, and decompressed over 21h (25h total run-time). Marked improvement was seen, but the bubble was not fully reabsorbed. Three days later the same animal was pressurized to an equivalent of 66fsw (~30psi, 3atm) for 6h, followed by a 25h decompression (31h total run-time), which showed complete resolution of the bubble, with the animal able to swim upright, navigate the holding tank, and find food effectively. See Figure 3 for decompression schedules used.

Case Study no.2: *Hippocampus erectus* 2.0.0 (TMA)

Two seahorses, *H. erectus*, at the Maritime Aquarium presented with gas emboli and were treated in an improved (Mark II) version of the keg-chamber. These animals were collected off Long Island between 15-28 July 2020. All of these animals underwent a 30-day quarantine period with standard prophylactic treatments, after which time some stayed in the quarantine rack system and some were transferred to exhibit (Autumn 2020); others were transferred to a (deeper) 500-gallon tank after exhibiting breeding behavior, to facilitate reproduction. During this time, a good amount of mating behavior was noted and a few males that had continuous issues with their pouch being filled with air. Often, these males could be 'burped' but there was no direct apparent cause for this other than routine breeding behavior, or occasionally holding on to air stones. The affected males were submerged in the Ocean Beyond the Sound exhibit as a trial for pressure, dropping these animals down to the bottom of the system (17 fsw), in a modified container. After 24 hours these animals were pulled up and evaluated, and no significant changes were seen. On 12 October 2020 they were recompressed using the Mark II chamber. The two males who were exhibiting air in the pouch that did not respond to submersion in the deepest exhibit or manual aspiration were compressed to 2atm (66 fsw) and decompressed over a 25-hour period. Afterwards, it appeared that the gas emboli were relieved and the animals were able to function normally afterwards.

Microflora: BOD and CO_2

In a small volume of water, the influence of bacteria and other microflora can be significant on depletion of oxygen and production of CO_2. While oxygen is abundant in this system, control of inert gas is important for two reasons: to maximize displacement of gas in emboli being treated, and to limit carbonic acid production which will depress pH. In one of the initial trials, chamber water was analyzed for total coliforms (Fig. 2) which were found to be 3402 CFU in 4L (85 CFU/100mL). Heterotrophic bacteria are commonly 3-4 orders of magnitude higher than total coliforms, so total waterborne bacterial levels can reasonably be expected to be >300,000 in this same volume.

Figure 2. An illustration of the amount of normal bacterial flora in 4L of aquarium water (left) which contribute to BOD, consuming oxygen, and creating inert gas (CO_2, N_2). Filter sterilizing water to 0.45µm eliminates this variable. At right, aggressive aeration of filter-sterilized water with pure O_2 to displace inert gas prior to hyperbaric therapy.

Ammonia and pH

Control of ammonia is a critical factor in a chamber design without water filtration or exchange. The biomass to volume ratio should be sized similar to a sealed-bag transport by air expected to take ~24h. Table 3 below shows the NH_3 one can expect to be produced as a function

of biomass and volume; this can be used to calculate dosages of ammonia binder (e.g. ClorAm-X™ or AmQuel™). Just as with shipping animals, ammonia binding agents can be successfully employed to mitigate gill damage and ammonia toxicity for the duration of hyperbaric treatment.

Table 3. Ammonia (mg/L NH_3 d^{-1}) production as a function of biomass and volume

Volume	Biomass (g)										
(mL)	5	10	20	30	40	50	60	70	80	90	100
500	0.48	0.97	1.94	2.90	3.87	4.84	5.81	6.78	7.74	8.71	9.68
1000	0.24	0.48	0.97	1.45	1.94	2.42	2.90	3.39	3.87	4.36	4.84
2000	0.12	0.24	0.48	0.73	0.97	1.21	1.45	1.69	1.94	2.18	2.42
3000	0.08	0.16	0.32	0.48	0.65	0.81	0.97	1.13	1.29	1.45	1.61
4000	0.06	0.12	0.24	0.36	0.48	0.61	0.73	0.85	0.97	1.09	1.21
5000	0.05	0.10	0.19	0.29	0.39	0.48	0.58	0.68	0.77	0.87	0.97
6000	0.04	0.08	0.16	0.24	0.32	0.40	0.48	0.56	0.65	0.73	0.81

**Metabolic data derived from equations given by Spotte (1992).*

Table 4. Estimated CO_2 production (mg/L d^{-1}) as a function of biomass and volume.

Volume	Biomass (g)										
(mL)	5	10	20	30	40	50	60	70	80	90	100
500	48	96	192	288	384	480	576	672	768	864	960
1000	24	48	96	144	192	240	288	336	384	432	480
2000	12	24	48	72	96	120	144	168	192	216	240
3000	8	16	32	48	64	80	96	112	128	144	160
4000	6	12	24	36	48	60	72	84	96	108	120
5000	5	10	19	29	38	48	58	67	77	86	96
6000	4	8	16	24	32	40	48	56	64	72	80

**Estimate based on Oncorhynchus mykiss model (Perry, 1986) and hematocrit of 38% PCV (Hippocampus abdominalis) from Vergneau-Grosset et al. (2023).*

Table 5. Estimated buffering (mg/L $NaHCO_3$ d^{-1}) required to counteract carbonic acid produced from CO_2 as a function of biomass and volume.

Volume	Biomass (g)										
(mL)	5	10	20	30	40	50	60	70	80	90	100
500	65	130	259	389	518	648	778	907	1037	1166	1296
1000	32	65	130	194	259	324	389	454	518	583	648
2000	16	32	65	97	130	162	194	227	259	292	324
3000	11	22	43	65	86	108	130	151	173	194	216
4000	8	16	32	49	65	81	97	113	130	146	162
5000	6	13	26	39	52	65	78	91	104	117	130
6000	5	11	22	32	43	54	65	76	86	97	108

CO_2 Production and pH Depression

Another factor with a chamber of this design, which limits the size of animals which can be recompressed/decompressed, is the accumulation of CO_2 and subsequent decline in pH. Significant amounts of CO_2 are produced with even miniscule animals, for example, referencing Table 4 above, we see that even a 20g seahorse would produce 24mg/L of CO_2 in 4L over a 24h period. CO_2 dissociates in water to form carbonic acid, depressing pH. Taking that same CO_2 value above, we would need to add at least 32mg of buffer to counteract the effects of the pH depression (Table 5). Buffering in a small, closed volume should always be done in tandem with the use of an ammonia binder (e.g. ClorAm-X™) to mitigate the toxic effects possible from a change in the NH_4^+/NH_3 equilibrium as pH fluctuates. It is worth noting that some effects of oxygen toxicity have been observed in lower vertebrates, but have only been studied at much higher pressures (Barthelemy et al., 1981), and as such CO_2 accumulation was considered a much greater risk to fishes in a small volume than elevated oxygen exposure.

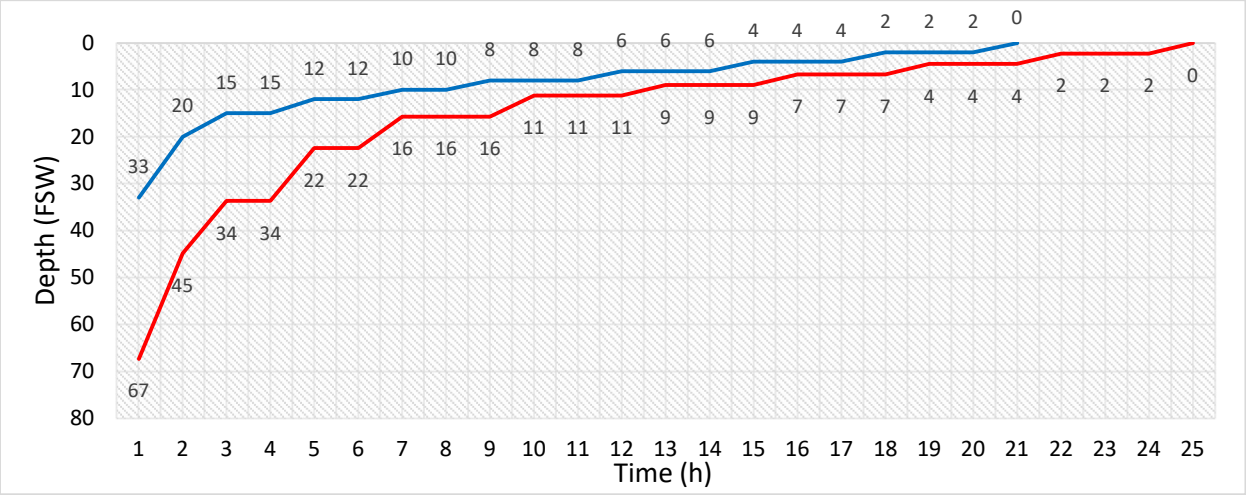

Figure 3. Decompression profiles used on sygnathid fishes to resolve gas emboli at the Dallas Aquarium at Fair Park and the Maritime Aquarium. Top curve (blue) is a 21h profile following 4h exposure at an equivalent depth of 33fsw (15psi). Bottom curve (red) is a 25h profile following 6h exposure at an equivalent depth of 67fsw (30psi).

Decompression Schedules

Decompressing animals, once pressurized, is a subject where much more study is needed. Human models have come to be reasonably well understood over more than a century of refinement, but for varying fish species the reliability of the few empirically-derived schedules leave much to be validated and studied. The published (human) schedules for hyperbaric medicine have been used as a starting point for animal treatment, including Treatment Tables 3, 4, 5, 6, and 6A (US Navy, 2016). The duration of treatment varies for each of these standardized schedules, but they have some commonalities that provide useful guidelines for animal studies, such as an ascent rate of 1fsw/min (US Navy, 2016), which was the rate used between decompression stops in these trials. Table 1 lists the operational depths (fsw) and decompression times for reported studies; decompression time increases with greater depth, with as little as 5-6h in some cases (Schneider and Rollinson, 2006; Ballard, 2008), and as long as 105h (Shepherd et al., 2018) and 150h (Smiley and Drawbridge, 2005). In this trial, duration of recompression was determined by following previous published accounts, and the shape of the decompression curve was extrapolated from a profile generated from saturation dives to 40 and 70fsw by a decompression program, GAP

1.0 (Bühlmann model) with gradient factors (GFHI/GFLO) set for maximum conservatism and deeper initial stops. Total decompression durations were more conservative than standard ascent rate recommendations of 3fsw/h (0-50fsw) and 4fsw/h (50-100fsw) for saturation dives (US Navy, 2016).

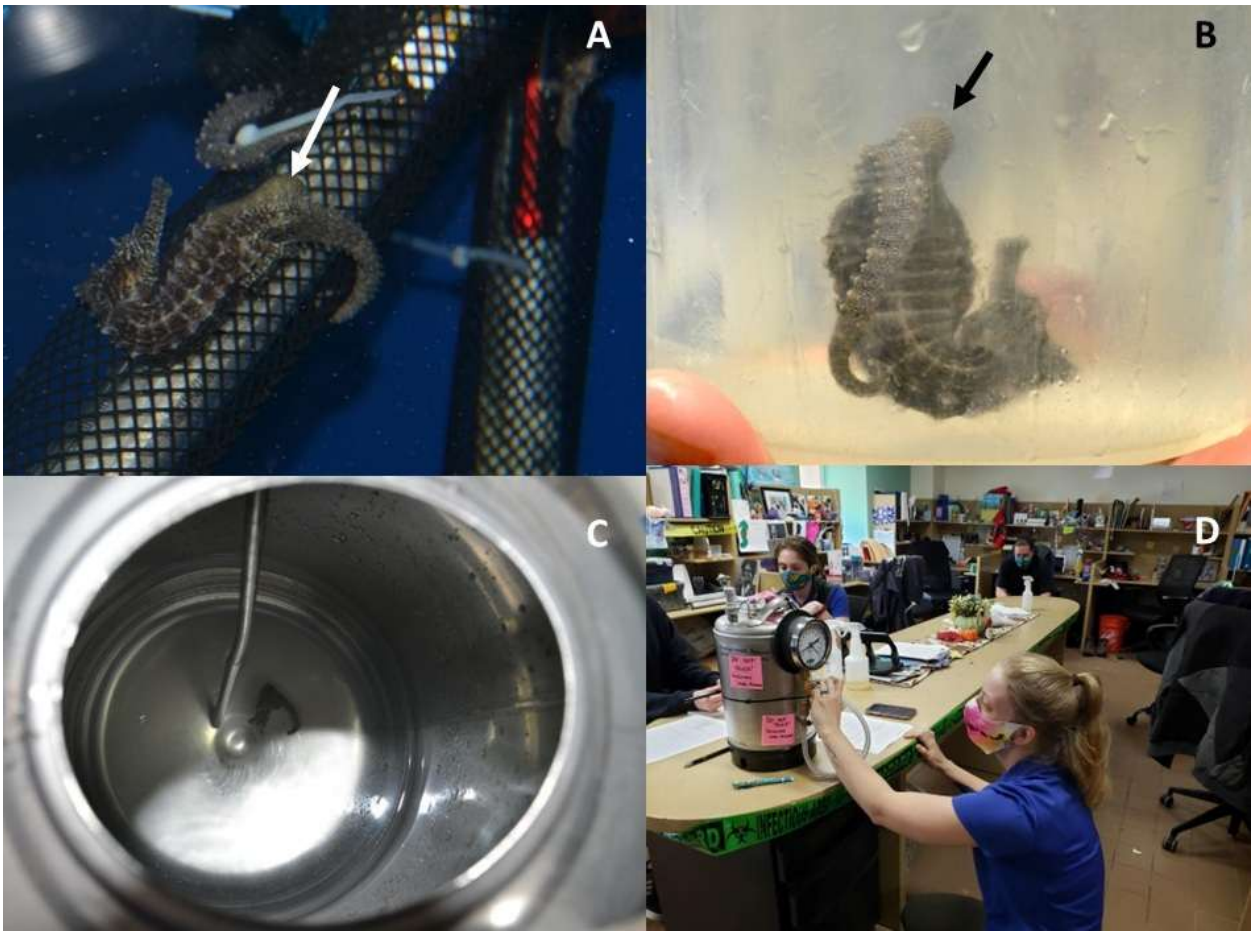

Figure 4. Syngnathid specimen, *Hippocampus erectus*, with gas emboli in the pouch (A,B) prior to hyperbaric therapy. The seahorse in filter-sterilized, hyper-oxygenated water (C) prior to hyperbaric treatment. An aquarist slowly relieving pressure (D) over a 25-hour period (during the 2020 COVID pandemic), the chamber should be kept in a space that is temperature controlled (in this case the staff office) and not subject to disturbance during decompression.

Schrödinger's ~~Cat~~ Seahorse

Any discussion around building recompression and barotherapy chambers within the public aquarium industry inevitably comes down to cost/benefit analysis of possibilities and preferences. Factors such as anticipated need, size, maximum pressure, parameter measurement and control, maximum residency time, and safety for aquarists and chamber occupants can have big impacts on the overall cost of the project.

For these modified keg chambers, frugality was given highest priority (out of necessity) over a number of other factors. Arguably, visibility of the pressurized animal is both the highest priority factor missing and possible to remedy in future variants (Mark III, et seq.) of this chamber design. Gas embedded in tissue can take variable amounts of time to be physiologically exported from the

body (depending on species, temperature, size, etc.), which can be observed as a physical return of symptoms during the controlled decompression. Being able to visibly assess the fish during barotreatment allows for responsive decisions to be made (i.e. if visible emboli return the animal can be sent 'back down') and expected decompression timelines to be adjusted.

An option to remedy this downside would be to work with a plastics specialist for a custom fabricated clear lid with material specifications for handling water and gas pressure up to at least your maximum anticipated needs. The risk here is that such a lid would be a relatively expensive retrofit onto a specialized pressure vessel, and plastic fabricators may be reluctant to take on such a job (let alone offer any guarantees). If it is necessary to contract this work out, the cost of the lid alone may be several times that of the rest of the project.

Any institution interested in expanding their treatment options into barotherapy should consider the factors important to their needs and accrue the funding necessary to build the chamber that will work for their team and collection.

With this design, small fishes can be recompressed and decompressed effectively and economically, but much like Schrödinger's cat, these fishes are simultaneously both alive and dead, healed and infirmed, emboli-ridden and bubble-free…until the box (in this case a keg) is opened.

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CONSISTENCY OVER PERFECTION: WATER QUALITY FOR WESTERN ATLANTIC CORALS IN HUMAN CARE

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Overview

In 2018 the Florida Fish & Wildlife Conservation Commission (FWC) contacted the Association of Zoos and Aquariums (AZA) and proposed a novel public / private partnership to initiate a large coral rescue project as a result of the impact of the coral disease known as Stony Coral Tissue Loss Disease (SCTLD). Prior to this, FWC had cooperated with a number of coral holders, in Florida, to create the Pillar Coral Rescue Project which influenced the Florida Reef Tract Rescue Project (FRTRP). Unlike the pillar coral rescue, FRTRP would focus on 25 species of corals and incorporate thousands of individuals.

The husbandry plan for the FRTRP was based on the collective coral knowledge of the public aquarium and hobbyist worlds at that time. As we know from our long history of keeping mostly Indo-Pacific corals, establishing and maintaining appropriate water chemistry parameters (having good water quality) are critical to the long-term health and welfare of corals in human care and is an excellent way to determine whether a system's life support is performing as designed.

Whereas Indo-Pacific corals commonly found in the hobbyist trade and public aquaria have been stress-tested and selectively propagated over time, with the hardiest individuals entering circulation, the acquisition of dozens of genetically unique and novel corals across multiple species has presented its own challenges. Additionally, the FRTRP was the first opportunity for

Table 1. List of corals susceptible to stony coral tissue loss disease. Corals marked with an asterisk (*) are Endangered Species Act (ESA) listed species. Low susceptibility species were noted as species that were rarely or not affected during outbreaks. Source: SCTLD Case Definition (2018).

Highly Susceptible	Intermediately Susceptible	Presumed Susceptible	Low Susceptible
Colpophyllia natans	*Orbicella annularis**	*Agaricia agaricites*	*Porites astreoides*
*Dendrogyra cylindrus**	*Orbicella faveolata**	*Agaricia* spp.	*Porites porites*
Dichocoenia stokesii	*Orbicella franksi**	*Mycetophyllia* spp.	*Porites divaricata*
Diploria labyrinthiformis	*Montastraea cavernosa*	*Madracis arenterna*	*Porites furcata*
Eusmilia fastigiata	*Solenastrea bournoni*	*Favia fragum*	*Acropora palmata**
Meandrina meandrites	*Stephanocoenia intersepta*	*Helioseris cucullata*	*Acropora cervicornis**
Pseudodiploria strigosa	*Siderastrea siderea*	*Mussa angulosa*	*Oculina* spp.
Pseudodiploria clivosa		*Scolymia* spp.	*Cladocora arbuscula*
		Isophyllia spp.	

a large number of coral aquarists to keep the majority of the tropical Western Atlantic corals included in the rescue project for an extended period of time. The intricate care requirements of some of these coral species surprised us, especially concerning water quality. With this article, the authors aim to document our communal findings in the water quality preferences of corals of the Western Atlantic and management practices that have helped us stay in those ranges.

Coral and Water Quality

Healthy growing corals constantly consume dissolved nutrients and trace elements and give off waste products. Management (including the regular and routine testing, examination and recording) of water chemistry values is essential for proper coral health. Corals are extremely sensitive to the dissolved elements and nutrients contained in the aqueous environment around them. The most expensive and well-constructed systems cannot hold and grow corals if the water in the system does not maintain proper and stable water chemistry for coral. It is recognized that individual aquarium systems may vary due to differences in their bacterial community, source water, and lighting but other factors such as nutrient ratios, heavy metals, or organic content will play a large part in coral health beyond the basic parameters. Technology can be a useful tool, but even very simple system setups can be just as successful. Quite importantly, water chemistry should be monitored and recorded through real-time monitors, regular testing, and/or submission of samples to outside testing laboratories. Historical water chemistry analysis is one of the first steps to aid in troubleshooting issues, even on flow through systems. It can also provide an opportunity to look back when new information comes to light.

The FRTRP provides significant and important latitude to the holding facilities to build, operate, and monitor their holding systems. This means there is no standardization of water quality methods between facilities. Over a 6-month period in 2021 and 2022, the FRTRP undertook a water quality diagnostic initiative (WQDI). The aims of the WQDI were to ground truth reported water quality values using two outside reference laboratories: Zooquatic Laboratories for general chemistry (see Table 2 for methods) and Triton Laboratories for inductively coupled plasma optical emission spectroscopy: ICP-OES. The results were used to cross-check holding facilities using different testing methods.

Table 2. Zooquatic Labs uses the following analysis methods from: SMWW Eaton et. al. 2005

Analysis	Standard Methods Reference #
Conductivity	**2510**
Salinity	**2510**
pH	**4500- H+**
Ammonia	**4500- NH3**
Nitrite	**4500- NO3**
Alkalinity	**2320**
Phosphate	**4500- P**
Calcium	**3500**
Nitrate	**4500- NH3/ 4110**
Bromide	**4110**

Table 3 below displays the authors' suggested ranges for commonly monitored reef aquarium water quality parameters when dealing with tropical Western Atlantic corals. The ranges below are derived from the holding experiences of the FRTRP holding facilities, reported over a six-month period in 2021-2022. **Not only should one strive to keep these parameters in range, but every effort should be made to keep parameter values as stable and consistent as possible. Stability may be more important than the absolute value.** Rapid changes within the acceptable range have been correlated with poor wellbeing outcomes. The ranges in Table 3 are somewhat different from typical, generalized hobby or professional targets for corals because we found that those target values, idealized for Indo-Pacific corals, did not provide us with the desired husbandry results for these tropical Western Atlantic corals. The recommendations in Table 3 are not absolute, as they represent the middle 50% of the WQDI dataset collected (Nelson, 2023). We utilized the middle 50% because mean +/- 1 SD of the data set produced an Alkalinity range that was too broad for comfort and did not correlate to published alkalinity values for the Florida Keys (Manzello et al. 2012). **It is possible to successfully hold Atlantic corals outside these ranges, but doing so may be more difficult.**

Table 3. Recommended water chemistry ranges by water quality parameter type.

Parameter	Lowest Recommended Value	Highest Recommended Value
pH	8.00	8.20
$NH4^{+}$	0 ppm	0 ppm
$NO2^{-}$	0 ppm	0 ppm
$NO3^{-}$	1 ppm	6 ppm
Salinity	33 ppt	36 ppt
Alkalinity	115 ppm $CaCO_3$	130 ppm $CaCO_3$
	6.44 dKH	7.28 dKH
	2.3 mEq/L	2.6 mEq/L
$_{Ca}+2$	395 ppm	440 ppm
$_{Mg}+2$	1300 ppm	1400 ppm
$PO4^{-3}$	0.03 ppm	0.2 ppm
$_{I}+$	20 ppb	80 ppb
$_{Sr}+2$	7 ppm	10 ppm
Temperature	74F / 23.3C	84F / 28.9C

Interpreting water chemistry analysis data, especially ICP-OES data, for coral aquarium systems can be daunting. Without a data set of comparable results over time, a one-off set of ICP-OES results is of limited value. To provide a starting point for comparison that is specific to the Western Atlantic, we present the following additional water quality data. Table 4 below shows the group of elements that have an average measured concentration higher than the published oceanic reference value for seawater among samples taken as part of the WQDI. The "recommended upper limit" is the value below which 75% of the values fell for the WQDI samples run (Nelson, 2023). It is not known how much difference these elements make when they are above either the oceanic or project reference values. Consider taking action to lower these values when above the third quartile if corals present with health issues that have no clear cause.

Table 5 lists trace elements and metals that average below the oceanic average in the WQDI dataset (Nelson, 2023). It is important to note that, in all cases except boron, zinc, and nickel, 75% or more of the data points fall below the detection limits of ICP-OES (at the time of testing) and should not be considered actionable. It is all too easy to get overly focused on and chase numbers that are not useful. Aquarists should pay attention if any of these elements with values above the detection threshold and certainly above the oceanic average, especially when those values coincide with health issues that do not have an obvious etiology.

Table 4. Trace element concentrations that run above "oceanic average" (Spotte, 1979) in the WQDI data set for Florida coral rescue holding systems.

Element	Oceanic Average (Spotte 1979)	Acceptable Upper Value (3rd Quartile)	ICP-OES detection limits	Units
K^{+}	380	415.00	0.001	ppm
Sr^{+2}	8.1	9.91	0.00004	ppm
I^{+}	60	81.50	2.0	ppb
Ba^{+2}	30	47.50	0.06	ppb
Br^{-1}	65	84.00	NA*	ppm
S^{-2}	885	934.00	10	ppm
Al^{+3}	10	19.50	0.03	ppb
Li^{+}	180	320.00	0.03	ppb
Si^{+4}	84.27#	149.50	1.4	ppb

* *Not a Triton detection value, but from other ICP-OES source. ICP Detection limits are as of the time of sampling throughout the study.* # Maldonado et al 1999

Caveats with Water Chemistry Testing and Management Strategies

Individual sets of test results are not a complete picture. Stability and trends are important, possibly more important than absolute, point-specific values. Different blends of manufactured salt mixes contain various concentrations of trace elements (or may not contain them at all) and source water, whether ozonated seawater or made with manufactured salt mixes, may need supplementation with known amounts of trace elements. Spotte's (1971) and therefore Bowen's (1966) table of oceanic water quality values have been referenced for a majority of classic salt mixes. While some of the newer formulations are more coral reef specific.

Water quality results can be affected by multiple variables in testing including: the individual performing the test, testing equipment, or other variations in laboratory testing technique. Consistency in these potential areas of variability is highly recommended. In any situation where you have received results that are of concern, some steps to consider before taking husbandry action include: retesting with a new sample in a new container; test results of source water; troubleshoot possible sources of contamination; review any changes in life support of the aquarium; question new food or additives; referencing tank trends and the possibility of a false positive. Some results such as elevated zinc can point to a rusty screw that has fallen in your system or lead contamination may be from a corroded magnet holding a power head in place.

Table 5. Trace element concentrations that run below oceanic average (Spotte, 1979) and/ or ICP-OES detection in the WQDI data set for Florida rescue coral holding systems.

Element	Oceanic Average (Spotte 1979)	3rd Quartile 75% of data points < this value	ICP-OES detection limits	Units
$_{B}+3$	4.6	4.53	0.0003	ppm
$_{Zn}+2$	10	3.04	0.05	ppb
$_{Fe}+2$	10	0.00	0.2	ppb
$_{Be}+2$	0.0006	0.00	0.01	ppb
$_{La}+3$	0.012	0.00	0.41	ppb
$_{Sc}+3$	<0.004	0.00	0.1	ppb
$_{As}+3$	3	0.00	0.98	ppb
$_{Cd}+2$	0.11	0.00	0.07	ppb
$_{Co}+2$	0.27	0.00	0.2	ppb
$_{Cr}+2$	0.05	0.00	0.3	ppb
Cu^{+}	3	0.00	0.3	ppb
Hg^{+}	0.03	0.00	0.7	ppb
$_{Mn}+2$	2	0.00	0.06	ppb
$_{Ni}+2$	5.4	1.24	0.2	ppb
$_{Pb}+2$	0.03	0.00	0.9	ppb
$_{Sb}+3$	0.33	0.00	0.9	ppb
$_{Se}+4$	0.09	0.00	1.8	ppb
$_{Sn}+2$	3	0.00	0.02	ppb
$_{Ti}+2$	1	0.00	7.6	ppb
$_{V}+2$	2	0.00	0.3	ppb
$_{W}+6$	0.01	0.00	1*	ppb

* *Not a Triton detection value, but from other ICP-OES source*

Additionally, the use of ozone or activated carbon to process natural seawater can strip essential elements, such as iodine, from the water and require supplementation. Many trace elements in seawater are below the detection limits of hobbyist test kits and most ICP-OES analysis, so determination of true concentration levels and any variations is difficult. Knowing the chemical makeup of source water used to create synthetic saltwater or used to make up for evaporation in an aquarium system is highly recommended. Similarly, using that information to

manage trace element availability in the coral aquarium's water resources should not be undervalued.

There are several tools and techniques available to aquarists that facilitate manipulation of aquarium water chemistry and nutrient levels. Some methodologies require extra equipment and planning to be successful. Whatever strategy is employed, it is crucial to understand the maintenance requirements, benefits, and implications of each. The goal is to maintain water chemistry parameters within ranges acceptable for the corals you are caring for, and to keep water chemistry as stable as possible to optimize coral health long term. This goal is best achieved using the simplest approach with the fewest number of variables. Complicated systems are not always more effective. Having a consistent strategy is important.

Managing Water Chemistry

Aquarium ecosystems involve many interconnected biological and chemical processes that directly influence water chemistry and coral health. Through constant and consistent observations, an aquarist will gain understanding of these processes. This allows for better recognition of how changes in water chemistry within aquarium systems can affect the behavior of corals, as well as how the biology of the corals will affect water chemistry. Changes within other aspects of husbandry, like lighting, feeding, and water flow, can also change coral behavior and biology that subsequently alter water chemistry. Understanding and applying this knowledge becomes an essential skill that an aquarist will need when working with unfamiliar species that have little reference material available, such as Western Atlantic corals.

Making husbandry decisions based on considering the biological processes that impact water chemistry in a coral aquarium can be referred to as a "holistic" approach. As previously stated, when it comes to water chemistry analysis, numbers can only provide half the story, and testing only to check if everything is within parameter goals gives a limited view of how a system is functioning. When approaching water quality management holistically, ranges of water quality parameters should be used as guidelines alongside sustained tracking of coral health indicators such as growth rates, color, disease outbreak, physical damage, bleaching, or recovery. Careful observation may result in the ability to track coral behavior in correlation with different chemistry concentrations, even when all parameters are "in range". Learning to approach water chemistry as a product of an ecosystem and observing how each individual product relates to each other, is how coral aquarists are able to develop an intuition about what parameter limits can be pushed, which can be adjusted, and what changes may affect the animals. Whenever working with corals that are new to the aquarium field, such as species of Western Atlantic corals, being able to adjust what is accepted as "healthy" for a coral aquarium system based on observation of coral behavior is essential to creating new successful husbandry practices. For example, an aquarist observing better polyp extension or feeding responses at water chemistry levels that are outside historical norms should, assuming no other changes to the husbandry have been made or observed, be willing and able to consider why this is and work with the animal and what it is showing the aquarist before taking immediate steps to bring the parameters back to those historic ranges. While these observations will never completely take the place of good quantitative water chemistry analysis, a skilled aquarist can come to an awareness of changes in water chemistry even before testing and be able to respond earlier to those changes based on subtle physical changes in the coral.

As mentioned above, this holistic approach is built on a foundation of both objective and subjective observations. Frequent and consistent observations can be used to build a structure for quantifying the health and welfare of corals. Standardizing observations and clearly defining them will remove most subjectivity thereby ensuring that these observations remain as objective and quantifiable as possible. Base observations including polyp extension, feeding response, growth, and coloration should be regularly recorded. Observations can be compared to water chemistry data over periods of time, allowing aquarists to find alignment between changes in water chemistry and animal behavior. Even just having a catalog of pictures, including at intake and then again at regular intervals can be an invaluable tool for long term monitoring. For growth, measurements performed quarterly or even annually are recommended. When recording symbiont density or color, a coral health chart is helpful to provide quantitative metrics to track changes that may be subtle day to day but can change drastically over time. Examples of coral health charts include The Australian Coral Watch Coral Health Chart (https://coralwatch.org) and the Hawaiian Ko'a (coral) Card from Hawai'i Institute of Marine Biology's Coral Reef Ecology Lab (https://www.pacioos.hawaii.edu/new-tools/hawaiian-koa-coral-card). If a system experiences seasonal shifts including changes to day length, light intensity, and temperature annually, you may see noticeable shifts to coloration, changes in coral growth rates and thus water chemistry, shifts in algal communities, or coral health. Specific considerations for systems with seasonal shifts will be covered at a later point.

Western Atlantic corals appear to be particularly sensitive to system water chemistry instability. Regularly scheduled water changes with "fresh" or new saltwater should be part of a complete husbandry routine. Not only do water changes maintain stability, but they replenish trace elements, improve overall water quality, and remove excess nitrate and solid waste. Performing additional water changes in response to elevated nutrient levels and replacing depleted trace elements is encouraged. However, large water changes are not recommended as a solution to long term water quality imbalances. Rather, it is suggested that water changes occur on a routine basis and exchange at least 10% but not more than 30% of the system volume at each change. Conducting irregular or large volume water changes, as a solution to reduce nutrients without implementing preventative countermeasures, can be costly and overly burdensome, leading to decreased water chemistry stability and a decline in animal health.

Some particular parameters and how they relate to Western Atlantic coral husbandry are highlighted below.

Trace Elements

Consider that trace elements can become depleted or elevated in aquariums. This is especially true of elements consumed by growing corals in closed aquarium systems. Previously discussed, routine water changes or having a plan to replenish or supplement other trace elements is important for healthy corals. Some may use commercial trace element mixes, come up with their own formulations, or use regular water changes of 20-30% to replenish trace elements. The bio load of the system and the source water are major considerations. Regular ICP-OES should be used to establish a routine and additional testing for monitoring. Some practitioners within FRTRP have found it helpful to dose manganese at a higher rate. Manganese and iron are key elements of photosynthetic molecules. Mn is indeed an essential compound used in photosystem II as well as a key component of antioxidant enzymes, such as manganese superoxide dismutase (MnSOD). Fe is needed for the structure of chlorophyll, of the photosystems I and II, the

cytochrome b6f complex, and the ferredoxin (Biscéré et al. 2018). Working from Tables 5's oceanic levels of 2ppb and building up to a management dose of 10ppb Mn weekly while monitoring (using ICP-OES [dl=0.06ppb]) still indicates 0.00ppb Mn demonstrates that this supplementation is being used. Also important to note is that iron-based anticaking agents are used by some salt manufacturers resulting in the addition of new water providing more than enough Fe and therefore not requiring Fe supplementation but regular water changes instead. Any aquarist should be sure to test their source water to fully understand what elements are being replenished at whatever concentration during a routine water change as compared to those elements that may need increased supplementation.

Alkalinity

Alkalinity is the ability of water to resist pH change or the buffering capacity of a liquid. Alkalinity can be defined using three different units of measurement in aquarium literature: milliequivalents per liter (mEq/L), degrees of carbonate hardness (dKH), and parts per million (ppm) $CaCO_3$. Corals need carbonate, primarily calcium carbonate, to calcify their skeletons as they grow. Keeping a stable alkalinity, in turn maintains a more stable pH, and supports the health of bacterial and animal communities in aquariums. Some Western Atlantic corals (family Meandrinidae) have consistently thrived at what reef keepers would call "reduced alkalinity" and maintaining stable alkalinity has proven imperative to many holding Western Atlantic corals.

At times it may be necessary to actively manage alkalinity. To lower alkalinity, water changes or incremental additions of dilute acid are recommended. Increasing alkalinity can be accomplished by dissolving an amount of either sodium bicarbonate or sodium carbonate into reversed osmosis (RO) or deionized (DI) water and then slowly dosing (dripping) the solution into aquarium water away from any animals. Large increases in alkalinity, such as changes greater than 20 ppm, are recommended to be completed over at least a two-day period. All additions should be performed away from direct contact with any animals or biological filtration media to prevent chemical shock. Alkalinity data from the Florida reef tract has relatively lower values of total alkalinity than most coral aquarists may be used to maintaining in their systems. According to Manzello et al. 2012, the normalized total alkalinity (nTA), which has been normalized to average salinity, had an average of 110.7ppm $CaCO_3$ ± 1.6ppm $CaCO_3$ for the inshore and offshore reefs throughout the Upper, Middle, and Lower Keys across spring, summer, fall and winter of 2009 through 2011. Maximum nTA was measured in winter at 117.3ppm $CaCO_3$ ± 5.3ppm $CaCO_3$ and minimum was in summer with 100.3ppm ± 1.7ppm. There are slight differences across seasons with inshore locations having lower alkalinity in the spring and summer and higher alkalinity in the fall and winter whereas there was very little seasonal variation across offshore locations.

Understanding the environments where the corals had been initially collected from did aid in their transition to human care. For example, when corals were first being cared for as part of the AZA-FRTRP, multiple coral holding facilities noted that rescue corals exposed to water with alkalinity in the higher range traditionally favored by Indo-Pacific corals (8.2-12 dKH or 147-214 ppm $CaCO_3$), seemed to correspond with a degradation in the physical condition of *Meandrina meandrites*, *Dichocoenia stokesii*, and *Eusmilia fastigiata* corals. Over time, it was observed that lower and consistent alkalinity levels often improved the physical condition of corals in the Meandrinidae family while having no observable negative effects on other species. With this

knowledge, aquarists had a better starting point to narrow down the preferred alkalinity range for Western Atlantic corals (see Table 2) and determined it was different from Indo-Pacific corals held in closed aquarium systems. Although the alkalinity measured where these corals were found originally are significantly lower than the average reef aquarium, these corals can be held in systems with a higher alkalinity of 140-160ppm without ill effect. Generally, the practitioners who report success with challenging species at this level of alkalinity also report lower variability in their alkalinity data.

Table 6. *Alkalinity unit conversion table.*

mEq/L	dKH	ppm $CaCO_3$
0.357	1.0	17.887
1.0	2.8	50.083
2.296	6.429	115
2.496	6.988	125
2.695	7.547	135
2.895	8.106	145
3.095	8.665	155

Calcium

Calcium is crucial to any aquarium system, especially those with organisms that build a calcium carbonate skeleton and shell. Calcium concentration is commonly measured in parts per million (ppm) in aquariums. There are many commercially available products that can be used to increase calcium concentrations in aquarium water. When using commercially available products to increase calcium concentrations, follow product directions carefully for successful use. Another way to increase calcium concentrations is to drip a concentrated calcium chloride solution slowly into aquarium water. Large increases in calcium concentration, changes greater than 20 ppm, are recommended to be completed over a two-day period. All additions should be performed away from direct contact with any animals or biological filtration media to prevent chemical shock. In a system with marine invertebrates, replenishing calcium and alkalinity should be done regularly. A balanced method is one that adds calcium and addresses alkalinity in the same ratio as they are depleted or changed by biological processes. Long term repeated use of "two part" additions of sodium bicarbonate and calcium chloride, as sources of calcium and alkalinity potential, can skew the ratio of sodium and chloride ions in an aquarium. A balanced method will add calcium and manage alkalinity at the same rate they are affected by coral metabolic processes and will not cause long term sodium and chloride ion imbalance (Holmes-Farley, 2002). Chemistry calculators exist to help determine how to keep the ratio balanced. A commonly used calculator is the Reef Chemistry Calculator (2026). Balanced additions can also be accomplished by utilizing calcium reactors or dosing with calcium hydroxide or *kalkwasser.*

A properly tuned calcium reactor can be beneficial in managing elements in a coral aquarium. Calcium reactors can be used to increase alkalinity, add calcium, magnesium, and a number of trace elements used by growing corals. The operation of a calcium reactor can be complicated. Reactors require carbon dioxide (CO_2) injection, precise dosing, regulators, and pH controllers. Calcium reactors, especially probes, must be maintained regularly. Managing a calcium reactor can be more of an art than a science, so proper preparation and mentoring during use may help learn the art of reactor use faster and with fewer mistakes.

Like the calcium reactor, the use of calcium hydroxide or *kalkwasser* (German: *limewater*) helps manage calcium concentration in aquarium water and adjust alkalinity appropriate for optimal coral health and growth. Unlike the calcium reactor, *kalkwasser* additions provide only a source of calcium and nothing more. Dosing *kalkwasser* will likely increase system pH, so careful pH monitoring is recommended. All additions should be performed away from direct contact with any animals or biological filtration media to prevent chemical shock.

A clear understanding of the relationship between water chemistry and an aquarium's animals provides insight into overall system function. It's known that regularly testing alkalinity and calcium levels, and dosing accordingly is appropriate. Additionally, one should recall that magnesium stabilizes calcium in solution by preventing abiotic precipitation of calcium, before uptake by corals for biomineralization (Holmes-Farley, 2002). Knowing this encourages close management of the magnesium concentration to help stabilize alkalinity and calcium concentrations. An example of these connections is provided in Figure 1, which illustrates some of the interactions between the nitrogen cycle, pH, alkalinity, and gas exchange within an aquarium system.

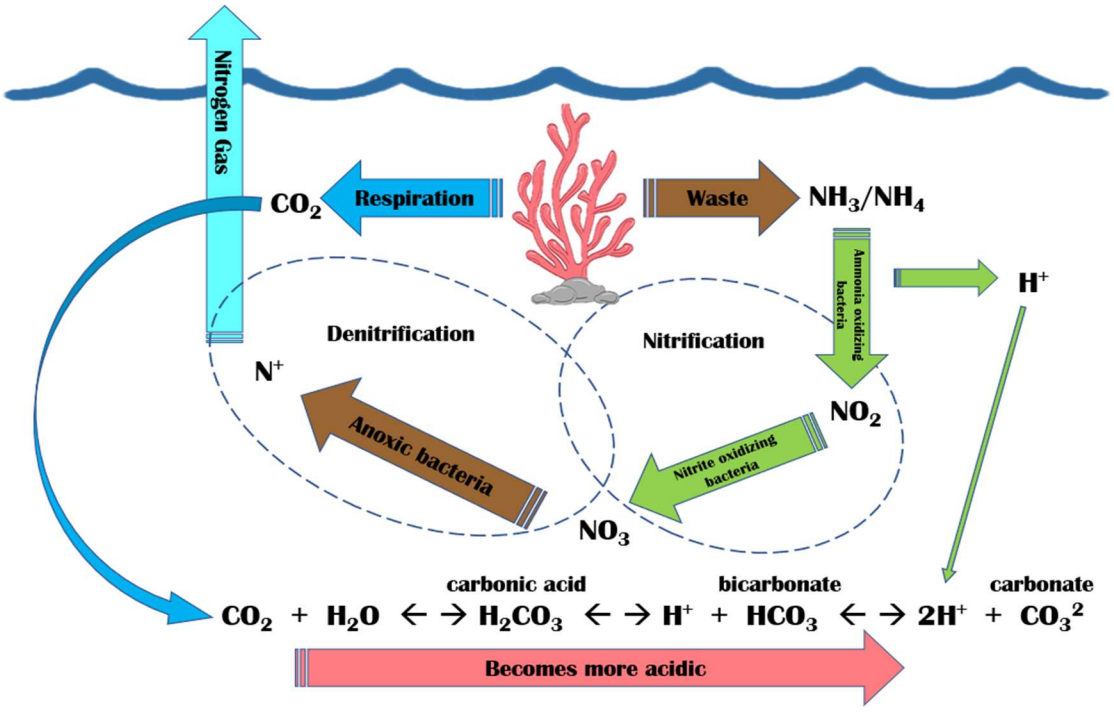

Figure 1. This diagram illustrates some of the interactions between the nitrogen cycle, pH, alkalinity, and gas exchange within a marine system. Brooke Zurita, Moody Gardens and Aquarium 2024.

Ammonia and Nitrate

Another value needed to be regularly monitored and managed is ammonia. While ammonia is toxic to fish and many invertebrates and is an inevitable byproduct of metabolism, its influence on corals is more nuanced (Thies et al., 2021). Ammonia is the preferred nitrogen source by both the coral and its symbiont. For example, exposure to elevated ammonium concentrations has mixed effects on corals, with some studies suggesting positive effects and others showing deleterious results, largely depending on the concentration (Nalley et al., 2023). Elevated ammonium leads to increased coral symbiont density, and decreased skeletal growth rate is reported at 15 μM (0.25ppm) $NH4^+$ (Stambler et al., 1991) and 20 μM $NH4^+$ (0.34ppm) resulted in decreased larval survival (Bassim & Sammarco, 2003). At lower levels, ammonium ($NH4^+$) enrichment at 4uM or 0.07ppm can result in increased calcification rates for *Stylophora pistillata* (Roberty et al., 2020) and lead to protection against oxidative damage during thermal stress (de Barros Marangoni et al., 2020). Ammonia is readily broken down through oxidation into nitrite in a mature system that is biologically active. Supplementation of ammonia may be incorporated especially if such systems do not incorporate teleosts into the bioload.

As the nitrification process continues, nitrite is converted into nitrate. Nitrate is less toxic than nitrite but cannot leave a system without proper maintenance. Overfeeding an underperforming filtration system or lack of appropriate husbandry attention can lead to an elevated nitrate concentration in aquarium water. High nitrate concentration in aquarium systems can encourage algae growth but also it can ultimately result in phosphate starvation, increasing a coral's susceptibility to disease or stress.

Phosphate

Like nitrate, phosphate is required for coral growth and can be a limiting nutrient in a reef ecosystem (Larned, 1998). However, excess phosphate can encourage algae growth and negatively impact coral health. At higher levels, phosphate has been shown to modify the skeletal density of some stony corals (Dunn et al., 2012). A system should not be entirely devoid of phosphate as it is crucial for essential physiological processes, including energy metabolism, cellular functions, and enzyme formation. We will continue to discuss nutrients, phosphorous and nitrogen, in a later section.

Metals

Lastly, we will be discussing reducing and removing metals. Metal toxicity is a concern for most marine invertebrates. Any aquarium should be designed to exclude any sources of unwanted metals. Although rare, it should not be ruled out when trying to diagnose health problems. ICP-OES testing is a common way to determine potential metal toxicity in an aquarium system. It is good practice to have access to either an onsite ICP unit or a laboratory that will test water samples when troubleshooting coral health response options. Commercial aquarium water testing companies may provide ICP-OES technology to test water samples for a reasonable cost. Having done testing to create a baseline to refer to rather than only testing when a problem arises is beneficial.

When trying to reduce elevated metal levels and the source of the metal is known, remove the contaminant source and perform large volume water changes over time to remove the metal from the system. If possible, it may be necessary to remove the corals or inhabitants impacted by

metal toxicity to an unaffected aquarium system for recovery. Activated carbon can be used and will slowly assist with the removal of metals and many other organic contaminants from aquarium water.

Life support equipment components can be a source of metal toxicity. To avoid this elusive source, ensure that all equipment and components that come in contact with either aquarium or source waters are made of materials other than metals. Even stainless steel can pit and rust in salt water, causing metal contamination. Consider Tables 4 & 5 to determine if tested concentrations of metals warrant further examination or action.

Below are water chemistry management solutions that can be used, but it is recommended that a plan for limiting nutrient inputs should be considered to keep nutrient levels within the recommended range before they affect coral health.

Nutrient Balance in Coral Aquarium Systems

Nutrients in aquariums are defined as any substances that provide nourishment or are essential for maintaining life. Nutrients in coral systems may include, but not be limited to, nitrate, phosphate, dissolved organic carbon, and trace elements. Concentration levels of all these nutrients should be monitored with appropriate periodic water chemistry testing.

There are many ways that nutrients enter coral systems. Feeding has the potential of increasing nutrients, and it is important to balance the needs of the aquarium inhabitants with the risk of elevating nutrients to unsafe levels. While heterotrophy is also essential, most corals of the family Scleractinia are considered mixotrophs and research has found that they often rely heavily on their algal endosymbionts for a significant portion of their nutrition. At night especially, corals will capture prey such as zooplankton and particulate organic matter (POM) from the water column. The needs of different corals vary heavily by location and by species, but many studies suggest the importance of certain amino acids gained either by autotrophy or heterotrophy (Fox et al. 2019, Ferrier-Pagès et al., 2011, Fitzgerald & Szmant 1997). It is important to note that water flow aids in prey availability as well as with nutrient transfer across the boundary layer above coral tissues. Corals that are unable to expel by-products from photosynthesis (i.e. reactive oxygen species) or waste may slowly diminish.

Closed systems with live rock will often support small populations of copepods, ostracods, amphipods, and mysids that are constantly reproducing and will additionally feed corals. Supplementing with manufactured foods is still recommended. Adding food to your system may affect the nutrient load and having a robust bacterial community as well as testing water quality to better identify any resulting swings can be essential. Many FRTRP holders have found success feeding corals 2-3x per week. The answer to any resulting coral issues will nearly never be due to lack of heterotrophic food offering.

Another potential source of nutrients is aquarium source water. It is recommended that nitrate and phosphate free salt mixes be used for coral systems when creating artificial seawater from a freshwater source. The freshwater source should also be evaluated for and treated to prevent it from becoming an additional source of nutrients. Ideally the freshwater source would have zero total dissolved solids (TDS) so as not to alter the chemistry of the salt mix. Additionally, water sourced from the ocean or a saltwater well can be used as a natural source of seawater. The

unique chemistry of each water source must be evaluated for optimal chemistry, avoiding contamination and adjusted as needed to meet optimum values.

Before we discuss the impacts of elevated or depleted nutrients, it is important to understand that the values for nutrients do not stand solely as single values. Although hard to quantify, a balanced flow of nutrients into and out of an aquarium is preferred. Alfred Redfield's "Redfield Ratio" from 1934 describes a nearly constant ratio of carbon to nitrogen to phosphorus as 106:16:1 that is required by phytoplankton growing at the ocean surface. Most recently Delbeek (2024) proposed a 50:1 nitrogen to phosphorous ratio as optimal for corals. While this is not a universally accepted ratio, if you plot out the ranges recommended in this article for Nitrogen and Phosphorus and overlay the 50:1 curve, it does run through the box made by the recommended values.

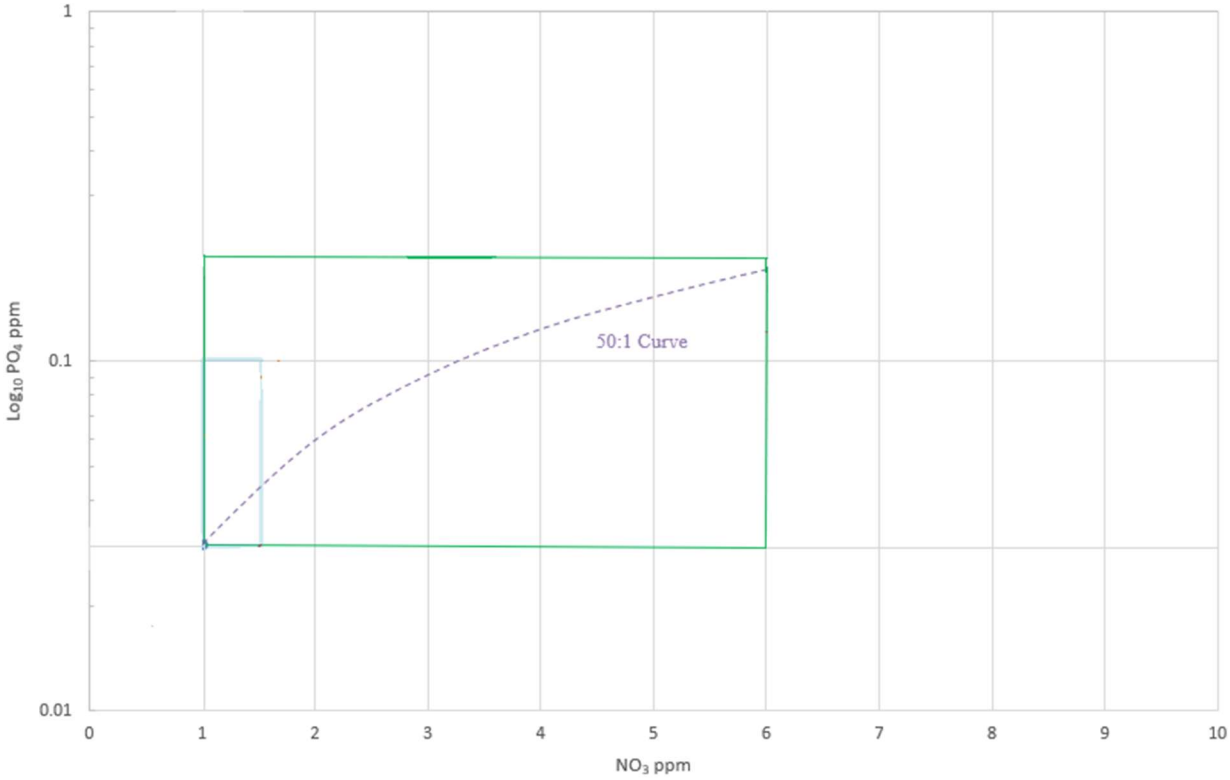

Figure 2. Plot of Phosphate and Nitrate recommended ranges displaying Delbeek's 50:1 curve within our recommended values.

With current advances in filtration technology and obsessive aquarist husbandry, it is possible to over filter, protein skim, or strip nutrients from aquarium water. It has been observed by Florida rescue coral holders that water that is "too clean" may cause corals to appear pale in color. Multiple holders note dosing urea, ammonium chloride, nitrate or phosphate salts, or adding an extra feed if their nitrate or phosphate values get too low.

Unbalanced and elevated nutrient concentration levels in coral aquarium water can cause excessive algae growth and coral health issues. Three nutrients that can slowly accumulate in

coral systems over time are nitrate, phosphate and dissolved organic carbon. Nutrient buildup can be managed by using good husbandry, planning, and an effective life support system. A well-tuned, high quality foam fractionator (protein skimmer) and appropriately sized mechanical filtration will remove food particles, lipids, and proteins before further chemical breakdown can occur. Good water flow within an aquarium will help prevent waste from settling and accumulating over time. Routine water changes are effective in reducing high nitrate and phosphates. Having a plan using these and other options to control nutrient concentration levels within recommended ranges is essential to success.

Remember, just because nitrate and phosphate concentration levels are very low on most coral reefs, it does not have to be, and probably should not be, that low in a coral aquarium. It is important for coral aquarists to have strategies in place for the addition of such essential nutrients through feeding and dosing as well as managing excess nutrients further when needed. Each life support system and husbandry team is different, and the strategy or solution used to manage system nutrients by one entity or team may not work for others at another facility. But overall, consistency is the key to success.

Managing Seasonal Changes in Aquarium Systems

Keeping coral in systems with ambient light or systems designed to mimic seasonal changes (like breeding or spawning systems) may require special considerations. As light intensity and temperature slowly change throughout the year, the biotic community may also shift. In a closed recirculating system, such shifts may result in differences in the corals' utilization of minerals or the proliferation of algae. Additionally, seasonal fluctuations of the bacterial community will result in changes to the nutrient levels unless mitigation is undertaken (Quek et al., 2023, Yu et al., 2021,). In a recirculating aquarium, maintaining a well-established system can help balance these changes as well as regular water chemistry testing. Furthermore, the uptake of minerals related to increased calcification in the spring and summer months as well as the reciprocal during late fall and winter months may require more frequent testing of those water parameters and adjustments to dosing. Dosing pumps can be incredibly useful, but parameters must be tested frequently, even daily. Keeping parameters perfect may be the overall goal but consistency will always be the most important factor.

If utilizing natural water systems with a continuous flow of sterilized ocean water, any slow shifts in light and temperature will likely be mediated by the stable and constant flow of new water. This can be a wonderful application for restoration practitioners. Source water should be just as closely monitored for any possible fluctuations in water chemistry including temperature, salinity, pollutants, disease, and any abnormalities should be mediated appropriately. This is where proper sterilization is essential. If open water systems cannot be designed to maintain proper water chemistry, temperature, water flow, and in-tank circulation then a closed system may be a better choice.

In closing

This article is not intended as a complete care article for tropical Western Atlantic Corals. We are not addressing light, flow, or other important abiotic factors. What we endeavor to do is to save any future aquarists who are called upon to care for Western Atlantic Corals to not have to start from the same point of knowledge that the FRTRP did in 2019. Above all, consistent water quality will lead to the best chance for success.

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BOOK REVIEW: LOBSTER DREAMS BY STEPHEN SPOTTE

Pete Mohan, Editor, D&C

The author obviously needs no introduction, as you likely have a copy of the classic aquarist's bible, *Captive Seawater Fishes: Science and Technology* on a bookshelf at home or at work. In retirement he's been writing fiction and the occasional scientific article when he's not fly-fishing on the beach behind his house in Florida.

The opening premise of *Lobster Dreams* is that lobsters live among us. Not just in our oceans, but also in Maine villages, in the guise of peculiar humans. That's the backstory of Sonny and his extended Downeaster family. While releasing a rare golden-morph lobster that had been on display in a dockside aquarium, Sonny goes overboard and is instantly transformed into his ancestral form, while retaining his human faculties.

At this point the novel becomes a detailed account of the biology and behavior of Homarus americanus as experienced and told by transformed humans. This fate has befallen others and Sonny soon meets up with a curmudgeonly, often politically incorrect, former university professor. Sonny's perceptions of his body and physiology, and the Professor's pre-transformation knowledge of the American lobster, become an interesting vehicle to inject volumes of real-world scientific observations into an equally entertaining marine fantasy.

There are moments where Sonny's "dreams" of his past life are intertwined with the imagined thoughts of a crustacean with no perception of time and just a few basic motivating urges. These side trips into complete fantasy reminded me of the last chapter in Spotte's previous mostly non-fiction book: *Candiru: Life and Legend of the Bloodsucking Catfishes*, that I reviewed in the 2003 issue of Drum and Croaker. If you enjoyed his imagining of a public aquarium titled "Candiru World," you'll love this book.

Lobster Dreams
Stephen Spotte
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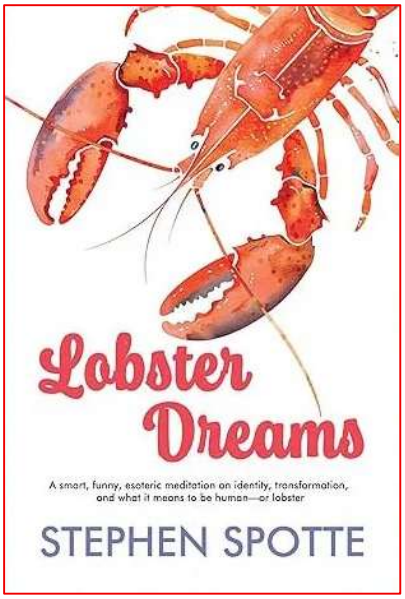

CONDITIONING OF THE YELLOW STINGRAY (*Urobatis jamaicensis*) AND RED LIONFISH (*Pterois volitans)* IN A STUDENT-LED MARINE BIOLOGY PROGRAM WITH NOTES ON OVULATION MONITORING OF *Urobatis jamaicensis*

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Abstract

The Marine Biology program at Central Campus provides students with opportunities to not only learn about careers in the field, but to begin their own professional development through networking, leadership, and completing different research projects. Here, two behavioral conditioning programs were developed in tandem to improve overall husbandry practices for two *Urobatis jamaicensis* and one *Pterois volitans* in a small-scale facility. Targets were created for each species and in the case of *U. jamaicensis*, distinct areas of the exhibit for each to be conditioned at. Over the course of several months, each *U. jamaicensis* was successfully fed by hand at different spots in the exhibit. Likewise, the *P. volitans* was successfully conditioned to a specific point in the exhibit and to eventually enter a "howdy cage" for future transfer to off exhibit holding, as necessary. These conditioning programs have provided opportunities for improved monitoring of overall health and improved the overall efficiency of weighing the *U. jamaicensis* consistently. Projects like these have also led to additional, student-driven questions for future research such as recording ovulation cycles and pregnancy time in *U. jamaicensis*. Conditioning and enrichment have been documented to improve overall husbandry and veterinary care of different species, which is a significant benefit to both the animal and person. Perhaps an under-valued or overlooked bonus of these methods, as shown here, is the future questions and research projects that come about as a result to continue to improve husbandry and the professional development of staff.

Introduction

Des Moines' student-led Marine Science programs stand among various extracurriculars at Central Campus, aimed at defining the career trajectory of each student and setting up every individual for success, no matter the subject. As one of the largest landlocked marine programs in America, Central Campus's Marine Biology class gives students valuable hands-on learning opportunities both in the classroom and in the lab. While the classroom work consists of the topics in marine geography, geology, and anatomy, students use the second half of the 1.5 hours provided to care for the multiple saltwater aquarium systems. As studies and system work progresses, students begin developing team and individual projects. Examples of these projects include grass shrimp culturing, mangrove growth, automated water quality monitoring, plumbing projects, and behavioral conditioning. Whether a student's career path follows the lead of these projects or a lead in the classroom, students are provided with every tool required to chart a path on the shoreline.

Urobatis jamaicensis Natural History

The yellow stingray, *Urobatis jamaicensis,* is commonly found in the western Atlantic, extending from North Carolina to northern South America, with traces of its presence also found in the Caribbean reef. The stingray's estimated maximum length is 76.0 cm, with a caudal fin

extending to the tip of the venomous spine-tail. *Urobatis jamaicensis* have a sand-colored disk with dark spots that form various patterns around the body (Figure 1). Due to their natural appearance, the ability of *U. jamaicensis* to blend into the sand is a beneficial tactic when hunting for benthic prey.

Figure 1. *Urobatis jamaicensis* on exhibit at Central Campus.

French naturalist, Georges Cuvier, described the animal in 1816 as *Raja jamaicensis.* However, due to our understanding of the evolutionary process, researchers changed the name to *Urobatis jamaicensis* after careful examinations of other similar species. The genus name originates from the Greek words "oura" (tail) and "batis" (ray). Yellow Stingrays also have junior synonym names such as *Trygonobatus torpedinus* (Desmarest, 1823) and *Urobatis sloani vermiculatus* (Garman, 1913). *Urobatis jamaicensis* population trends are stable and have not historically shown a decline, according to researchers. Several reefs have been sampled, and it has been discovered that the species has spread through the Greater Caribbean from central Florida to northern South America.

Urobatis jamaicensis habitats vary, though a key historical part of these stingrays' habitat is the surrounding indigenous community in the Caribbean region(s). The Taíno people are a living group of indigenous peoples who reside in the surrounding islands of the Caribbean Sea. Like many indigenous communities, the Taino people are often viewed as 'non-existent.' It is essential to understand that the Taino have evolved and continue to thrive within the Caribbean to this day. Taíno Indian chief, Cacique "Panchito" Ramirez, encourages individuals to pay more attention to the gifts of nature for a happier life. Understanding a marine species goes hand in hand with understanding the indigenous communities, such as the one C. Ramirez grew up in.

Pterois volitans **Natural History**

The Red lionfish, *Pterois volitans*, are reef apex predators containing acetylcholine (venom) in their anterior dorsal fin, pelvic fin, and anal fins (Díaz-Ferguson et al., 2019). Various colors of red, orange, and white striped patterns cover the body with occasional black and brown

dots (Figure 2). The *P. volitans* average total length ranges between 30-40 cm in the wild and 50 cm in captivity. Being ambush predators, lionfish will corner prey and swallow it whole, maintaining a slower speed and well-controlled buoyancy until prey can be reached (OCEANA). *Pterois volitans* regionally originate in the Indo-Pacific, and are invasive in the Caribbean Sea, the U.S. East Coast, and the Mediterranean Sea (Río et al., 2023). Red lionfish can live up to 15 years, though longer lifespans in captivity have been recorded (eSHA Labs, 2022).

Figure 2. *Pterois volitans* on exhibit at Central Campus.

Spreading to the Western Pacific and Indian Ocean, native to the Indo-Pacific, *Pterois volitans* were first documented in 1985 in the Northwestern Caribbean (Díaz-Ferguson et al., 2019). In 1991, lionfish entered the Mediterranean Sea, and in 2010, considered an invasive species (Río et al., 2023). Between 2000 and 2015, Lionfish appeared in South America, the US east coast, Bermuda islands, Bahamas, Colombia, Puerto Rico, the Dominican Republic, Venezuela, Cuba, Costa Rica, and Brazil (Río et al., 2023). The spread of Lionfish is both accidental and not, nevertheless enhancing the lionfish's ability to adapt to new environments quickly. This adaptability leads to rapid increases in population, and density per acre of sea. The highest densities as of 2014 were in the northern Gulf of Mexico and Florida. The most well-known form of *P. volitans* population control began before their documentation in 1980, when cooked *P. volitans* was popular in the Pacific Rim (Río et al., 2023). By removing the venomous dorsal and anal fins and raising the cooking temperature, all venom can be neutralized, making *P. volitans* completely safe to eat. The practice became popular as people noticed many different young reef fish within the lionfish's stomachs, subsequent to the catch-and-kill method. Other forms of population control between 2000 and 2024 include promotion and conservation of the *P. volitans* few predators, artificial concentration habitats to attract overpopulated prey, scarce prey habitat restoration, and lastly, one of the most effective, cash prizes for those who submit a certain number of caught *P. volitans*.

Conditioning/Enrichment Background

Enrichment through the target training of reef apex predators is a common practice amongst aquariums across the world. The majority of aquariums in the US practice conditioning with sharks, both for medicinal reasons and potential predation conflict. The purpose of conditioning larger predators is to direct natural predatory behaviors towards a single point (target). This reduces the chance of predation within the tank, alongside the industry's desired external benefits. Few individuals use the concept of target conditioning with lionfish in current aquatic industries. Conditioning these organisms is just as unique as it is dangerous. The practice of targeting offers a chance at the reduction of immediate safety concerns by relying less on behavioral possibilities and more on solidified research-based successes. Behaviors are logged, while decisions must be based on data. Psychological observations such as irregular movement patterns and predation behavior are deciphered by one main determinant: Stress. Targeting works around the absence of this information in marine institutions with the goal of redirecting predation. Each notation of data and randomized observation is still recognized as a contributor towards the final conclusion. Having the ability to look back upon the analytical history of a project is vital when addressing which mistakes had a negative/positive effect on the end result.

Methods and Results – *Urobatis jamaicensis*

A total of 1.1 *U. jamaicensis* arrived at Central Campus on December 3, 2023, and were immediately moved into 380-liter holding tanks separately. Stick feeding was tried initially, though both stingrays did not approach the feeding stick. The second attempt was a broadcast feeding. Pieces of herring, capelin, krill, squid, clam, and shrimp were dropped into a corner of the tank, and the stingrays were observed for up to 5 minutes, while students recorded observations. Within the first week, the male stingray showed the least interest in food foraging, and eating, only eating twice per week. The female, however, ate consistently, at least 6/7 days. Students noted that the rays ate more often in the afternoon between 1:30-3:00. The female ate 1/7 mornings and 5/7 afternoons. The male stingray ate 3/7 mornings and 4/7 afternoons. The estimated transitional period for moving both stingrays to the 1,000-gal tank ranged from 12/10/2023-12/20/2023. The 3880-liter tank, named 'Gulf of Mexico' (GOM) would be the rays' permanent habitat. The GOM was a mixed species exhibit including Florida pompano (*Trachinotus carolinus*), lookdowns (*Selene vomer*), blue damselfish (*Chrysiptera cyanea*), golden trevally (*Gnathanodon speciosus*), sergeant major (*Abudefduf saxatilis*), and neon gobies (*Elacatinus oceanops*). Eventually, students discontinued broadcast feeding as the tank's carnivorous fish ate the food before it completed the 3ft drop to the substrate. For a combative method, students began using a pair of tongs to plant the food into the substrate of the tank for the stingrays to find. There was a long-term effect, however. The required length of observation during the use of this method increased the time it took to feed the tank, as students prioritized addressing whether both stingrays got food, and how much of it was eaten.

The next step toward direct targeting began with a clear gravel vacuum (generally used for the removal of waste from substrate) to allow for the protected transportation of food from the top of the tank to the bottom. Once the stingrays identified the tube, it would be lifted upon contact, and the stingrays would immediately eat the food. The final target design was made of a piece of hard plastic, cut out, and adhered to a 3ft piece of PVC (Figure 3). The female stingray's target was configured into the shape of a cross with the word PONYO (a character from the Japanese animated film "Ponyo") written across. The males target, made into the shape of a rectangle,

Figure 3. Use of the target during conditioning of *Urobatis jamaicensis*.

Figure 4. Advanced conditioning of *Urobatis jamaicensis* during hand feeding.

displayed the word SAPO (the Spanish Portuguese word for toad). Students followed the same routine using the gravel vac; dropping food down the tube and releasing it upon contact with the stingray. However in this case, the target would be placed behind the tube, to normalize the close presence of the target during feedings. The final method was for both stingrays to contact the designated targets, as students slowly brought the target to the surface, with the stingray following the target. When the ray reached the surface of the water, it was hand-fed by the feeder (Figure 4). During all methods, the female was the most successful in completing the task at hand, with the male ray taking multiple days or weeks to do the same. The female successfully ate by hand in July of 2024, after 3 days of attempted hand feeding. The male completed the same, two weeks after the female (Table 1).

Table 1. Timeline of conditioning steps for *Urobatis jamaicensis*.

Notable Dates	Status	Notes
4/20/2023	Not started	Male stingray was born
7/18/23	Not started	Female stingray was born
12/03/2023	In progress	Female and male stingrays arrive at Central Campus from the Missouri Aquarium at the boardwalk. Male at 8 months old, Female at 5 months old.
12/04/2023	In progress	The first attempt at feeding stingrays attempted to feed caplin, clam on a half shell, and krill by dropping them inside the tank. After several attempts, the female was the only one that ate a piece of Caplin
12/20/2023	In progress	Estimated date of transferring both stingrays into the 1000-gallon tank. Began feeding by using three feet tongs to bury pieces of food into the water
March	Under review	Using gravel vac as a way to introduce target training.
5/6/2024	Approved	Fully adjusted to using two separate targets, recognizing their own personal targets.
6/17/2024	Approved	First-hand feeding by female ray
6/28/2024	Approved	First-hand feeding by male ray

Methods and Results – *Pterois volitans*

One *Pterois volitans* was acquired in February 2024 and housed in a 1900-liter mixed species exhibit. Over a span of 25 days (7.1.24 - 7.25.24) the first protocol for conditioning used two feeders: a main trainer and a secondary feeder, stationed on the right and left side of the tank. Both feeders began by simultaneously feeding every fish in the tank except for the lionfish. This lowered the likelihood of other fish displaying food-aggressive behaviors in the conditioning area. The larger fish in the tank, including the longhorn cowfish (*Lactoria cornuta*), striped dogface puffer (*Arothron nigropunctatus*), zebra moray eel (*Gymnomuraena zebra*), and the smaller red lionfish would be fed half their diet at the start of the process. The other half would be fed either during the lionfish conditioning time or afterwards. The rest of the diets were only fed during conditioning if an interest was taken in the subject lionfish's food, causing indefinite focus from the lionfish during a time of psychoanalytic requirement.

Four different areas in the tank were listed as three different placements: 'Front right corner,' 'Back Right Corner,' and 'Back wall,' which represented the specific spots where the target would be placed 4 times throughout the session for 4 pieces of food. On the 20th, a 4th placement was created at the leftmost side of the tank, approximately 1½ feet from the left wall.

Alongside target conditioning, visual conditioning was required for better association between the target and food. For this reason, feeding tools were set on the tank rims, out of the Lionfish's view, to avoid any distractions of target-unrelated food. If conditioning practice became compromised by the overcrowding of non-lionfish-organisms in the conditioning area, both feeders stepped off the ladders and away from the tank until fish dispersed. On Saturdays, conditioning was skipped to assess differences in visible stress amongst the fish compared to conditioning days. Regular feedings, with the same type and amount of food, were still fed to the tank on Saturdays. On 7.10.24 the next stage of progression measurements was created. This stage measured how many inches remained between the Lionfish and target after its initial progression towards the target, from the midway point. A probable test was included in the protocol to assess whether the Lionfish would continue to swim towards the target if the target remained in the tank for more than 10 seconds, after the Lionfish stopped swimming forward. After the 20th, the Lionfish did not swim away from the target regardless of the Main feeder's choice to wait more than 15 seconds to present food, or take the target out earlier. Results with greater success in target recognition occurred when the target was submerged at least 2-3" under the surface of the water. 12/25 Days the Lionfish was fed shrimp, 3/25 days herring, 2/25 days squid, and 4/25 days silverside (Table 2). The system was fed between 9:00 a.m. and 10:00 a.m., lasting for 10-12 minutes per session.

By 8.10.24 the 'Howdy Cage Era' of conditioning began. A 'Howdy Cage' was created out of a 2-gallon bucket, with zip-ties acting as a hinge for the plastic mesh cut into a circle as a lid to the bucket (Figure 5). The 'nub' end of a zip tie was placed at the end of the lid, which would attach to a bracket-like hole on the end of the bucket. Another zip tie was tied into a loop on the middle of the lid's backside to help prevent it from closing when not intended to. From 8.5.24 to 8.9.24, the Lionfish was conditioned to swim to the target stick, placed in front of the Howdy cage (Figure 5).

Due to lower personnel, 8.10.24 to 8.15.24 feedings were performed without the targets. By the following weekend, a new target piece (the same pattern, size, and colors as the stick target) was permanently placed at the back of the Howdy cage. From then on, the Main feeder would not make the stick target and howdy cage visible at the same time. The Howdy cage would be placed in the water, and a feeding stick with food would be angled into the Howdy cage, encouraging the Lionfish to swim about ⅓ of the way in. By 8.31.24, the final conditioning method began. Food was previously cut up into 4 pieces for the Big Lionfish, but with this method, two of the pieces were cut up again for a total of 6 pieces to avoid overfeeding. Placement #1 was unchanged. This placement was vital in continuing to demonstrate the stick target's association with the Howdy Cage. Placements #2 and #3 took separate protocols when it was confirmed that the Lionfish would swim fully into the Howdy cage with food set at the back, on the bottom. Food would be placed within the howdy cage, the lionfish would swim in the howdy cage, eat the food, and then be fed again once it exited. With two of the 4 food pieces divided in half, only placements #2 and #3 would use this method. By placement #4, food would not be put into the howdy cage, giving the lionfish the option to swim into the howdy cage on its own. It was observed that the lionfish would

Table 2. “Target Placement Progress” from 7.14.24 to 8.1.24 shows “SDFT,” Stopped Distance From Target (how far the Lionfish was from the target after it stopped moving forward), and “SSTT” Seconds Swam Towards Target (Seconds it took to swim towards the target before the Lionfish stopped) according to the different target placements within the tank.

Front Right Corner		**Back Right Corner**		**Back Wall**		**Second Tank Divider**	
SSTT	**SDFT**	**SSTT**	**SDFT**	**SSTT**	**SDFT**	**SSTT**	**SDFT**
16	3”	13	5”	11	3”	12	7”
17	4”	20	6”	14	4”	4	7”
16	5”	11	6”	13	4”	20	5”
14	6”	17	4”	6	4”	11	7”
8	2”	11	4”	14	4”	10	3”
		8	4”	10	4”	7	2”
		13	9”	10	5”	5	2”
		9	3”	8	6”		
		13	8”	10	4”		
		18	6”	8	5”		
		9	5”	6	2”		
		10	6”	8	2”		
		10	5”	8	4”		
		10	5”	9	2”		
		8	2”	8	5”		
		13	3”				
		8	3”				
		10	4”				
		8	4”				
		9	4”				

Figure 5. Howdy Cage and Target stick (left) and an underwater look at the Lionfish facing the target after having swam towards it (right).

Figure 6. Conditioning of *Pterois volitans* to move the entrance of the howdy cage (left) and finally enter it (right).

remain stationary in front of the howdy cage for a minimum of 20 seconds if it did not swim inside. Whether it went in the howdy cage or remained stationary in front of it, the lionfish would be fed after 15-20 seconds (Figure 6).

By the twelfth day of conditioning, the Lionfish swam to the target in 11.10 seconds, stopping at 2 inches in front of the target for the first time without food being shown. The average ratio of how long it took to reach the target versus where it would stop in comparison to the target was 10 seconds, 5 inches. By 7.30.24, the Lionfish began swimming to the target, touching it, at any place in the tank, in under 5 seconds. After conditioning the lionfish to swim to the entrance of the Howdy cage, it began entering ⅓ of the way in, stopping with its pectoral fins against the bottom and sides. On 8.16.24 (12 days after Howdy Cage conditioning began), the Lionfish would swim into the howdy cage, touching the back, with food presented. This continued every day until 9.16.24, when the same steps were completed without food presented. Stick target protocols were taught to new students to both uphold conditioning consistency and provide a safe educational practice to everyday feedings.

With the passage of several months of conditioning and method adjustments, both stingrays were able to differentiate each target and recognize the individually assigned targets. Targeting proved beneficial during the conditioning period, as weighing and blood draw processes required the use of targets to begin transporting the rays. Health checkups or stingray 'physicals' were more straightforward; therefore, medicinal sessions/checkups became a consistency. Central Campus students continue to test various feeding methods with the Yellow Stingrays, along with many other organisms in each system.

Discussion and Future Plans

The *Urobatis jamaicensis* completed target training and handfeeding in August 2024. Following successful target feeding conducted, a formal protocol was written and taught to other lab assistants and, eventually, students. This milestone sparked an interest in learning more about stingray husbandry, particularly in relation to reproduction.

In the wild, yellow stingrays exhibit a biannual ovulation cycle, statistically producing two broods per year, with the first brood typically consisting of more pups than the second. The objective of this project was to determine whether aquarium-born stingrays exhibit the same ovulation pattern as wild-caught individuals. Both adult rays at Central Campus were born roughly in alignment with the cycle observed in wild rays. The goal was to assess whether aquarium rays follow this same reproductive pattern and to identify environmental factors that could be adjusted during ovulation and birth to support the most successful outcomes. To meet this objective, it was necessary to determine a method for detecting active ovulation. One unofficial method used by some aquariums involves adapting a human pregnancy test to produce a result using stingray serum spun from whole blood. However, this process is highly stressful for the ray, and because our rays are small at maturity, the amount of blood that can be safely collected is limited. Another approach involves measuring key hormones that fluctuate throughout the reproductive cycle to indicate ovulation and pregnancy. Testing these hormones requires advanced radioimmunoassay techniques to produce variable results. Several programs, including ISU and UC Davis, were contacted in hopes of sending samples for analysis. Due to travel time and the infrequency with which these hormones are tested, this method would result in limited data while increasing environmental stress on the females. An additional method considered was adapting a human ovulation test to read stingray serum or whole blood. However, unlike hCG, the hormone marker used in human ovulation tests has a non-compatible beta enzyme compared to that of rays, making this method ineffective.

The rays have been weighed and measured monthly to track growth and diet, with some fluctuation in weighing dates. The female is closely monitored to ensure sufficient food is provided for both her and the pup(s) throughout pregnancy, while also using these data to assess body condition. A few days prior to the female's most recent birth, an examination revealed a highly distended abdomen and dorsal cavity. On the day the pup was born, the female showed an immediate reduction in abdominal size, and examination of the ventral side revealed a reddened cloaca, confirming the birth. Pregnancy is now monitored primarily through changes in body condition and behavior, as previously discussed methods are invasive and largely exploratory. At 90 days of age, the pup received its first weigh and measure, initiating a cycle of close growth monitoring.

The goal for *Pterois volitans* was to condition it to enter a holding container that would act as a transportation mechanism for temporary holding, with the purpose of increasing student safety during cleaning and transitional periods. Target stick conditioning is a common practice with marine apex predators. Promoting natural predatory behavior acts as enrichment and a regulator of stressors during feeding time, which is highly beneficial in a large multi-species tank. Once the goal was achieved, feedings could be anything from practicing long-term periods within the howdy cage to placing the target at the bottom of the tank for the lionfish to swim to. The greatest takeaway from the project as a whole is its ability to continue beyond the learning period of the lionfish. New student feeders can participate in the conditioning process safely, and quickly learn a new skill to care for the lab and apply to other species.

This study presents itself as another addition to the growing body of research on the successful impacts of target training on marine organisms. Each targeting form underwent intermittent observational assessments throughout the project, with results determining the next step in each protocol. The observations, which have occurred in an assessment manner over eight months, have proved successes in stabilizing previous diet concerns, approaching the individually assigned targets timely, and receiving food directly given by the feeder's hand. This project has eased procedures like weighing and drawing blood from each stingray, as both willingly enter a net carrier post-target presentation.

Students at Central Campus continue to be innovative in personal projects, adding to the diverse successes of past student projects. What started as a makeshift program in 1985 has now flourished into a community of students who constantly maintain each system, both during and outside of school. Endless research is conducted, encouraging students and staff to apply their curiosity and creativity to unique projects, thereby laying a stronger foundation for the future of the student and the lab. The results of these projects provide further insight into how students can learn best from their mistakes. The well-being of each organism depends on these individualistic factors, and this out-of-the-box thinking that Central Campus aims to promote. Each students' willingness to learn, experiment, fail, and succeed is what drives projects like organism conditioning to a testable and consistent state. Every decision and achievement derives from every volunteer who puts time, commitment, research, and most importantly, perseverance into a possibility.

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IN MEMORIAM – TOM TUCKER

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Tom Tucker became the steady presence who provided continuity at the Steinhart Aquarium from the late 1960's when he first started as an Aquarist until his retirement as Curator 41 years later in 2009. He held the Curator position for nearly thirty years. Tom was born in California's San Joaquin Valley in September of 1943 during World War II. He mentions in his oral history of Steinhart Aquarium, which he recorded in 2002 (Tucker, 2003), that one of his earliest memories is of sitting on the shoulders of his father shortly after his father returned from serving in the South Pacific during the war. This particular memory was significant for Tom because it occurred at Steinhart Aquarium and he specifically recalls a leopard shark swimming right towards the glass directly in front of him and his father. Little did Tom realize the he would have direct responsibility for that exhibit aquarium years later.

Mid-century Steinhart Aquarium, like many similar institutions of that era, and especially those with a municipal connection, tended to have directors with significant academic qualifications. All of the Steinhart directors from its opening in 1923 through the early 1990's were professional ichthyologists. This is in contrast to many of the rank-and-file staff who often had somewhat modest relevant education or experience, if any, before being hired. Tom was in contrast to this in that he had both a bachelor's and master's degree when he started at Steinhart. His master's thesis on the speckled dace was titled: Contribution to the Study of Feeding in *Rhinichthys osculus robustus* (Rutter) in Lake Tahoe. He also had a minor in chemistry which put him in good stead in the Steinhart laboratory.

Tom's route to Steinhart Aquarium began with first working in the California Academy of Sciences Ichthyology Department on a major fixed term project moving the large preserved ichthyology collection at Stanford University to the Academy collection. This position was no doubt influenced by his ichthyologist mentor Dr. Margaret Bradbury (Iwamoto et al 2011). Dr. Bradbury was also Tom's major professor for his Master's degree. Tom was first hired at Steinhart shortly after the significant Stanford fish project was completed. Like most young American men in the 1960's the draft was an ever-present issue. Tom had received several deferments from the draft board while completing his degrees, and even an additional one when he nearly lost his big toe when a huge vat of preserved Stanford fishes severely injured his foot. Once he was fully recovered, and already working at Steinhart, he was drafted, and served two years in the Marine Corps on Okinawa. Due to his chemistry minor the Marines had decided to train him as a chemical and biological warfare specialist. Upon discharge he was able to return to his job at Steinhart which had been held for him.

Figure 1: One of Tom's early roles at Steinhart Aquarium was in the water quality laboratory, where he put his background in chemistry to good use. Photo © California Academy of Sciences.

Tom began his public aquarium career under the venerable Earl S. Herald. Dr. Herald became Director of Steinhart Aquarium about the time that Tom would have started kindergarten in the late 1940's. Following Earl's untimely death in 1973, he was succeeded by Dr. John E. McCosker. Although both of these ichthyologist directors were very different men, each excelled at showmanship with remarkable media savvy in their respective eras. Tom was the ideal counterpoint to both of these men, as while he was very comfortable in front of the public, he never sought the limelight, and was happy to let others take the lead in those arenas.

Tom was much the same way with the aquarists, herpetologists, and aquatic biologists that he led. More than one aquarist who worked under him has noted his willingness to let individual aquarists get their job done without him getting in the way. He was extremely attentive to the

myriad of public exhibits, and every aquarist and herpetologist who worked under him will remember finding a small hand written note from him each weekday morning when we arrived at work. Tom had typically already been there for an hour or more and completed his morning rounds taking notes of individual exhibits which needed our attention. Most of these action notes were related to a spot of algae, an exhibit animal needing attention, or the occasional mortality. During the six years that the senior author worked under him, he was responsible for a total of 43 smaller exhibits, or jewel tanks. Only once did he find a note on his desk when he arrived telling him to "relax today" as Tom could find nothing needing special attention that day. Lest he be taken at his word, Tom added the postscript in parenthesis "Just Kidding."

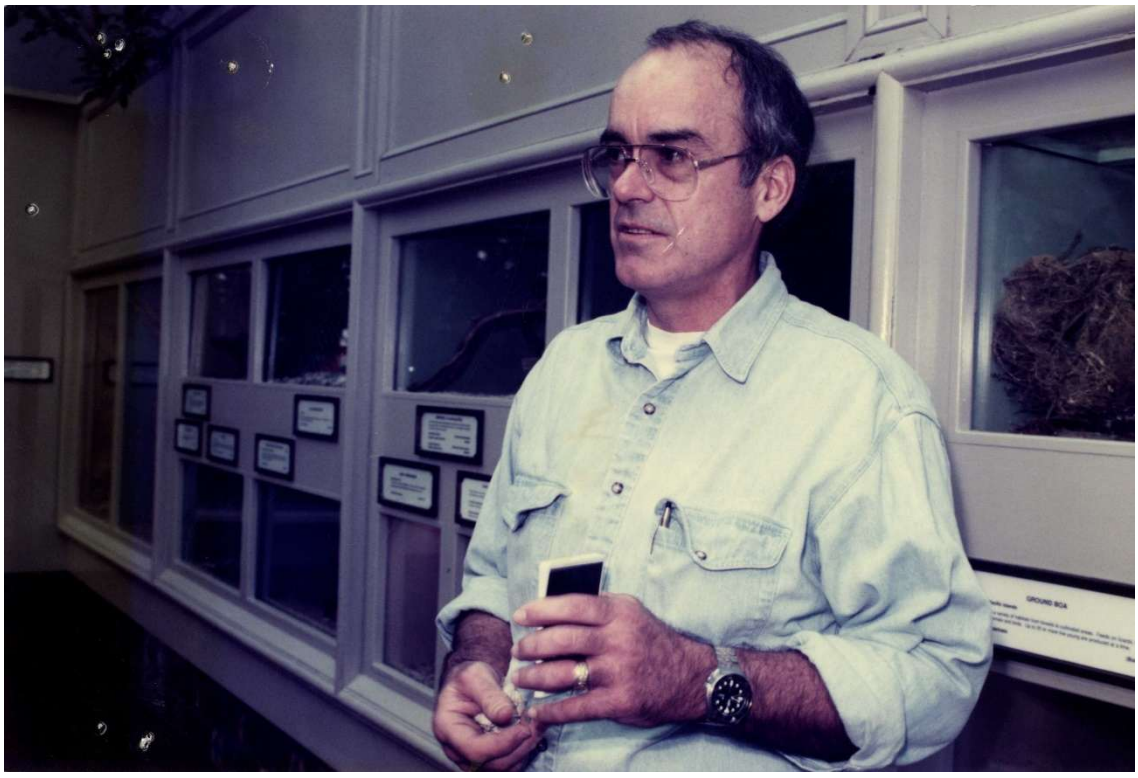

Figure 2: Tom, notepad in hand, conducting rounds in the old Steinhart Aquarium Swamp gallery. Photo © California Academy of Sciences.

Tom indeed had a good sense of humor. Prior to Frank Talbot's appointment as director when he was visiting the various departments at the California Academy of Sciences, including Steinhart Aquarium, Tom assembled all of the aquarium staff in the aquarium library. Tom had set up a small stool under a single shaded bright light and turned off the overhead lights. Dr Talbot played along with this, and stated that he would only give his name, rank and serial number. The lights were soon back on and we had a cordial introduction to the man who would soon be the director of the Academy.

Tom always presented a calm and confident demeanor. While he could get angry or annoyed, he never shouted at anyone, regardless of the situation. Likewise, he was a gentleman in his speech, and rarely, if ever, used profanity. This was sometimes in contrast to his Senior Aquarist

who had been promoted at the same time that Tom moved to Curator. This individual was well known for remarkably colorful colloquialisms, both in private and in aquarium staff meetings. Nevertheless, they worked closely together for decades.

Although Tom let those under him get on with their jobs without interference, he was also happy to get wet and lend a hand whenever needed. During the many years that Steinhart maintained two Pacific white sided dolphins, Tom was always in the drained exhibit for the weekly cleaning regime. These two dolphins were some of the longest held individuals of their species, and his constant calm demeanor during these weekly exhibit cleanings was perhaps a contributing factor to their longevity at Steinhart.

On one occasion in the 1980's Tom's hands on support to his team had some unexpected consequences. A false gharial, *Tomistoma schlegeli*, had to be sequestered in the large Alligator Swamp exhibit. Tom was assisting the reptile keeper in this endeavor, and the latter was on the business end of this crocodilian while Tom was at the safer tail end. Just as they had it cornered and were about ready to secure it, the gharial pushed up, pivoted on its tail and came down with its mouth open towards Tom. Tom managed to quickly pivot himself too, but the gharial grazed his foot, and the bleeding was profuse. Aquarium staff dropped him off at a nearby emergency room, where he received a number of stitches, and was cautioned to take it easy. Tom called to the aquarium for someone to come and pick him up, but in those pre-cell phone days, he could not get through to anyone. He decided that since it wasn't too many blocks, and all downhill back to the aquarium that he would just carefully walk. After a few blocks with his shoe rapidly filling with blood, he thought better of his plan. This time he called until he got through, and waited for someone to pick him up for his return trip to the ER.

Tom was a master of sourcing and rehoming animals. In the days of land-lines and typewriters, he cultivated a massive rolodex of colleagues, collectors, and animal vendors. This was essential in 2004 when Steinhart Aquarium moved to a temporary location in downtown San Francisco for four years, while the new California Academy of Sciences building was being constructed. Tom found new homes for many Steinhart residents, including such challenging species as alligators, nurse sharks, and even pacu. A notable transfer during this time was "Boris," one of only two Volga River sturgeon in the country. Boris and his sibling Horace, who resided at Tennessee Aquarium, originally arrived at Steinhart in 1976 in a cold-war era scientific exchange with the (then) U.S.S.R. They were received from Moscow University as a trade for a piece of frozen coelacanth gonad. Thirty years later, in 2006, Tom organized the massive effort to move Boris to Tennessee Aquarium to be reunited with his old friend. This high-stakes animal transport was accomplished with support from Dynasty Marine and Delta Airlines.

Tom was also a family man who never uprooted his family to move to greener pastures. In addition to Earl Herald and John McCosker, Tom served as Curator under Robert Jenkins and Chris Andrews. He also worked under Dave Powell as Senior Aquarist when Dave was Curator in the late 1970's. Dave's departure in 1980 to begin the planning for Monterey Bay Aquarium, opened the door for Tom's promotion to Curator. In 2005, as the Steinhart staff started to grow and develop the new facility, Tom was again promoted, to General Curator, with a focus on institutional collection planning, permitting, and AZA-accreditation. One of his last projects before retiring in 2009 was to prepare and submit Steinhart Aquarium's successful AZA accreditation application.

Many who read this, and especially those who have been in the public aquarium profession for some time, are well aware that it can often be a very difficult field to enter. The authors of this memoriam did not initially realize that each of us began our careers as Steinhart Aquarium volunteers due to the direct encouragement, and sometimes intervention, of Tom Tucker. During his many years at Steinhart Tom no doubt interacted with hundreds of volunteers. Only a fraction of these followed Tom's lead into aquarium and zoological professions, but his influence in many of these lives remains today. The authors are privileged that Tom somehow saw something in each of us which he encouraged and nurtured, and we are forever grateful.

Following his retirement, Tom and his wife Prudence moved to Bodega Bay on the Northern California coast where he lived until his death in August of 2025. He is survived by his wife, two daughters, and one grandson. He will be remembered with great fondness and admiration by at least two generations of aquarium professionals.

Figure 3: Tom getting his hands dirty assisting with the capture and transport of several species of sharks from the old Steinhart Aquarium facility in 2004. Photo © California Academy of Sciences.

Acknowledgments

A number of individuals provided insightful comments and helpful suggestions during the preparation of this memoriam. The authors wish to particularly acknowledge the following: Prudence Tucker, Tomio Iwamoto, Charles K. Morris, and Martin Wisner.

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UNKNOWN VESICLE DISEASE (UVD)

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This rare syndrome seen in aquarium fish has an unknown cause. Currently termed the "Unknown Vesicle Disease" (UVD), it is characterized by one or more clear to translucent fluid-filled "bubbles" under the skin of certain species of fish. The cause of these vesicles is unknown. The outcome of infected fish varies; in some cases, the vesicles resolve on their own, while in other cases, they become more severe, and the fish perishes.

Diagnosis of this syndrome lays in the visual symptoms of the vesicles; gas filled vesicles are different, they are caused by either gas supersaturation of the aquarium water, or gas produced by bacteria under the fish's skin. These UVD are clearly fluid-filled and this fluid is typically clear or translucent. The location of the vesicle(s) is often on or near the fins, next to the eye, or on the head.

The variety of fish species affected by UVD is not completely known. Clownfish develop this syndrome most commonly, but that may reflect how frequently they are seen in aquariums. Other species reported to develop this syndrome include mollies, cardinalfish, blennies, gobies and mandarin fish. A case in a fancy goldfish, seen on the Internet, was apparently related to a severe case of dropsy in the affected fish.

UVD does not appear to be highly, if at all contagious. It could be caused either by a virus or bacteria that in turn causes some localized defect in the fish's ability to osmoregulate. It is also possible that not all cases have related causes.

Since the exact cause is still unknown, treatment is primarily supportive. Maintaining a peaceful aquarium environment with good water quality and ensuring the fish is well-fed are the best steps for care.

** Note: I've not had any samples in-house to send out for histopathology. If anyone has done so or had some other determination as to the cause of this syndrome, please let me know.*

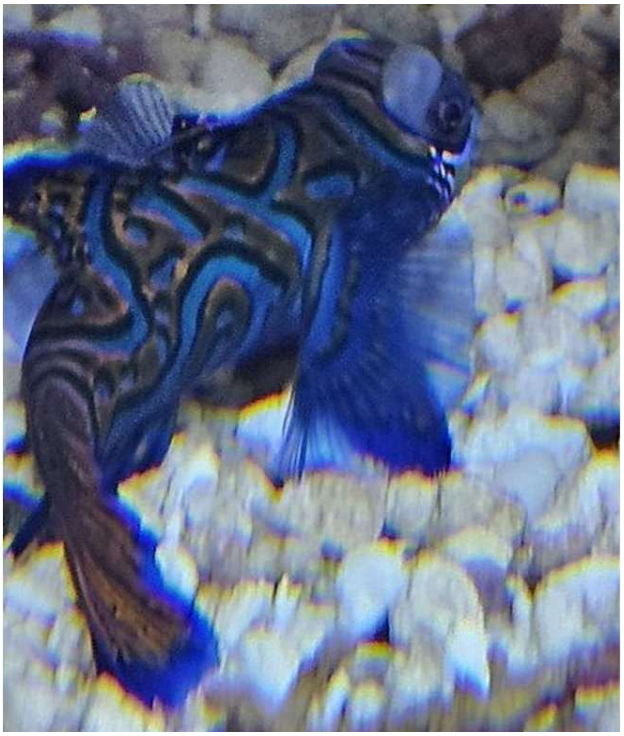
Case #1: The clownfish on the left has a gray fluid-filled blister on its left pectoral fin. This reportedly resolved on its own within two weeks.

Case #2: A blenny housed in a home aquarium developed multiple vesicles along its dorsal fin. Over six months, the vesicles grew in size and the fish began having difficulty maneuvering.

December 2024:

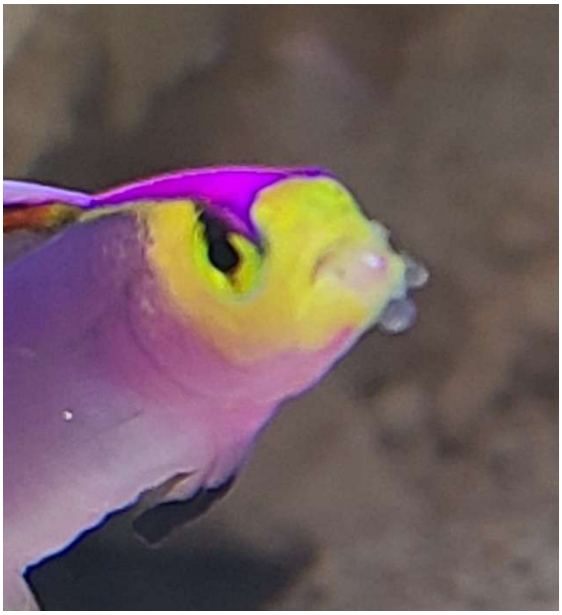
July 2025:

Case #3: A mandarin fish was photographed with a single vesicle protruding from its eye. The was no report made as to the outcome of this case.

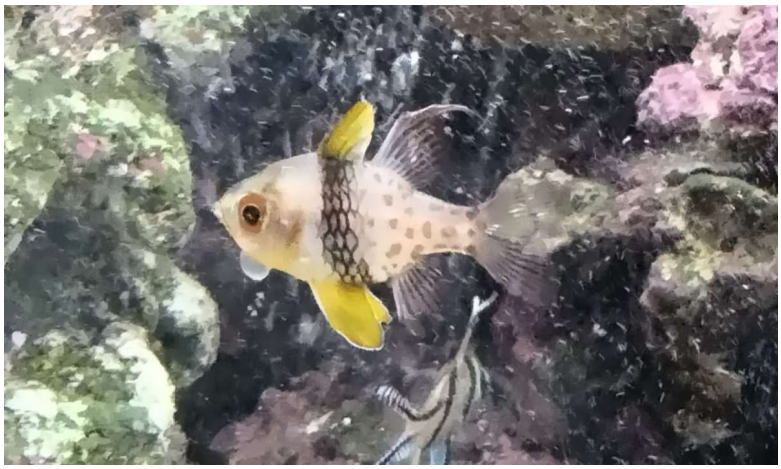


Case #4: This clownfish developed a single vesicle but recovered. Interestingly, it had been housed with the blenny in case #2.

Case #5: A Helfrich firefish was seen with multiple vesicles on its lower jaw. It was reported to have recovered after two weeks.



Case #6: A single vesical was reported on a cardinalfish, it was reduced in size after two weeks.



MORTALITY RATES IN CAPTIVE REARING OF MARBLED WHIPTAIL CATFISH (*Loricaria simillima*)

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Introduction

Little has been published on *Loricaria simillima*, but it belongs to the large taxon group Loricariidae (Londoño-Burbano et al., 2023). Members tend to utilize the bottom of the water column, but inhabit a variety of water sources, including streams and tributaries at varying current speeds. An omnivorous group, they consume plant detritus, small worms, and larvae (Covain & Fisch-Muller, 2007). The Family Loricariidae exhibits high morphological and reproductive diversity. This group of small to moderate-sized catfish is endemic to South America (Burgess, 1989; Covain & Fisch-Muller, 2007), with 18 valid species described in a variety of habitats (Thomas et al., 2013). Recent studies have focused on taxonomy (Reis, R. et al., 2003), though recent cytogenetic work has been presented (Benitez et al., 2017; Bitencourt et al., 2012).

Loricariidae, as a family, is quite varied in egg-rearing strategies (Mongabey 2013). Styles range from "mouth-brooding," where the sire holds the egg mass in his mouth to protect, clean and aerate the clutch; "egg-depositors" in which the female lays eggs that stick to a surface, and one or both of the parents maintain the clutch site to keep it safe from predation and algae growth (Carnicer et al., 2023). There is also "egg-scattering," where the eggs are laid by the females and then left completely unprotected by the parents (Teletchea et al., 2009; Mongabay, 2013). Parental care is more frequently observed in freshwater species (Gross & Sargent 1985; Godinho, Lamas & Godinho, 2010), with techniques ranging from guarding of the nest territory to full-mouth brooding of eggs or young. Among species that exhibit parental care of eggs, males are more common caretakers in teleosts than are shared parenting or female-only care (Gross & Sargent 1985). However, much of this behavior involves guarding a territory from predation rather than mouth brooding.

The Smithsonian National Zoological Park acquired a reproductive group of marbled whiptail catfish (*Loricaria simillima*) in 2015. During breeding and egg laying, the group was housed in a mixed-species exhibit with golden whiptail catfish (*Rineloricaria lanceolata*), twig catfish (*Farlowella acus*), and royal farlowella (*Sturisoma aureum*). Reproductive activity was first seen in 2015; however, successful rearing of young was not achieved until 2016 despite six clutches of viable eggs on exhibit. Initial clutches were left in the care of the male catfish, allowing keepers to document egg brooding and embryo development. Although fry were observed hatching from eggs, no young survived. In 2016, a single clutch was pulled from the enclosure and cared for by animal care staff, resulting in the successful rearing of *Loricaria simillima* at the National Zoo.

Methods

Husbandry of Adults

Breeding Tank

Animal care staff observed repeated clutches of fertile eggs laid on exhibit without survivorship, so the decision was made to pull an egg mass and attempt rearing in a controlled environment. The adult breeding group of collection *Loricaria simillima* inhabits a 75-gallon aquarium, with an attached canister filter. Temperature was maintained at 25-28°C, and lighting coordinated to mimic a natural photoperiod: 12 hours of daylight per 24 hours from May to October, and a 10-hour cycle from November to April. The tank is heavily stocked with both driftwood and live freshwater plants, providing ample cover for natural behaviors.

Tankmates included the aforementioned catfish species, as well as predatory leaf fish (*Monocirrhus polycanthus*), which were assumed to be potential aggressors in past survivorship failures. The diet in this tank includes a varied selection of Hikari Algae Wafers™ and Mazuri® aquatic herbivore gel, along with animal protein offerings of mysis shrimp, bloodworms, and live blackworms. Life support for this tank consists of biweekly water changes between 25-40%, and alternating biweekly filter cleans. Due to the high number of wood-eating catfish in the tank, these frequent measures were necessary to maintain water clarity.

Reproduction

The brooding of *L. simillima* is interesting, as it shows a unique style of parental care. The male catfish holds and protects the egg mass once fertilized and cleans the eggs throughout the 10–15-day incubation period [Figure 1]. The mass itself is larger than the male's mouth, and there is no parental care post-hatch, so this is not a case of actual mouth-brooding behavior. However, the high level of attention given to the clutch indicates a hybrid style of parental care, with some aspects of mouth brooding and egg deposition. When examining the mass outside of the parent's mouth, eggs are spherical and measure approximately 0.4cm in diameter. The eggs stick together and are difficult to separate without damaging at least some of the clutch. Embryo development is easy to observe, with color changing from orange to gray as they approach hatch.

Figure 1. Adult male catfish maintaining clutch of eggs with mouthparts

Figure 2. Egg mass pulled from brooding male's mouth. Embryos can be seen in the individual eggs of the clutch.

Clutch Removal and Egg Husbandry

In September 2016, the eggs were removed from the enclosure and placed in a 10-gallon tank with a glass heater, air stone, and sponge filter. The hatch occurred 8 days after relocation, and it is assumed the clutch was fertilized between 10 and 15 days previously. Nine (9) fry hatched on the first day and, over the course of the next 7 days, a total of twenty-four (24) fish hatched.

For the first few days after hatching out, the fry were fed live brine shrimp. Over the following weeks, ground algae wafers and ground fish flakes (Tetra® TetraMin®) were also fed. Added for variety at 7 days old, finely chopped blackworms and bloodworms were introduced to the group. This diet was based on the diets of other similarly sized freshwater catfish fry. Consumption of these food items was monitored closely, and volume adjustments were made on an as-needed basis.

Salinity was maintained at 2 ppt to deter fungal growth, and was discontinued when hatch was deemed complete and affected egg casings were removed. Water changes were not performed until after the clutch hatch was complete and the yolk sacs had been absorbed. Following this, samples were tested weekly, and at no point during the rearing process did they exceed 0.02. Post-hatch, water changes were performed daily at 25%, then decreased to every other day when the fry were maintaining good health.

Discussion

Twenty-four (24) fry successfully hatched from the clutch. Two mortality events occurred, resulting in a 54.1% survivorship rate for this clutch. Approximately 24 days post-hatch, 0.0.5 individuals were found dead in the tank. Due to the small size of the specimen and significant autolyzation, necropsies could not determine a specific cause of death.

Fungal growth appeared three days after the clutch was pulled from the exhibit. Several methods were used to separate the fungus from the clutch. Mechanical removal of fungal patches using forceps or a siphon proved damaging to the overall clutch body and was discontinued after 2 attempts each. After introducing 2 ppt salinity to the rearing tank, the affected area decreased

slightly. It was observed that the growth was occurring on exposed surfaces [Figure 3], so accommodations were made for the remaining egg masses. The clutch was suspended roughly halfway up the water column in a semi-permeable basket, with an air stone placed beneath to create a current that would pass over the clutch. Though the clutch was no longer a single mass, the goal was that increased circulation would decrease the risk of fungal growth on the eggs [Figure 4].

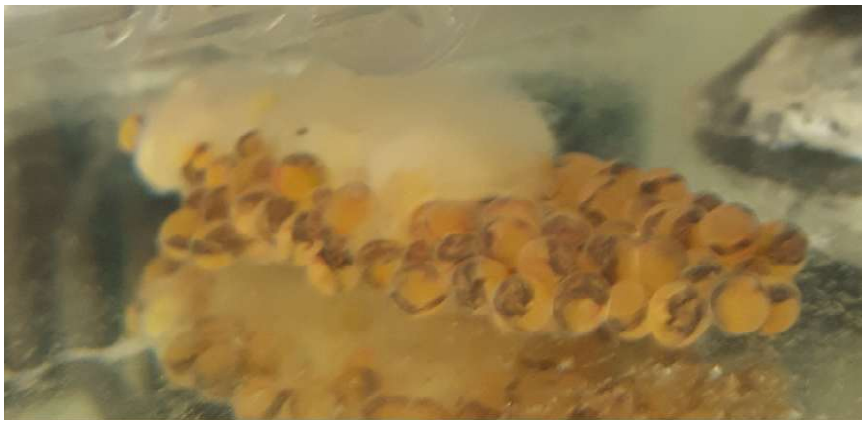

Figure 3. Fungal growth on egg mass. Embryo development observed, but not in areas affected by fungus.

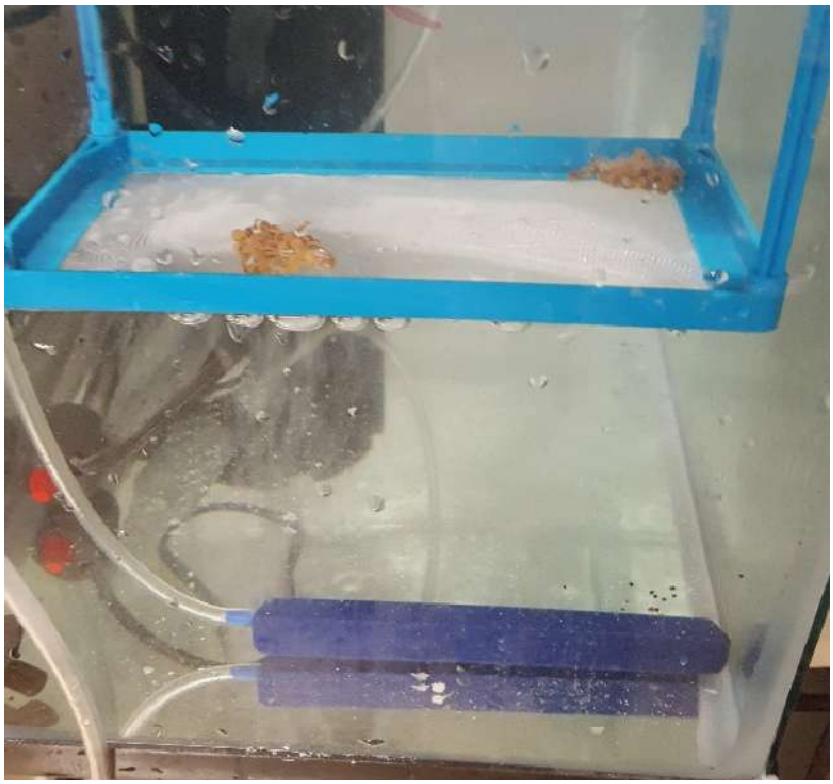

Figure 4. Mesh-bottomed basket used to increase oxygen flow around eggs where fungal growth was observed. Egg mass from earlier has broken apart in repeated attempted to clean the affected areas.

Multiple sequences of death led to the low survivorship rate. While some sources of error that manifested themselves in the large drops in population are more obvious, such as the volume of provided foods decreasing water quality, some other sources that could have contributed to the limited success in this rearing process include excess filtration, lack of filtration, lack of space, and lack of hides. Excess filtration would prevent the growth of good bacteria on and around the filter, which can lead to poor biological filtration, while a complete lack would leave the system unable to maintain good water quality. The space limitations of a 10-gallon tank and the limited variety of hide options may also have contributed to early mortality rates. When the fry were 71 days old, another mortality event occurred. Four (4) individuals were found deceased, and an additional two (2) the following day. At this point, the decision was made to vacate the rearing tank out of suspicion of filtration failure and poor water quality. Fry were moved to a 75-gallon aquarium with a sump filtration system in hopes of increased space and increased survivorship.

A lot has been learned from this process that can help improve the care of future clutches. We plan to prophylactically increase salinity after placing the clutch in the rearing basket, while immediately applying the increased oxygenation around egg masses. Future adjustments will likely include consideration for initial egg disinfection to abate fungal growth. This has successfully been applied to other closed-system incubation methods (Sutherland et al., 2014).

Additionally, providing larger spaces once fry are over 2cm in length, with increased hide options, would give individuals more opportunities to isolate from one another. Although the survival rate was low in this instance, it is still preferable to the 100% mortality rates observed in the parental tank. Therefore, hand-rearing will be the recommended method for reproducing this group in future breeding incidences.

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USE OF A PROSTHETIC SWIM BLADDER FOR BUOYANCY FOLLOWING DAMAGE TO THE SWIM BLADDER IN A LARGEMOUTH BASS (*Micropterus salmoides*)

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Introduction

The "Toyota Sharelunker Program" is run by the Texas Parks and Wildlife Department (TPWD). Anglers can donate exceptionally large bass caught in Texas waters to be used in a selective breeding program to enhance the overall quality of largemouth bass (LMB) populations. Essentially, a "Sharelunker" is a very big bass that is loaned/donated to the program to help breed bass with the potential to grow to exceptional size. Sharelunker collection season is from January 1 to March 31 annually, but the spawning season is typically April to June depending on water temperatures. This means Sharelunkers spend between 3-6 months at the Texas Freshwater Fisheries Center (TFFC). Since Sharelunkers are collected via angling and require transferring from an angler's live well to TPWD personnel and then to quarantine at the TFFC, injuries to Sharelunkers are common.

Forward facing sonar has become more popular recently for anglers because it allows anglers to target large fish in deep water. As a result, multiple Sharelunkers each year are caught in deep water. However, pulling a fish up rapidly from deep water can cause rapid decompression and barotrauma (Carlson, 2012; Brown et al., 2014). One of the most common injuries to Sharelunkers is overinflation of the swim bladder because of barotrauma. For a physoclistous fish like the LMB, this rapid decompression will cause expansion of the swim bladder with no mechanism to rapidly relieve the trapped gasses (Teresa and Maciej, 2019). A technique known as "fizzing" (puncturing the swim bladder with a hypodermic needle to releasing the gas) can be performed by anglers and fish keepers (Nguyen et al., 2009; Madden and LaRochelle, 2024). However, significant barotrauma can sometime cause perforation of the swim bladder and releasing too much air while fizzing can cause the swim bladder to collapse. In these cases, fish will not be able to maintain their position in the water column and can suffer from "negative buoyancy disorder" (Wildgoose, 2007). In the wild, this would result in almost certain death. In captivity the prognosis is only slightly better as the lack of buoyancy will result in prolonged contact with the tank walls and bottom.

Background, Methods, and Timeline of Recovery

Sharelunker number 655 (SL655) was caught by Alec Morrison on February 5th, 2024, while pre-fishing for a tournament on Sam Rayburn Reservoir in East Texas. The fish weighed 6.27 kg (13.82 lbs.) on a certified scale. Stress from handling and transport and potential barotrauma from capture resulted in an overinflated swim bladder, leaving SL655 unable to maintain correct orientation in the holding tank. SL655 was fizzed immediately upon pickup but many hours post capture. SL655 was then transferred back to TFFC. During intake at TFFC, SL655 was anesthetized using tricaine methanesulfonate (aka. MS-222). A health assessment, and external examination were conducted. SL655 was then fitted with a PIT tag and then placed in static 450-L quarantine tank. DO was maintained near saturation, temperature was held above

15°C and salinity was maintained between 3-5 ppt. During quarantine, SL655 never regained the ability to maintain correct orientation in the water. On day 3 post intake the swim bladder had reinflated and SL655 began to float on its side. The fish was fizzed again, but instead of regaining proper orientation, SL655 sank to the bottom of the tank. SL655 was held in quarantine for 5 days, after which her tank was connected in a recirculating system which maintained the same holding conditions and water quality. SL655 had been in contact with the tank floor for 2 days at this point. On February 10th, 2024, a "prosthetic swim bladder" was cobbled together using an inflated latex glove, a handful of cable ties, and a binder clip (Figure 1). The prosthetic swim bladder was attached to SL655 using the binder clip to pinch the anterior portion of the spiney dorsal fin (Figure 2). Once per week, the prosthetic swim bladder would be removed to check if SL655 had regained the ability to maintain correct orientation and control buoyancy. Periodically, the glove would need to be reinflated to maintain positive buoyancy. Live rainbow trout (*Oncorhynchus mykiss*) were offered to SL655 for food. Fifteen days post capture (ten days post prosthetic attachment), SL655 was observed feeding on live rainbow trout. SL655 began to consume approximately 5 live rainbow trout/week while still wearing the prosthetic swim bladder. While checking on SL655 sixty-five days post capture (sixty days post prosthetic attachment), staff discovered SL655 had shaken the prosthetic swim bladder lose and was maintaining correct orientation and buoyancy independently.

Figure 1. Prosthetic swim bladder used to separate SL655 from the tank bottom, constructed using an inflated latex glove, cable ties, and a paper binder clip.

Figure 2. SL655 on day ten of wearing the prosthetic swim bladder.

Discussion

SL655 was able to successfully recover from negative buoyancy disorder with the use of a prosthetic swim bladder. Similar techniques for combating negative buoyancy disorder in LMB with the use of buoyancy compensation devices (BCDs) were described by Morrow (2021). The devices described by Marrow (2021), however, involve belting the BCD around the fish, which resulted in skin abrasions, mucus layer disruption, and secondary infections. By attaching the prosthetic swim bladder to the spiney dorsal fin via the binder clip, contact with the skin and other fins was minimal and the mucus coat was not disturbed. Slight damage to the spiney dorsal fin was incurred (Figure 3) however it has not affected the overall health of SL655. Long term observation of SL655 has been possible because Alec Morrison donated this fish for display in the exhibits at the TFFC visitors center. One year later SL 655 still resides at TFFC (Figure 4).

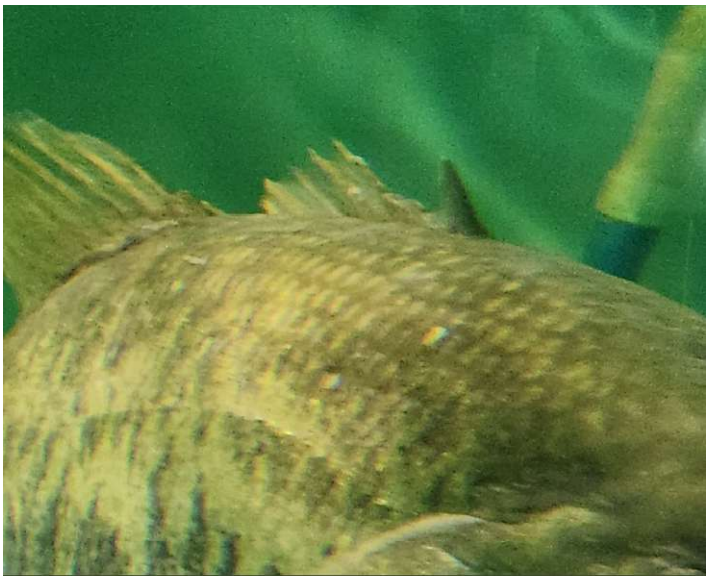

Figure 3. Condition of the spiney dorsal fin approximately 1 year after attaching the prosthetic swim bladder to SL655

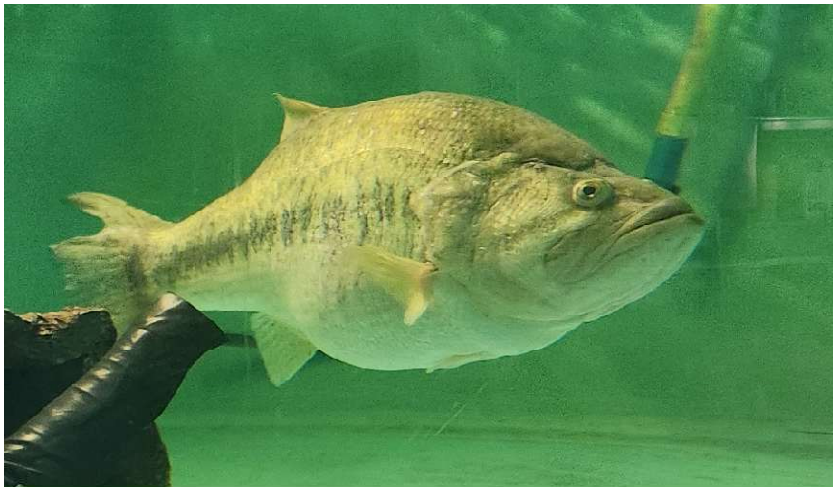

Figure 4. SL655 approximately one year after capture.

The use of a prosthetic swim bladder or BCD may be useful to combat buoyancy disorders in other physoclistous fish held in captivity provided it does not create additional stressors or disrupt the fishes innate immune system any further. However, depth of containment during recovery should be considered. The holding tank at TFFC was ~ 60 cm (2 ft.) deep. This shallow depth meant that buoyancy compensation did not need to oppose exactly the negative buoyancy of SL655. Instead, the glove was inflated so that the positive buoyancy compensation would exceed the negative buoyancy of SL655. This way the inflated glove could float at the surface and suspend SL655 off the bottom of the tank. In deeper containment systems, either the tether must be lengthened between the floatation and the fish, possibly leading to entanglement issues, or the floatation must be exactly opposed to the negative buoyancy of the fish. Balancing the opposing positive buoyancy of the float to the negative buoyancy of the fish could be exceedingly

challenging as fish begin to regain function of their swim bladder. Optimum containment and BCD design will be dependent on the species requiring aid.

The time it took for SL655 to regain buoyancy control was 65 days from capture (60 days after attaching the prosthetic). Without the prosthetic, SL655 would have maintained contact with the tank indefinitely. The probability that this fish would have developed secondary infections as a result of contact with the tank, had a prosthetic swim bladder not been implemented, is likely quite high. Other Sharelunkers that have experienced swim bladder injuries have succumbed to secondary infections as a result of contact with the tank in as little as 3 weeks. It is impossible to conclude that SL655 would not have recovered without the use of the prosthetic swim bladder. However, the prolonged timeline for SL655 to regain buoyancy control along with the absence of tank contact abrasions, suggests that full recovery of SL655 and the use of the prosthetic swim bladder are correlated.

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2-PHENOXYETHANOL AS A EUTHANASIA AGENT IN GIANT PACIFIC OCTOPUS (*Enteroctopus Dofleini*)

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:

Euthanasia of animals under human care can be a contentious topic. For the most part, those of us in the aquatic ectotherm world bear less of this ethical and emotional burden than our colleagues who care for terrestrial or endothermic animals. After all, what kind of weirdo gets attached to a feather star? However, octopuses stand out amongst the world of the cold and wet due to their charisma, personalities, and recent appearances in popular culture. In no octopod is this more evident than the Giant Pacific Octopus, *Enteroctopus dofleini* (GPO). Native to the Northern Pacific and exhibited worldwide, few other invertebrates inspire as much awe and connection as a full-grown GPO. This can be especially evident among guests, volunteers, and staff who view, observe and care for these animals. Unfortunately, their lifecycle does not match up to their prodigious size, as most will live no longer than five years, even with the best care.

Due to their short lifecycles, end-of-life care and considerations are constant for any facility housing GPOs, possibly more so than for any other invertebrate. Research suggests that octopuses can feel pain (Crooke, 2021), so special attention must be given to any euthanasia procedures to ensure they are carried out with animal wellbeing in mind. Making the decision to switch from palliative care to euthanasia can be complex and difficult for those involved, but as always, animal wellbeing is paramount.

According to the American Veterinary Medical Association's Guidelines for the Euthanasia of Animals: 2020 edition, a two-step process for euthanasia is recommended. Typically, the first step is administration of a chemical anesthetic followed by physical destruction of the brain, or continued addition of chemical agents until a lethal level is reached.

For cephalopods in aquarium care, the most well-documented methods of euthanasia are the use of freezing/reduced temperatures and magnesium salts. Due to their northern range, GPOs will remain active to a much lower temperature than many smaller, tropical species, so without access to a large, low-temperature freezer, effective freezing of a large specimen is unfeasible.

Previously at Birch Aquarium, magnesium salts have been utilized – both alone and in tandem with ethanol for GPO euthanasia – however, neither method seemed to work particularly well. We believe this may be due to the cold temperature of our Pacific Northwest System (~42°F/5.6°C) or the larger size of this particular species. The other methods recommended in the GPO animal care manual also came with their own challenges: benzocaine was determined to be unsafe for staff usage; rapid freezing was not logistically possible due to the size of the animal and pentobarbitone would require a lot of paperwork.

With this in mind, when one of the aquarium's GPOs began to exhibit advanced signs of age-related senescence, we pursued euthanasia options that would prove satisfactory to both staff and animal wellbeing. However, the animal's large size further complicated the issue, as he had not been weighed for several months. [Figure 1]. Based on visual assessments, the Animal Care Team estimated the octopus weighed approximately 65 to 80 lbs (30 to 36 kg), with arms exceeding five feet (1.5 m) in length.

Figure 1. Giant Pacific Octopus on display at Birch Aquarium. Photo by Jordann Tomasek

Reaching out to colleagues, we were directed to a study involving the use of 2-phenoxyethanol (2-PhE) in the Musky Octopus, *Eledone moschata* (B. Christie, personal communication, July 15, 2025).

Recently, we had begun using 2-phenoxyethanol as an anesthetic for routine shark physicals on the aquarium's Leopard Shark (*Triakis semifaciata*) population, and its usage compared very favorably to Tricaine methanesulfonate **(**MS-222). Induction and recovery times were significantly shorter than with MS-222, as well as a reduced impact on water quality. After discussion among the aquarium's Husbandry Leadership and Veterinary staff, the decision was made to use 2-PhE as the initial agent to anesthetize the animal, followed by pithing and decerebration with a suitable blade as a secondary method.

It was assumed that a dose of at least 3.2ppm would be needed for effective euthanasia, given the results from Şen & Tanrıkul (2009), where 1.6ppm 2-PhE was found to be the best dose for anesthesia and recovery. This is a significantly lower concentration than would be needed for other chemical means [Table 1].

Methods:

Using a modified version of the welfare matrix developed by Holst and Miller-Morgan (2020), the animal's condition had deteriorated enough to warrant removal from display and

subsequent euthanasia. On the day of the procedure, the animal was near the surface of the water, and a 1% EtOH in seawater solution at the same temperature as the system was administered to the mantle via tubing. After infusion of ~240mL of dilute ethanol, the animal relaxed and was able to be safely transferred via rubber net into an off-display holding tank.

Table 1. Comparison of Various Anesthetic and Euthanasia Agents

Agent	Dosage	Amount Needed	Cost per Amount (USD)	Total Cost	Notes
$MgCl_2 \bullet 6H_2O$	3.75%*	5.66Kg	$171/35 lbs	$60.83	*75g/L dissolved in RO/DI, then combined 1:1 with seawater
Ethanol, 100% (anhydrous)	10%	15.1 L	$65.74/4 gal	$65.74	Hard to get if you're not a university
Ethanol, 40% (Popov)	10%	37.75L	$10.99/1.75L	$237.07	Raises some questions at the liquor store
2-phenoxyethanol	3.27 ml/L	490 mL	$65.93/L	$32.30	

For the euthanasia set up, a 45-gallon (150 L) Rubbermaid® Brute® trash can was placed in a 4' (120 cm) tote to act as a water bath, allowing for temperature control without continually diluting the anesthetic bath [Figure 2]. As the back-of-house area was unconditioned and the procedure was occurring during a warm, San Diego September it was critical to keep the Brute's temperature stable as not to unnecessarily stress the animal. Aeration was initially added to assist with mixing the Brute, but the animal had a particular affinity for interacting with air bubblers. To prevent inflation of the mantle or similar injury during the excitement phase of light narcosis, the bubbler was removed and a PVC rod used to stir the brute to assist with mixing.

Figure 2. The water bath set up

Once filled with seawater, the Brute held 151 liters; to reach the 1.6ppm from Şen & Tanrıkul (2009), it was calculated that 239 mL of 2-PhE would be needed. It was decided to add this in three stages of 80 mL, aiming to limit sudden chemistry shifts in the seawater. The animal had a strong reaction to the initial 80 mL, and an oil-slick like cloud was seen dispersing into the water. This was followed by two more additions of 80 mL at ~5-minute intervals, with much diminished reactions. Over the next hour, additional 2-PhE continued to be added, and the animal's behavior was recorded [Table 2]. Once ventilation was observed to have ceased, the animal was removed from the bath and decerebrated using a large knife. By slicing between the eyes to a suitable depth, the central ganglion of the animal is destroyed. Out of an abundance of caution, the knife was also used to split the nerve ring in two opposite positions.

Table 2. Timeline of GPO Behavior during Euthanasia

Time	2-PhE		Observations
	mL added	ppm in Brute	
13:42	80	0.53	strong reaction animal immediately surfaced, but no attempt to climb out
13:47	80	1.07	less reactive, moving arms like grooming [Figure 3]
13:51	80	1.60	-
13:58	-	-	pH of bath: 7.89 pH of brute: 7.86
14:01	50	1.93	still moving, though less vigorously
14:04	-	1.93	color paler, arms beginning to hang limp [Figure 4]
14:07	80	2.47	obviously slowing down in movement, uncoordinated
14:14	80	3.00	-
14:18	-	-	pH of bath: 7.89 pH of brute: 7.82
14:20	-	3.00	not responsive to physical stimuli, suction cups not adhering, very pale
14:25	45	3.30	no response to addition of anesthetic
14:31	-	3.30	able to be lifted without major reaction, very sedated
14:34	-	3.30	no ventilation observed from mantle/siphon
14:35	-	-	pH of bath: 7.89 pH of brute: 7.81
14:40	-	3.30	Animal transferred to necropsy basin, decerebrated with knife. Arms moving on own
15:30	-	-	excised arms still responding to stimuli
16:00	-	-	"

Figure 3. The GPO at 13:47

Figure 4. The GPO at 14:04

Discussion:

Post-mortem weight was 78.8 lbs (35.7 kg), and arm length was in excess of the 48" (120 cm) measuring tape. An accurate measurement of the arms was further hampered by the continued movement of the arms, even after complete separation from the central nerve ring and rest of the body. Findings from the necropsy were limited - the animal's age was evident as he had been housed at Birch Aquarium since November 2022. Interestingly, 6+ spermatophores were recovered from the gonad, in addition to the eight that had been deposited on exhibit since May 16, 2025.

Compared to prior octopus euthanasias using magnesium salts as the primary agent, this was significantly more rapid, with cessation of ventilation in under an hour. Additionally, after the initial, strong reaction, the animal had a much-reduced response to 2-PhE compared to $MgCl_2$, which also improved staff morale. Future procedures would break the 2-PhE dosing down into smaller, 40 or even 20 mL initial aliquots, to limit stress on the animal, or perhaps continue administration of EtOH in addition to 2-PhE once in the brute.

Overall, 2-phenoxyethanol proved to be a very effective agent of euthanasia, and will be the agent of choice going forward for use in GPOs at Birch Aquarium.

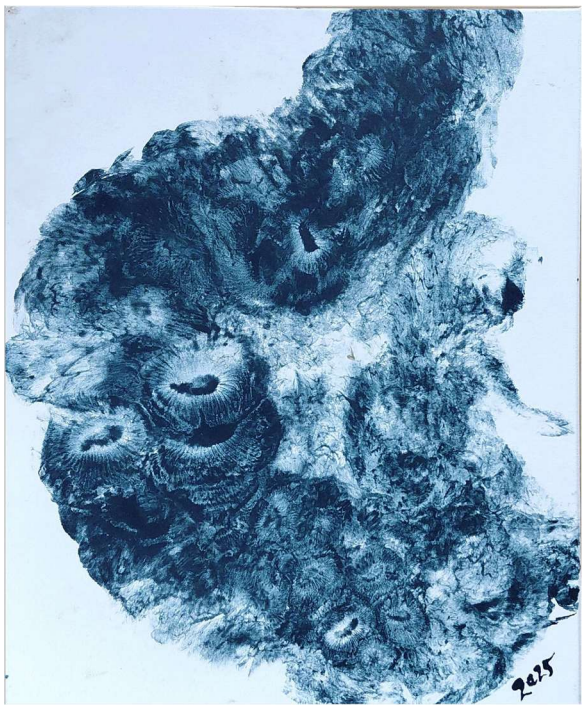

Figure 5. A print taken of the animal's arm

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Alex Feltes, Cari Paulenich, and Jenn Nero for review and feedback on this manuscript.

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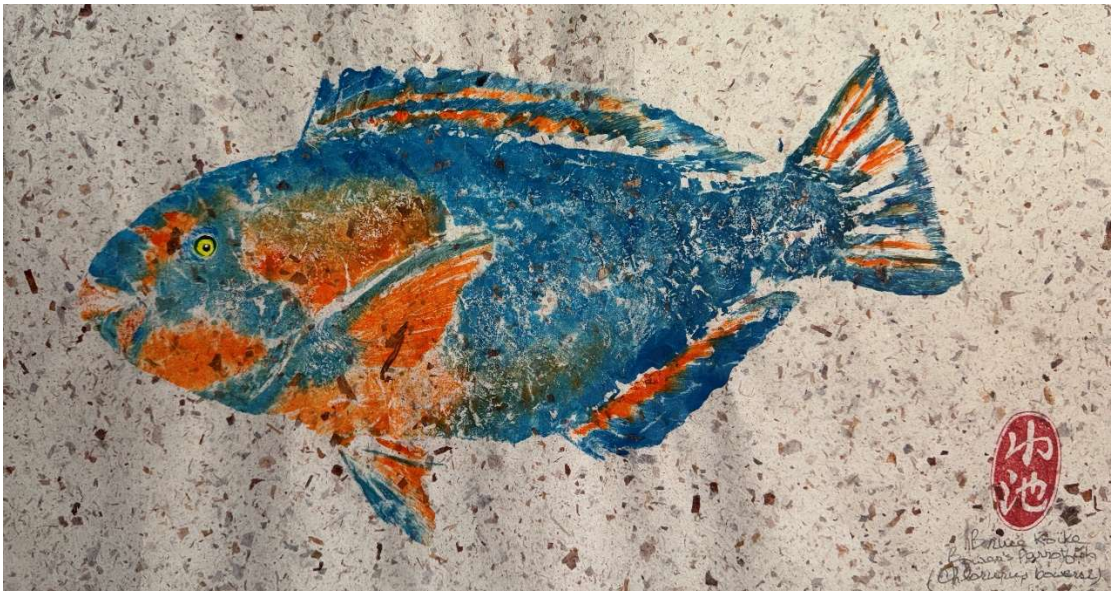

HOW OLD IS MY GPO? USING GROWTH MODELS TO ESTIMATE AGE AS A FUNCTION OF WEIGHT FOR *Enteroctopus dofleini* IN AQUARIA

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Introduction

As short-lived semelparous species, one common question asked by aquarium biologists is how old is an animal of a given size, in order to estimate how much lifespan may be remaining. The Giant Pacific Octopus (GPO), *Enteroctopus dofleini*, has been the most popular cephalopod kept in AZA aquaria and zoos over the last 18 years (Nelson, 2025; Nelson 2020, Mohan 2014), and is the longest-lived octopod, known to have a (wild) lifespan of 3-5 years (Christie et al., 2014). As the cost of acquiring this species has risen in recent years, many aquaria have taken to acquiring smaller specimens, ostensibly extending the amount of viable time the animal can be exhibited. Using published growth models based on fisheries data to estimate age of animals based on size is a common technique, however it is difficult to make such extrapolations for octopods because growth rates in cephalopods are highly variable compared to teleost fishes. Additionally, seasonal variations in wild populations result in disparate growth patterns depending on whether paralarvae developed in predominantly colder, or predominantly warmer temperature waters, (Rigby and Sakurai, 2004; Brewer et al., 2017). It is also theorized that distinct subpopulations with differing growth rates ensures that sexual maturity occurs in different seasons, which may confer an advantage in maintaining genetic diversity to the population (Noro and Sakurai, 2012).

The earliest growth model for *E. dofleini* is that of Robinson (1983), followed by a refined model (Robinson and Hartwick, 1986) from populations in British Columbia. Uriarte et al. (2024) provide growth data for the paralarvae of a congeneric species, *Enteroctopus megalocyathus*, showing rapid exponential growth, as would be expected, but also extreme variability. Rigby and Sakurai (2004) note that GPO specimens <1kg have a markedly different metabolism and growth rate than adult specimens, as would be expected for octopods with planktonic paralarvae.

Methods and Results

No published models of GPO growth account for the wide disparities in rate between paralarvae vs. juveniles/adults, however once animals are of a certain size comparisons can be made. Owing to the disparities in paralarval growth, various studies assign different weights to 'time zero', Robinson and Hartwick (1986) used a biomass of 1.6kg, and Noro and Sakurai (2012) found the lower masses of the two faster growing groups in their investigation to be 1.1-1.3kg, corresponding roughly to animals of 1 year of age. Rigby and Sakurai (2004) note that there are significant metabolic differences in GPO specimens <1.0kg from animals >1.0kg, and this is the point where growth rates shift from exponential to logarithmic. Gillespie et al. (1998) also noted that subadult animals took roughly 1y to reach a size of 1.0kg.

Because 1.0kg approximately corresponds to animals of about 1 year of age in faster growing groups, and because this is the point where paralarval metabolism shifts to that of adult animals, the growth model of Robinson and Hartwick (1986) was modified to set age at 1.03 kg to 366 days (1y+1d), and one can extrapolate out from that starting point. Robinson and Hartwick's (1986) original growth model was modified as follows (original left → modified right):

$$W = 26.87\ (1+e^{(-0.0136(t-203)})^{-1} \quad \rightarrow \quad W = 26.87\ (1+e^{(-0.0136(t-238)})^{-1}$$

This modification made no significant change to data produced by the growth function plotted from 366-1267d (student's t-test; α=0.31757) but made a more reasonable approximation of age, taking metabolic change into account. This modified growth curve is shown graphically in Fig. 1.

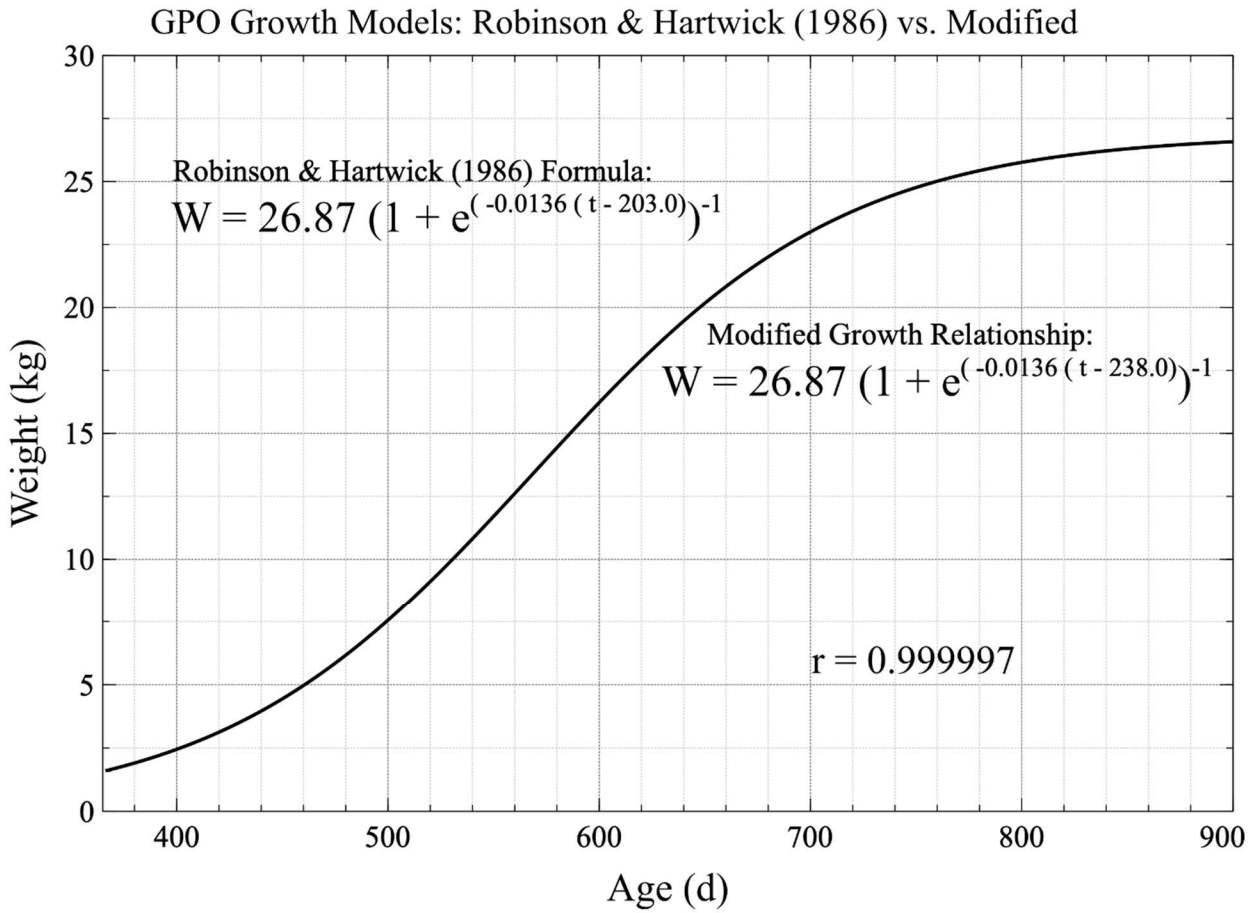

Figure 1. Growth curve (weight v. age) for *Enteroctopus dofleini* populations in British Columbia from 366-900d. Modified from Robinson and Hartwick (1986).

This growth function (Fig.1) provides a range of approximate ages for a given size, which is extrapolated into Table 1 for quick reference. Using these data, a GPO specimen weighing 2.0kg would be 418d of age, 2.5kg would correspond to 427d, and 3.0kg would correspond to 451d. This, however, should be viewed as an estimate at best, owing to the wide disparity in growth rates for GPOs. Other studies have shown slower growth (Cosgrove, 1987), or the presence of distinct groups with differing growth rates (Noro and Sakurai, 2012). To exemplify differences even within a single growth curve, the same growth function modified from Robinson and Hartwick (1986) is plotted with deviations of ±30% (Fig. 2), which is approximately the standard deviation in growth seen among adult aquarium specimens (Christie, unpub. data). Figure 2 shows that when

using a growth model to estimate age the margin of error increases proportionally as size/age increases. Above 15kg, the difference in age estimate may vary by 120d or more, however, at the size most animals are acquired, <5kg, the difference is much less, roughly 40d. This allows one to put a reasonable proximate age to newly acquired specimens, with a confidence interval of <2 months. For example, if an animal is acquired at a weight of 2.5kg, one can use Table 1 to assign an approximate age- in this case 436d.

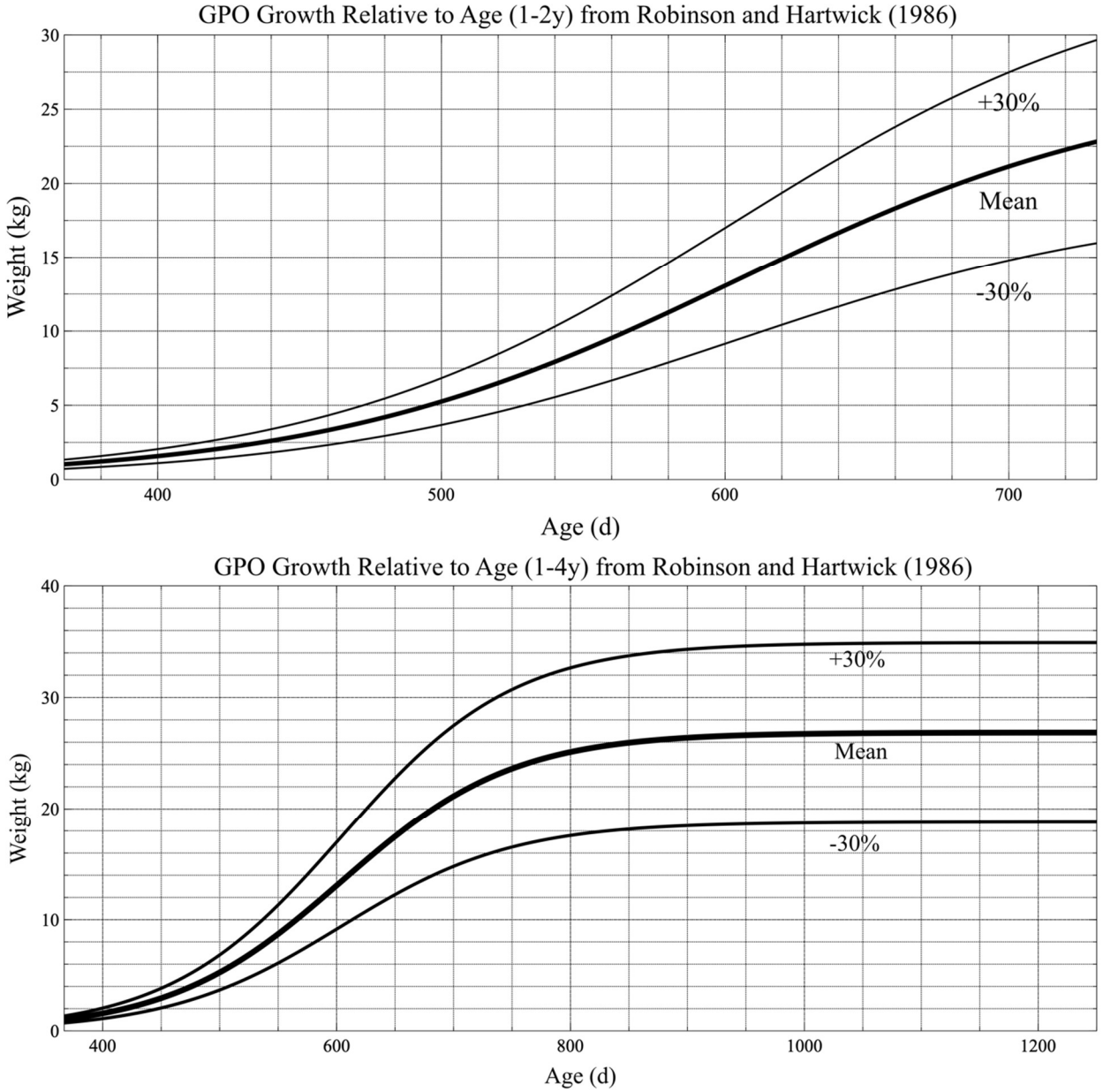

Figure 2. Growth curve of *Enteroctopus dofleini* from populations in British Columbia (mean) from Robinson and Hartwick (1986). Growth curve (mean) at center with deviations of +/- 30% shown to illustrate the wide variance in growth rates. Growth from ages 1-2y (top) and 1-4y (bottom). Note that theoretically, GPO specimens will attain 90% of their maximum size within 726d**.** Note also that at sizes animals are typically acquired (<5kg) the difference between a deviation of ±30% is roughly 40d.

Discussion

Calculating the approximate age of cephalopods is an important metric in empirically assessing whether lifespan in the aquarium is comparable to that of the wild, however there are caveats, and the variability of growth forms even within a single cephalopod species introduces a greater degree of error in these estimations than would be expected with fishes or other marine species.

Considering the growth rate in Fig. 2 it becomes obvious that GPOs reach their adult size relatively rapidly. Following this growth function a GPO will reach 50% of its maximum size by 567d, 90% by day 726, and 95% by day 779. These estimations may be added to the known lifespan in the aquarium to better estimate whether the observed lifespans are comparable to the commonly cited upper limit of wild longevity, 3-5y (1095-1825d). However, these comparisons should be done with caution, as there is a lack of data on what the *average* lifespan of *E. dofleini* is in the wild. Note also that this estimate works best on young GPOs, for example, while small (<5kg) specimens may only have variances of 40d within a deviation of ±30%, specimens at 15kg may have variances of 150d or more, meaning this estimate grows more imprecise when applied to animals of increasing size.

Table 1. Estimated age of GPO, *Enteroctopus dofleini*, from 1-2y as a function of weight, from 1-25kg.

Mass (kg)	Age (d)	Mass (kg)	Age (d)	Mass (kg)	Age (d)	Mass (kg)	Age (d)
1.03	366	4.25	480	7.56	534	14.07	610
1.25	381	4.30	481	8.01	540	14.53	615
1.50	395	4.50	485	8.55	547	15.07	621
1.75	407	4.76	490	9.04	553	16.05	632
2.01	418	5.03	495	9.53	559	17.00	643
2.25	427	5.25	499	10.04	565	18.00	655
2.51	436	5.49	503	10.56	571	19.01	668
2.74	443	5.73	507	11.00	576	20.03	682
3.02	451	6.04	512	11.53	582	21.02	697
3.24	457	6.24	515	12.07	588	22.01	714
3.53	464	6.50	519	12.52	593	23.00	734
3.74	469	6.77	523	12.98	598	24.03	760
4.01	475	7.05	527	13.53	604	25.01	794

**Data from a growth model modified from Robinson and Hartwick (1986). Note that cephalopod growth is variable, and as such margin of error will increase with size.*

Applying these estimates to actual cases, we can estimate that a GPO acquired at 5.25kg specimen would be 499d of age, and if it lived for 2.25y (821d) in the aquarium we can extrapolate a total life span of 1320d or 3.6y. These metrics can provide a more accurate assessment of how aquarium life expectancy compares to that of GPOs in the wild, potentially informing discussions of welfare or collection planning. Application of fisheries data to animal husbandry is often

revealing, however it should be remembered that these are *estimates* based on theoretical data which carry some inherent imprecision, until more is known about the growth patterns of GPOs.

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ABSTRACTS from RAW 2025
The Regional Aquatics Workshop, April 23-26
National Aquarium, Baltimore, MD USA

Tuesday, April 22nd
AZA TAG Meetings

AZA Aquatic Invertebrate Taxon Advisory Group (AITAG) Steering Committee Meeting
AZA Freshwater Fishes Taxon Advisory Group (FFTAG) Steering Committee Meeting
AZAMarine Fishes Taxon Advisory Group (MFTAG) Steering Committee Meeting

Wednesday, April 23rd
Session 1: Aquaculture – Part 1

Welcome Addresses
Jennie Janssen, Stephanie Allard, John Racanelli (CEO)

Sponsor Presentation
Abyzz

Building a Community for Sustainable Aquatic Collections: The AZA ACSC Larval Programs Initiative

Kylie Lev[1], Barbara Bailey[2], Monika Schmück[3]
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The AZA's Aquatic Collections Sustainability Committee (ACSC) established the Larval Programs Working Group in 2019 with strategic priorities to build capacity, increase support, and

develop resources for larval and live foods programs. This initiative has fostered a collaborative community focused on enhancing resources, expertise, and knowledge in larval culturing.

A key component of the program's success is the development of essential resources, including live foods guides and larval rearing protocols. Continuing to create and share these living documents will be invaluable in addressing one of the greatest challenges in larval rearing: effective resource utilization.

The Larval Programs Initiative exemplifies how building a strong, collaborative community can drive success in aquaculture. By fostering partnerships and sharing expertise and resources, the program has not only expanded capacity for larval rearing but also contributed significantly to the sustainability of aquatic collections across AZA institutions.

Utilization of Salinity as a Tool for Egg Separation in Multiple Species Pelagic Spawning Events

Ramon Villaverde[1], Kirk Embree[2]
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Pelagic spawning of marine fishes has become a regular occurrence in most public aquariums and even many private home aquariums. Often spawning occurs as an unintentional by-product of good husbandry when multiple marine species are kept in the same large aquarium. When conditions are correct, spawning will occur resulting in a mix of hundreds to thousands of eggs from multiple species. To prevent over-competition and dominance by a single species, eggs from multiple species spawns must be separated by species prior to growout. Using a pipette and microscope to separate eggs one-by-one is not a sustainable method for mass culture of marine fishes due to its unrealistic time constraint. One possible solution to this egg separation dilemma utilizes the knowledge that the physical properties of eggs from each species differ as well. The eggs from varying species are unique in the specific gravity required to make them float. We have found that by creating salinity gradients within the egg separator cylinder, we may be able to quickly differentiate and separate eggs from different species. This technique will save time and has the potential for a wider variety of species to be successfully raised from each mass spawning event.

Simple, Cost-Effective Solutions to Small Scale Aquaculture of Pelagically Spawned Marine Fishes

Kirk A. Embree
Central Campus Aquarium Science, kirk.embree@dmschools.org

Central Campus Aquarium Science students in Des Moines, Iowa have settled two pelagically spawned marine fish species in their high school lab. Students successfully raised the Lemonpeel Angelfish, *Centropyge flavissima*, and the Orbiculate Batfish, *Platax orbicularis,* along with four additional benthically spawned marine species this school year. Before students could complete the construction of their aquaculture remodel, their new broodstock started spawning. Not wanting to wait for construction to be completed, new temporary aquariums were assembled in the limited space still available. Small glass aquariums, inexpensive heaters, air

pumps, lighting, and live foods were all that were required to raise six "new to our lab" species. Students constructed inexpensive "Kydex" type inserts for standard ten-gallon aquariums. They believe these inserts aid in the survivability of newly hatched prolarvae. The design helps with water flow and surface tension issues faced with standard rectangular aquariums. These tanks can be assembled in half the amount of space as traditional black round tubs. Live food requirements are minimized in these smaller tanks as well. Challenges include allotting time daily for live food production, water quality analysis, and salinity adjustments. Minimal to no time is required for cleaning interior aquarium surfaces, instead allowing the biofilm to thrive and naturally process the waste produced by the growing fishes. These budget friendly, space saving solutions can be easily adapted to public aquariums interested in conservation through aquaculture.

Session 2: Aquaculture – Part 2

Sponsor Presentation
TJP Engineering

From Dragon Beginner to Weedy Breeder: Success of Raising Weedy Seadragons *(Phyllopteryx taeniolatus)* at the Columbus Zoo and Aquarium

Aaron Jeskie
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When the Columbus Zoo and Aquarium opened a new weedy seadragon (*Phylloperyx taeniolatus*) habitat in the spring of 2023 no one expected to have reproductive success with this notoriously difficult to breed species anytime soon. Individuals in the population were either thought to be too old or too young to reproduce. This all changed with a first successful egg transfer to a male dragon in late spring of 2024. The journey leading up to this point was long and winding with many ups and downs, especially for a team with very little sea dragon experience. The process of designing and building holding and habitat space, finding and transporting animals and simply learning the quirks or sea dragon husbandry had led us to a now gravid male with only 6 weeks to figure out what to do next. Hatch plans were drawn up, kreisels were set up and ideas were tossed around on how to best isolate and transfer the new fry to their new homes. Once the babies started hatching, even the best laid plans needed to be changed on the fly to accommodate the constantly changing needs of the fry. Luckily, with the advice of other seasoned dragon breeders, we were able to find the right mix of things that worked for us and at five months old the baby dragons are thriving. Even with this first small success for our institution, there are many things that can be improved before next year's breeding season.

Sustainable Fish Breeding: A Mesocosm Approach for Breeding Brackish Fish

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With a growing industry focus on sustainability, an increasing number of institutions are focused on breeding fish for exhibit. Marine species are frequently the focus in larval rearing due to the challenges and costs associated with sourcing them. The National Aquarium has recently invested in breeding brackish species, such as those housed in the Chesapeake Salt Marsh Exhibit. This exhibit is a 1,330-gallon brackish system (10-12 ppt) showcasing native Maryland species, including seven species of fish and two diamondback terrapins (*Malaclemys terrapin*). In an effort to become more sustainable and improve the welfare of exhibit animals, aquarists were tasked with breeding six species of fish from this exhibit. After months of refinement, a single species mesocosm approach was developed, allowing aquarists to stimulate adult breeding behaviors, collect eggs, and rear larvae in the same enclosure. This method allowed for a regular production of eggs and minimized disruption of eggs and larvae during vulnerable developmental stages. Aquarists have been able to plan breeding events, predict survivorship, and move toward a healthier, in-house production of fish while being cost-effective and time efficient.

Sustainably Breeding Lumpfish *(Cyclopterus lumpus)* for AZA's Larval Fish Program

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Lumpfish (*Cyclopterus lumpus*) are a cold-water species housed in many aquatic facilities. They are commonly used in fish hatcheries as juveniles for sea lice control. Lumpfish populations in the wild have declined and their populations are considered to be Near Threatened by IUCN due to overfishing for their roe, demand from fisheries, and habitat changes. Lumpfish are oviparous with females laying over 100,000 eggs at a time making them an excellent candidate for in-house breeding. At the Downtown Aquarium, we have raised several generations of lumpfish successfully through husbandry practices shared within our facility. This has allowed us to sustainably maintain our collection. As eggs are laid and fertilized, I was able to collect and incubate them until fry hatched. We have successfully raised hundreds of lumpfish to adulthood through these methods. With these methods, we are now a part of AZA's Larval Fish Program as a sustainable source for lumpfish in zoos and aquariums.

Hatched, Reared and Delivered: Becoming an Expert in Shipping Fish

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Between August 2022 and December 2024, the New England Aquarium (NEAq) has shipped over 2,171 fish to aquariums throughout the country, in addition to those between our Quincy Animal Care Center and our main campus on Central Wharf in Boston, MA.

Over the past three years, the NEAq larval program has been working with the Aquatic Collections Sustainability Committee (ACSC) in rearing Atlantic lookdowns (*Selene vomer*), glassy sweepers (*Pempheris schomburgkii*) and smallmouth grunts (*Haemulon chrysargyreum*) to

provide its members with more sustainable acquisition methods for their aquatic populations. Once the fish reach a substantial size in their juvenile stage, the final step is packing up and shipping off the fish. Many factors influence a successful shipment, such as mapping out the quickest route via air cargo or ground transportation, proper bag sizing, ensuring each box has the proper amount of heating or cooling packs, and preparing the shipping water. Disinfecting the shipping water using 6% concentrated bleach to reach 10ppm, adding AmQuel and stress coat to detoxify and condition the water, and adjusting the pH and DO ensures the fish arrive in the best quality water.

With over 41 separate shipments under our belt and a <1% DOA rate, we've learned that practice certainly does make perfect when it comes to shipping fish. We might not exactly be "expert" status yet, but we have worked the past two years on perfecting our shipping protocol to a point where it can be recreated with similar, if not better success rates.

SAFE Sunflower Sea Star Update

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This talk will focus on a multitude of actions carried out by the SAFE and its partners over the past year. We will focus on the results of a coalition of SAFE Sunflower Sea Star aquaculture partners and what the ex situ population looks like a year later. We have successfully grown the institutional knowledge of rearing this species and are now shifting focus to the welfare and population management as we advance the ex situ management of this species. Cryopreservation techniques developed in collaboration with the San Diego Wildlife Alliance and Omaha's Henry Doorly Zoo and Aquarium have led to successful long-term storage of sperm for biobanking of genetic material, and preliminary results raising cryopreserved larvae will be shared. We will describe the progress and application of an e-DNA tool, how it can be utilized to track population level distribution data, and the actions to follow. Partners at Friday Harbor Laboratories have released *Pycnopodia* back into the wild and will describe how they have managed this population post release and how this will lay the ground work for developing regional recovery plans with ex situ populations. Additionally, we will describe a new tracking technology they are developing and how we are applying these technologies among partners. Teams will be working with Alaska Sea Life Center to coordinate one of the largest controlled spawning events for the species. We will highlight Project Alaska and its impacts on aquaculture, cryopreservation, genetics, and machine learning technology.

Sponsor Presentation
McRoberts Sales Company, Inc.

AITAG Reporting Meeting
FFTAG Reporting Meeting
MFTAG Reporting Meeting

Thursday, April 24th
Session 3: Aquatic Herpetofauna

Oh Snap! A Look into Alligator Snapping Turtle Husbandry

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Alligator snapping turtles (*Macrochelys temminckii*) are remarkable reptiles known for their unique physical traits, including a vermiform appendage used for luring prey, a 1,000-pound bite force, and a lifespan that can exceed 150 years. These features, while fascinating, present challenges in their care and management in zoological settings.

Despite their intriguing characteristics, limited husbandry information is available for this species, and much of the existing advice is insufficient. This talk will highlight a recent survey of aquarium and zoo staff who care for alligator snapping turtles, compiling data on many aspects of their husbandry; including but not limited to habitat requirements, feeding practices, nutrition, morphometrics, training, safe handling protocols, and veterinary care.

Using data from the survey, this presentation aims to foster a collaborative discussion on improving alligator snapping turtle care and develop best practices for their long-term well-being under human care.

Hot Out of the Croc Pot: Recipes for Success in Classifying and Mitigating Crocodilian Behaviors

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The complexity a mixed-taxa habitat presents to its caretakers is a unique challenge of recognizing and understanding the behaviors of the various species and individuals that are represented. Few species in aquatic and semi-aquatic mixed-taxa habitat are as feared or as misunderstood as crocodilians, especially in those cases where caretakers are not primarily trained as herpetologists. This presentation will cover the notable behaviors of crocodilian families (Alligatoridae vs. Crocodylidae) and species, possible interpretations of those behaviors, and how to work safely around these animals while providing care for the other species they cohabitate with.

Thinking Inside the Box: Fungal Pathogen Management in Green Anacondas, *Eunectes murinus*

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Beginning in 2019, New England Aquarium observed evidence of fungal pathogens in their exhibit green anaconda, *Eunectes murinus,* collection. Polymerase chain reaction (PCR) testing revealed known contagious reptile fungal pathogens in the genera *Paranannizziopsis* and *Ophidiomyces*. Addressing fungal epidermitis involved a multifaceted approach that combined improved husbandry practices and environmental management. In early 2022, an adult individual

underwent an 11-week terbinafine nebulization treatment conducted in a nebulization chamber that was custom built by aquarists. Following treatment, the animal's plasma terbinafine concentration was tested and found to be well above in vitro minimum inhibitory concentration (MIC) for *Ophidiomyces*, suggesting that the nebulization method was effective for distributing the drug systemically.

In early 2023, fungal pathogens on skin biopsies were once again confirmed by PCR test. In response to persistent fungal pathogen presence, animal care staff evaluated how the exhibit design impacted animal welfare, staff safety, and fungal pathogen risk. In late 2023, partial exhibit renovation included exhibit disinfection, full LSS update, and addition of interior shift box inspired by the nebulization chamber. At present, animal care staff is managing a low burden of fungal pathogens and is continuing to prioritize improvements to welfare.

Ex situ Conservation Efforts for the Beale's Eyed Turtles in Hong Kong

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Beal's eyed turtle (*Sacalia bealei*) is a small aquatic turtle species characterized by distinctive ocelli on its head. This endangered species, listed as Critically Endangered by the Tortoise and Freshwater Turtle Specialist Group (TFTSG) and Endangered by the IUCN, faces significant threats from habitat loss and hybridization with non-native turtles.

Conservation efforts have been made by collaborative initiatives between Ocean Park Conservation Foundation Hong Kong (OPCFHK), Lingnan University Hong Kong, and local organizations Hong Kong Society of Herpetology Foundation (HKHerps). These partnerships have established an ongoing ex-situ breeding program, focusing on improving husbandry techniques and breeding outcomes.

Notable achievements include the first successful hatch in 2020 and an increase in egg production, with 14 eggs collected in 2023. Despite challenges in fertilization rates, the program has successfully hatched two healthy turtles this year (2024). Enhanced breeding protocols, including optimized temperature and humidity control, have contributed to improved hatching and survival rates.

The ongoing success of the breeding program is vital for future reintroduction efforts, ensuring the long-term conservation of Beal's eyed turtles and addressing the urgent threats they face in their natural habitats.

Sticking Your Neck Out for Freshwater Turtles, 101: A Home Beyond the Shell

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With an industry focus on multi-taxa, naturalistic exhibits, aquatic turtles are popular in aquaria across the country. While many facilities benefit from the expertise of herpetologists, many more operate with an aquarist-only staff. Career aquarists have access to institutional knowledge and rigorous educational materials for fish and sea turtle husbandry but may have a limited knowledge of non-Chelonioidean turtle husbandry. To provide the best care and welfare for

aquatic turtles in collection, it is essential to understand the natural history, physiology, and common pathologies of the species in care. Issues with appropriate lighting, exhibit design, diet and supplementation, or preventative veterinary care can shorten lifespans and impact aquatic turtle welfare. In recent years, emergent pathogens and advances in reptile lighting research have led to shifts in best practices for management of these taxa. By expanding the list of known resources on aquatic turtle husbandry and exhibit design, husbandry staff can be empowered to provide the best care possible for the aquatic turtles in their care.

Sticking Your Neck Out for Freshwater Turtles, 102: Don't Bite My Finger!

Matthew Benedict, Kristin Coury, Jessica Nelson, & CJ Weaver
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Aquatic turtles display a wide variety of behaviors under managed care. The implications of these behaviors can be easily overlooked or misunderstood, especially in mixed-taxa habitats where interspecific interactions can confound the interpretation of individual behaviors. Commonly observed behaviors of Chelonian species and the possible reasons for these behaviors will be identified and classified. Mitigation of problematic behaviors regarding aggression, territoriality, and reproduction will be addressed as well as enrichment strategies designed to complement a multi-taxa habitat.

Sticking Your Neck Out for Freshwater Turtles, 103: Let's Take this Outside

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Holding spaces for freshwater turtles can be an invaluable resource that can serve a variety of functions to help maintain and improve welfare. Problems that develop in a population or exhibit can be not only corrected but illuminated by isolating a turtle and providing it with a better ability to self-regulate; observations made in backup can assist in understanding how to improve exhibits. Methods of allowing the animal to self-regulate while off exhibit will be discussed here, using cues learned from behavior as a guide for thoughtful design of backup enclosures and exhibit improvements.

Sponsor Presentation
Aquarium Builders (featuring Top Shelf Aqualics)

Honors and Awards Session
Brian Nelson for 25 Years of Aquaticinfo ("The List")

Session 4: Emergency Preparedness

Sponsor Presentations
Aquatic Equipment and Design, Inc
Piscine Energetics (PE)

The Building of a New Multipurpose Use Marinelife and Coral Facility in the Florida Keys

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Dynasty Marine has been a world leader in sustainable and ethical supply of Atlantic and Caribbean marinelife to aquariums around the world for more than 40 years. In that time our company has seen a lot of growth and a lot of change. In 2014, with much input and advice from our friends and colleagues in the public aquaria community we opened our hometown public aquarium, Florida Keys Aquarium Encounters.

Now, in 2025 we will embark on building a new 30,000sq/ft facility that will combine not only Aquarium Encounters and Dynasty Marine onto one 9-acre property, but it will also be a home for our partners at Reef Renewal USA as well as other partners within the AZA coral rescue and restoration community. At completion, we will have the only Category 5 hurricane purpose-built facility in Florida with coral holding. With its Central Florida Keys Location, in Marathon, it is ideally located to be a significant asset and working educational space for locals, visitors, and to the coral rescue and restoration community at large. This presentation will have renderings of the new facility and discuss potential to work together to create a restoration pathway and help rebuild the United States' only living barrier coral reef.

Aquarium Nutrition Contingency and Emergency Preparedness

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Contingency planning in aquarium nutrition is all about ensuring the animals continue to have sufficient food. Working with a diverse network of vendors is key, and working with vendors to ensure delivery with minimal interruptions is vital. Diversity of seafood offerings also extends beyond the freezer into the animals' diets. Diets should consist of a minimum of three different species, with five or more preferred. This diversity ensures any animals (even specialty feeders) can weather supply-chain challenges. As climate change continues to impact our oceans we must be prepared for changing product availability.

Food preparation must continue to operate throughout emergency situations. At Disney, we annually weather the Florida hurricane season, which continues to see increased storm strength and frequency from climate change. We must be prepared with enough product to carry us through several days of service interruptions, which requires coordinating with vendors to receive products leading up to and immediately following the storm and ensuring critical systems like freezers and

refrigerators are well maintained and have emergency backup power. Advance planning is invaluable in the face of weathering a storm.

The other common emergencies we face are animal rescues. Manatee and sea turtle strandings require keeping items to support critical care nutrition when needed. Assist-feeding recipes provide critical nutrition and often require specialty equipment and trained staff to accurately make this essential supportive nutrition. Increasing pressure on wild space from human development in Florida means these rescues will continue to be essential in supporting native wildlife.

Congratulations on Your AZA Accreditation: Here is a Category 4 Hurricane to Celebrate!

Carly Hulse
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The Bailey-Matthews National Shell Museum & Aquarium is a natural history museum solely dedicated to mollusks, located in Sanibel, a barrier island off the coast of Fort Myers, Florida. A Category 4 storm, Hurricane Ian made landfall on September 28, 2022, less than a month after the Museum received its initial AZA accreditation. Several portions of the only bridge that connects Sanibel to the mainland were washed away in the storm, resulting in loss of access to the island, bringing about yet another level of challenge to an already stressed Museum team. Hurricane Ian significantly damaged the Museum as almost six feet of water entered the building and a 30-foot hole was left in the roof, resulting in mass mortality of marine life in the aquarium. In the years since the storm, the Museum's recovery efforts have been focused on the restoration of the exhibits and aquarium, infrastructure, programming, as well as the strategies employed to safeguard its unique scientific collection of over 550,000 shells. Looking ahead, the Museum faces ongoing challenges, including adapting to a shifting coastal environment. The storm's powerful winds and significant surge led to severe erosion, loss of vegetation, and increased the island's vulnerability to subsequent hurricanes. In 2024 this was put to the test, as the team was faced with two hurricanes within nine days. By sharing lessons learned and fostering partnerships, the Bailey-Matthews National Shell Museum & Aquarium aspires to serve as a model for resilience and innovation within the aquarium and museum sectors.

We've Got What? Where? How? Accidental Copper Exposure to a Large Artificial Reef Housing Elasmobranchs at the Columbus Zoo and Aquarium

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Often in the zoo and aquarium field emergencies are well prepared for with strict planning, procedures, and equipment always ready. What happens when a situation arises that cannot be accounted for? At the Columbus Zoo and Aquarium, our team found ourselves in one such situation in April of 2024. During the process of life support improvements to our 85,000-gallon mixed species artificial reef habitat, contractors accidentally introduced a source of copper directly into the habitat despite careful planning between animal husbandry teams and project managers. The source of the contamination was not detected for several days until changes in behavior to the

habitat's population were noted, specifically, two adult zebra sharks (*Stegostoma tigrinum*). As most seasoned aquarists are aware copper is toxic to elasmobranchs and a quick response was necessary. What that response was, however, was not immediately known as copper toxicity in elasmobranchs is not a common occurrence. Clinical symptoms of cooper exposure as well as how an elasmobranch's physiology is impacted is not fully understood. During this crisis our husbandry and vet teams learned a great deal about the signs of copper exposure in elasmobranchs, how to neutralize copper in a large aquatic habitat and what recovery from copper toxicity looks like. These experiences will help drive future emergency planning for outside the box situations such as this.

Got Milk? When a Novel Bacterial Bloom Causes a Water Quality Collapse in a Flagship Exhibit

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The Glover's Reef exhibit is a 167,000-gallon system representative of the Glover's Reef ecosystem in Belize. In 2011, after an extensive renovation process, the New York Aquarium reopened Glover's Reef as the first exhibit visitors experience when entering the park. The large aquatic enclosure has since become an icon of the aquarium and the building that houses it (Conservation Hall).

In October 2021, Glover's Reef experienced a massive bacterial bloom caused by a novel bacterium, *Neptuniibacter sp*. Within a day, the exhibit turned milk-white and dissolved oxygen plummeted. Emergent management response included relocating fish, oxygen supplementation, and flushing the system. Despite the tireless efforts of numerous staff from multiple teams to stabilize the system, the bacterial bloom resulted in a significant mortality event and decommissioning of the system for ten months. The event was challenging for all teams involved, and evoked questions about why and how it happened.

This presentation will highlight the complex conditions, communications, actions, and lessons learned from the event. A brief exploration of the event's water quality data, life support system operations, animal husbandry practices, infrastructural challenges, and unresolved questions will be discussed. Followed by a review of the steps staff have taken to prevent another event by adopting new practices and technologies, increasing vigilance, strengthening communications and focusing on unified team goals.

Sponsor Presentations
Asahi/America
Tracks Software

Session 5: Back to Basics – Part 1

Sponsor Presentation
Fairway (pool scrubbers)

What Do You Know About the ChondroCensus?

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The ChondroCensus is much more than a collection of information for various parties to contribute and access data on chondrichthyans in human care. Much like the RAW Conference, the ChondroCensus 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 has its leadership team. As the ChondroCensus enters its 8th year, the co-leaders aim to engage with RAW attendees to highlight the opportunities available for individuals to grow their professional networks by assisting in the flow of information through this global network of chondrichthyan professionals. By facilitating communication and collaboration between public aquaria that care for chondrichthyans – and also with the research community – individuals can serve a pivotal role in achieving the goals of the AZA SAFE Shark & Ray program: to enable evidence-based support for conservation action, support science-based chondrichthyan conservation communication, and create opportunities for partners to provide direct, impactful, and collaborative support for the conservation of these taxa.

Old Habits Die Hard: Training Nurse Sharks at the National Aquarium

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The National Aquarium's 1.2 nurse sharks (*Ginglymostoma cirratum*) have resided in their 225,000-gallon mixed elasmobranch exhibit for 20-40 years each. As typical with nurse sharks, they exhibit a high food drive, particularly in comparison to their co-inhabitants, including two large jacks (Carangidae) and four other elasmobranch species. This, in combination with the exhibit's design, has made it challenging to control the nurse sharks' consumption, resulting in long-term over-conditioning. In 2023, the Blue Wonders and Behavioral Husbandry teams worked collaboratively to train the nurse sharks to voluntarily shift into an attached holding pool during feeds to limit competition with other species. This was a lofty goal given the deeply ingrained habits of the animals, unique exhibit infrastructure, historical associations with the holding pool which had previously been used primarily for medical exams, and the number of people needed for each training session. Nevertheless, after five months, all three nurse sharks began routinely shifting into the holding pool for feeds, resulting in improved diet management for all animals in the exhibit, increased ease of separation and handling for examinations, opportunities to respond to seasonal behavior changes, and a foundation for future enrichment and training goals.

Where We're From – Diverse Collections from Diverse Habitats

Lyle Squire[1]
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Knowing an animal's origin is essential for understanding its ideal husbandry and care. The quest to display a wide range of fascinating species in aquaria may require sourcing animals from around the world. Some of the world's best managed aquarium fisheries are located on the east coast of Queensland, Australia, in the Coral Sea and Great Barrier Reef, where biodiversity is high.

A common misperception is that fish from the Great Barrier Reef cohabitate and share a common home, but the reality this vast marine park is extraordinary with many unique spaces. There are 70 distinct bio-regions within the Great Barrier Reef Marine Park; 6 of these habitat types host many of the most desirable display species for public aquaria. These areas are distributed far and wide, often several hundred miles apart. Not only does the physical nature of the habitats vary dramatically, but so can the water parameters, flow, nutrient levels, food availability and ecosystem dynamics.

Understanding these huge variations in wild habitats, their water movement, water quality and species make up where our animals are collected can help explain some of the nuances to consider when developing our animal displays, establishing water parameters and designing LSS needed for populations to thrive in our care.

Breeding to Conserve: Reproductive Strategies of Three Portuguese Gorgonians

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Gorgonians are vital components of marine ecosystems, contributing structural complexity and serving as habitats for numerous species. However, wild populations of gorgonians are facing significant declines due to various threats, including habitat destruction, climate change, and unsustainable human activities.

This study investigates the reproductive biology of three key gorgonian species along the Portuguese coast: *Paramuricea clavata, Paramuricea grayi,* and *Eunicella verrucosa*. It focuses on analyzing gonadal development, spawning periods, gametogenesis, and the development of larvae and juveniles.

Among the species studied, *Paramuricea grayi* proved the most challenging to maintain in controlled environments, underscoring the need for further research into its specific ecological and physiological requirements to support effective ex situ conservation and restoration efforts.

Paramuricea clavata exhibits a distinctive reproductive strategy, with embryonic development occurring near the tissue of the parent colony, leading to the release of competent larvae. Conversely,

Eunicella verrucosa appears to release eggs and sperm in smaller quantities; however, its juveniles demonstrate a high survival rate following settlement.

The results reveal significant interspecific differences in reproductive timing and strategies, providing valuable insights into their ecological resilience and vulnerabilities. These findings are

critical for designing targeted conservation strategies to ensure the survival and recovery of these essential marine species and the ecosystems they support.

Sponsor Presentation
Animal Professional

Friday, April 25th
Session 6: Back to Basics – Part 2

Sponsor Presentation
121 Animal Handling Products

What's in a Name? Examining the Use of House Names in Public Aquariums

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The use of "house names" for animals in public zoos and aquariums is a practice that sparks varied and often strong opinions among animal care professionals. This presentation explores the implications, perceptions, and operational impacts of assigning house names to animals, contrasting them with the use of collection identification numbers.

Seeking to investigate how house names influence emotional connection, record-keeping, behavioral observations, and guest engagement, an anonymous survey was distributed to animal care professionals. Key questions examined whether house names are used internally or shared publicly, their prevalence across institutions, species-specific naming practices, and personal opinions regarding their usage.

Through a comparative analysis of survey responses, the presentation highlights the perspectives of both proponents and opponents of house names. Proponents argue that house names foster stronger bonds with animals, enhance behavioral monitoring, and encourage positive guest interactions. Opponents cite concerns about anthropomorphism, emotional strain on care takers, and operational inefficiency.

The session will feature live audience polls, direct quotes from survey respondents, and a discussion on the evolution of house name policies across institutions. By delving into the underlying reasons for differing viewpoints, this presentation aims to provide a balanced framework for evaluating the role of house names in animal care and public engagement, fostering informed discussions on implications of house names for animal welfare, professional practice, public relations, and institutional policy.

Back to Basics: A Case for Individually Identifying All Animals in a Collection

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In facilities with large diverse species groups, discerning individuals from one another can be difficult. Moreover, it can be easy to stagnate with broadcast feeding methods or struggle to

determine which animal has a new wound without catching it. However, being able to recognize individuals by slight markings and recurrent behavior allows for greatly improved husbandry.

Individual care allows aquarists to ensure every animal receives its full diet, note body condition, monitor training, and observe daily health and behavior changes. At St. Louis Aquarium, aquarists have successfully created individual identifications, without silver nitrate markings or physical tagging, for multiple elasmobranch and teleost species. These populations range from two to twenty-eight individuals; these identifications have been crafted over time with careful, dedicated observation with the use of target and basket training.

Aquarists worked through roadblocks such as identifying animals while they are splashing or swimming quickly, learning identifications from different lighting and viewpoints in an exhibit, and adapting with changing body marks and scarring. Without these individual identifications, many past health issues would not have been noticed as quickly by aquarists.

Individual identifications allow aquarists to distinguish whenever an individual is acting outside of its normal feeding or behavioral habits, as well as subtler injuries and their healing progress. Even in larger facilities, individually identifying all animals is a challenge to be undertaken when striving to provide the utmost care possible. In the future, St. Louis Aquarium aquarists will continue to create identifications for all individuals within their collections.

Level Up Your Record Keeping: How Using Your Data Well Proactively Lends to Creative Problem Solving

Amanda Vaughan
Disney's Animals, Science, and Environment, Amanda.M.Vaughan@Disney.com

Accurate record-keeping is a vital industry standard in today's aquaria. At Disney's The Seas with Nemo and Friends®, thousands of animals representing 50+ species are managed within a 5.7-million-gallon Main Environment. Due to the biomass and versatility of the habitat, individualized tracking of elasmobranchs and sea turtles is critical to maintain top-notch animal care. To achieve this precedent, the Seas husbandry team has built a customized system of user-friendly tools that produces data in a digestible fashion. Through regular use of these tools, husbandry decisions happen in a more efficient fashion while eliminating extraneous variables.

Animal professionals know that nutrition, behavior, health, social grouping, and environment are a few of the welfare categories that impact an animal's overall well-being. By incorporating personalized behavioral husbandry indicators into daily records, Disney's aquarists have built unique scoring systems across species that allow for correction of potential animal issues before obvious symptoms or behavioral aberrances have had opportunity to present. In instances when problems do arise, tailored records allow the team to more precisely tease out root causes rather than sort through a multitude of possibilities.

Used regularly, this style of record-keeping has produced invaluable data that has become critical to proactive management of higher maintenance species like Bowmouth Guitarfish, Spotted Eagle Rays, or the overall health of entire teleost populations. Raising the bar in animal welfare doesn't just take place on the frontlines while physically tending to our animals, but also behind the scenes by generating data that contributes to evidence-based animal management.

In Trace You Didn't Know: Trace Element Detection in Seawater by ICP-OES Spectrometry

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Trace elements have been an important aspect of marine animal care since testing techniques became possible in the mid-20th century. Yet most aquariums and fish keepers do not have the in-house equipment or means to get a refined picture of what is really in their water. In addition, most trace element sampling through ICP and other means, have not been refined in seawater – where the abundance of elements such as sodium, calcium, and sulfur may obfuscate lower-level trace elements without proper method modifications.

Two years ago, the Monterey Bay Aquarium Water Science Lab obtained an ICP-OES spectrometer. We have been using this instrument to refine the methods for testing sea water samples in aquarium settings – producing a baseline of what the trace metals of our local seawater look like and laying the groundwork for new projects to look at a spectrum of aquarium waters from aquariums around the country. Through cooperation with other institutions, our long-term goal is to produce a more refined reference guide for the range of trace elements within healthy marine exhibits.

June Sucker Training: Unique Species Challenges

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At the Loveland Living Planet Aquarium we maintain a habitat with two species of Utah native fish: the June sucker (*Chamistes liorus*) and Utah chub (*Gila atraria*). The June suckers face competitive exclusion by the Utah chub, which is a common problem in aquariums and a difficult problem to solve. June suckers are unique because they are sucker fish that feed in the mid water column, they are not bottom feeders. They also eat zooplankton which can present challenges when training. So, how do you train June suckers with zooplankton mid water and avoid competition?

Initially, I attempted to train the June suckers to feed from my hand, allowing me to close my hand to prevent the chubs from accessing the food. The zooplankton didn't stay in my hand well, so I modified the diet by introducing a gel containing zooplankton and ground fish. This formulation maintained the nutritional value of their natural diet while offering a more solid structure, which would help with training. The gel still lost consistency in the water column and resulted in the June suckers not fully coming up to the point we wanted so we switched to administering through a syringe. This achieved all our goals of providing a nutritious diet to get the June suckers to gain weight, a feeding strategy that encouraged their natural behavior of eating in the mid water column, training the June suckers to come up to a certain point, and reducing competition from the chubs.

Long-Term Maintenance of the World's Largest Nature Aquarium at Oceanário de Lisboa: Challenges Over 10 Years

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The Oceanário de Lisboa's Nature Aquarium, which is part of the "Forests Underwater" exhibition at the Oceanário de Lisboa was created by renowned aquascaping master Takashi Amano. Over the past decade, maintaining this iconic exhibit has posed numerous challenges, demanding a seamless integration of technical expertise, biological knowledge, and innovative solutions.

Key challenges in sustaining the exhibit included maintaining consistent water quality in such a vast system. This required regular monitoring of water parameters, and precise adjustments to promote the well-being of the existing plants and animals. The vitality of aquatic plants, essential to the aquarium's design, necessitated meticulous management of lighting, CO_2 levels, and nutrient dosing, alongside routine pruning to uphold the aesthetic vision set by Mr. Amano.

Algae control emerged as another significant challenge, requiring a delicate balance of light, nutrients, and biotic factors to prevent outbreaks.

This 10-year journey not only highlighted the intricate complexities of managing a large-scale Nature Aquarium but also emphasized its importance in fostering public awareness of the importance of aquatic ecosystems. The knowledge and experience gained offer a valuable benchmark for future projects, uniting artistry, technology, and conservation in a living masterpiece.

Hot Dogs, Coke, and Biofilter Cycling: Can Nitrite Dosing Really Help?

Larry Boles
Aquarium Science Program, Oregon Coast Community College, larry.boles@oregoncoast.edu

Cycling new aquariums to establish a healthy biological filter has historically been a mixture of art and science, especially in the hobbyist world. Professional aquarists usually rely on ammonia dosing using ammonia salts to start a community of nitrifying bacteria. Providing the food source for Ammonia oxidizing bacteria (AOB) should create an environment supporting the recruitment of naturally occurring bacteria or enhancing the growth of commercially prepared bacterial cultures added to the tank.

In this traditional approach to tank cycling, AOB's will consume ammonia and generate nitrite that then becomes food for nitrite oxidizing bacteria (NOB's). A fully cycled system will consume any free ammonia and nitrite quickly and prevent the compounds from reaching toxic levels in the environment. During the establishment period, it may take weeks before an adequate bacterial population is established in the biological filter and many aquarists report getting "stuck" at the point ammonia is being oxidized quickly but nitrite is persisting and accumulating rather than being converted to nitrate.

We studied the development of nitrifying bacteria in replicated, newly-established marine systems under varying conditions of ammonia and nitrite concentrations. We will report on the differences in time for establishing biological filters under varying conditions. Our hope is that

the results will help inform the practices of aquatic professionals and hobbyists when setting up new systems for aquatic animal care.

Sponsor Presentation
MDM Pumps

RAW Business and Reporting Meeting

Kansas City chosen for 2027 host
Progress in establishing RAW, Inc. as a 501c6 was presented.

Session 7: Innovations - Invertebrates

Sponsor Presentations
Manwarren Exhibits
Vitalis Aquatic Nutrition
Species 360

Innovations in Coral Recruit Rearing at The Florida Aquarium

Samantha Tanguay[1], Keri O'Neil[1], Rachel Morgan[1], Emily Williams[1], Matt Wade[1] and Gabrielle Vaillancourt[1]
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As coral reefs decline worldwide, there has been growing interest in developing more ex situ nurseries to support their restoration, especially along Florida's Coral Reef. The Florida Aquarium Coral Conservation and Research Center specializes in the rearing of ex situ coral recruits and overall production has increased significantly, leading to the expansion of our nursery. To enhance efficiency in our coral rearing procedures, we are continually refining our techniques to optimize coral survival, growth, and outplanting success. Introducing floating PVC racks in place of our stationary racks to the coral recruit settlement systems have optimized water flow and simplified set up during the larval settlement period. Effective management of pests such as hydroids and ctenophores has been achieved through the integration of specialized filters within the system eliminating their impact on coral recruits. Nutrient supplementation, such as amino acids and ammonium chloride, has further enhanced coral growth. To mitigate algal growth and minimize labor demands, we are testing anti-algal coated tiles and plugs, along with hydrogen peroxide dips and the use of various herbivorous species. Additionally, we have developed more secure outplanting structures and transport methods by transitioning to Coral Lok plugs which offer increased durability and streamline facility operations. These advancements support the various stages of coral life cycle management and contribute to the overall efficiency of our restoration techniques. Sharing and continuing to improve on coral recruitment rearing techniques

will support other ex situ nurseries and contribute to global advancement of coral restoration efforts.

If You Build It, They Will Come:
Establishing A Modern Living Reef Ecosystem in the Heart of a Historic Aquarium]

Noel Heinsohn
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Shedd Aquarium has transformed its iconic 90,000-gallon Caribbean Reef habitat, originally built in 1971, into two towering ecosystems in the historic rotunda: one freshwater and one marine. This presentation highlights the development and opening of a 28,000-gallon live coral reef system, showcasing the utilization of cutting-edge advances in reef-keeping technology. Key topics include the design process, from blending the use of fiberglass inserts with live rock, to employing cranes for precise aquascaping. The innovative use of LED lighting to achieve optimal spectrum penetration at depths of 12 feet, while advanced flow mechanics were adapted to ensure habitat health.

The presentation delves into the meticulous planning of the animal collection, including cultivating a diverse array of corals over three years to create a mature and vibrant display at launch. Details on system preparation, such as using artificial seawater, cycling, and parameter manipulation, will be shared alongside challenges like addressing unexpected metal contamination with enhanced filtration solutions. The final phase included the intensive planting of corals—requiring over 60 hours of dive work within two weeks—and the careful introduction of additional marine life.

Throughout the project, the team navigated the complexities of renovating a nearly century-old building, overcoming unexpected hurdles to deliver a state-of-the-art marine ecosystem. This case study offers valuable insights into the integration of modern technology and ecological stewardship in aquarium design and operation.

From the Classroom to the Field: Can High School Students Save the Nautilus?

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Aquariums, zoos, and other educational facilities play an integral role by connecting global, marine conservation issues and projects with local communities that might be thousands of miles away. Building empathy with a habitat, species, and person that you may never visit, see, or speak with in your lifetime is difficult, but this is also the key towards collaborating on the solutions to the current problems we face. But what happens when people, young people, from different sides of the planet, are actually able to come together, collaborate, and learn from each other? For the last 10 years, high school students in the Department of Marine Sciences at Central Campus have been utilizing an advanced laboratory and aquarium to improve their ocean literacy, while being far, far, far away from the ocean. Each year, about one third of the students participated in an optional Field Studies Expedition to a coastal area of the United States. In March/April 2025, 40 students will be traveling to… Fiji to collaborate with Save the Nautilus, the Fijian Ministry of

Fisheries, and University of South Pacific to conduct population surveys of nautiluses (*Nautilus vitiensis*) and their habitat. Additionally, the students will be networking with local researchers and professionals, discussing marine conservation issues with local high school students, and assisting with local coral conservation initiatives. These students will be connecting their classroom preparation to scientific fieldwork, while learning how local communities interpret the data to collectively come up with action-oriented solutions.

Collection and Transport of Delicate Deep-sea Jelly Species: When in Doubt, Ship the Babies out!

Evan Firl
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Over the past 5 years the Monterey Bay Aquarium has conducted blackwater dive collections and utilized a commercial shipping container to construct a wet lab at the National Energy Laboratory of Hawaii Authority in Kona, Hawaii to facilitate holding and shipment of pelagic deep-sea jelly species for exhibition and culture. The combination of blackwater diving and innovative shipping methods has resulted in the successful exhibition of delicate jelly species, including ctenophores and siphonophores, that were previously "un-shippable". The Kona, Hawaii based wet lab was designed for use as both a collection holding site as well as a spawning location for multiple delicate species whose larvae and eggs would be shipped 1-2 days post spawn in sealed jars. Shipment of eggs and larvae of jellies had far greater survivorship and allowed for greater quantities of a species to be shipped with the same spatial restrictions compared to their adult counterparts. Similarly, shipment of large quantities of larvae and eggs vs adults allowed for attrition during the shipment, resulting in hundreds of surviving specimens to be grown for exhibition. These progressive collection and shipping practices have led to great success in the exhibition of delicate deep-sea species previously thought to be unexhibitable in public aquaria and allowed for breakthroughs in aquarium culture of several deep-sea pelagic jelly species, including the red spot ctenophore, *Eurhamphaea vexilligera*, as well as crown jellies, *Nausithoe* spp. and *Atorella* spp.

Coral Spawning and Larval Development in Santa Marta, Colombia

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In late August of 2024 pioneering work was done by Odysea Aquarium and Remote Ecologist during the yearly *Acropora palmata* major spawn in Santa Marta Colombia. The collection site was a novel geographic location for this species of Acropora. Coral spawning events are a narrow and crucial window for understanding reproductive processes, ecological timing, and resilience in reef ecosystems.

During the observed spawning event, scuba divers collected gametes using specialized nets and containers to help ensure gamete viability. The collected gametes were fertilized in situ and placed in a controlled environment for further evaluation. Larval development was monitored

every 2-4 hours under varying conditions, focusing on metrics such as fertilization success, embryonic development, and settlement efficiency on multiple different substrates for comparison. Preliminary observations revealed unique patterns of gamete release over the course of two nights and included a significantly delayed initial release. This could offer insight into species specific reproductive patterns and strategies.

This work greatly emphasizes the importance of local research for reef restoration and conservation. A positively disproportionate impact can be achieved by aquarists and researchers working together in developing areas that are understudied. As collaboration and data increases with this species and others we are better equipped to fight larger issues coral reefs are facing. International collaboration and the exchange of information and husbandry practices is also critical in combating coral reef degradation. New methods and practices are being explored to improve post settlement survival rates and increase the number of corals eventually replanted on the reefs.

Sponsor Presentation
Dynasty Marine Associates, Inc.

Session 8: "Lightning Round" (Professional Development - Short Presentations)

AZA Learn & AZA Courses, Stu Clausen, Jennie Janssen
Kraken Curriculum, Barrett Christie
Drum and Croaker, Pete Mohan
MIAZS, Jennie Janssen

Saturday, April 26th
Session 9: Innovations - Medical

Sponsor Presentation
The Aquarium Vet

Large Scale Surgical Procedure in an Adult Ocellated Eagle Ray

Charlene M. Burns[1], Natalie Mylniczenko[1], Ryan De Voe[1], Dee Murphy[1]
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Performing surgery on a large elasmobranch can be challenging. Animal size, orientation of body during surgery, and supportive care can make execution of the procedure logistically difficult. Surgical intervention was elected on an 80 kg ray after multiple gastric perforations were identified during a recheck exam for a chronic facial ulcer. To be able to perform surgery on the large dorsally flattened animal, a collaborative effort was needed. This included constructing a surgical table that was strong enough to elevate, provide support, and position the animal in such a manner to access an ideal surgical site, as well as recirculate anesthetic water. The animal did well post-surgery and tolerated daily treatments which included injectable analgesics, fluid therapy

and intravenous nutritional support. Despite initial healing, one perforation site continued to have a small leak causing persistent coelomitis, and euthanasia was ultimately elected.

Development and Testing of Body Condition Scoring Tool for Tambaqui (*Colossoma macropomum*)

Hilary Colton
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Zoo and aquarium populations offer the unique opportunity to advance the knowledge of animals under our care and develop methods to evaluate their welfare state. The need for species-specific indicators is recognized in welfare science, and some monitoring methods used in laboratory research are impractical in zoo settings. Developing cost-effective and user-friendly welfare tracking tools would allow lifelong monitoring of individuals using a referenceable metric. Body condition assessment is particularly challenging for aquatic animals, given the challenges of capture and handling. Though subjective in evaluation, creating a referenceable condition assessment tool is considered helpful for team discussions and benchmarking through the individuals' lives.

Aquarium facilities in North America and Asia collaborated on creating a novel body condition scoring (BCS) chart for adult Tambaqui (*Colossoma macropomum*). To develop the tool, measurements of individuals, photographs from prescribed angles, and video clips were collected. A three-part survey was conducted among zoo and aquarium professionals, examining institutional practices and participant backgrounds. The developed tool was then applied to video clips of individual Tambaqui from multiple facilities.

Analysis of scores showed high interobserver reliability from participants and good intra-observer reliability in comparison scores of repeated samples. Feedback from participants was positive, with high agreement on its outlining of different fat deposit areas and simplicity in application. Aquarium institutions can enhance participation in collaborative projects to develop further species-specific tools for monitoring the welfare of individual fish.

Creating a Fish-Focused Welfare Assessment Form

Sydney Gould[1]
[1]New York Aquarium, sgould@wcs.org

The Wildlife Conservation Society created an Animal Welfare Assessment form to be used to assess all taxa housed at their five parks across NYC. After several years of working with the original model, a committee was convened to reassess the efficacy of the assessment and discuss how it can be improved. I was selected to be part of the committee that represented "fish," and was one of four representatives from the New York Aquarium. To better serve the diverse collection, it was determined that the assessment should be split into six forms, each one representing a different taxon: mammals, birds, reptiles, amphibians, fish, and invertebrates.

Over the course of several months, I helped adjust the original model to be a more useful tool in assessing the welfare of fish within an aquarium. This was accomplished by comparing the original model to other external fish welfare assessments, and then presenting the findings to the team that I work with at the NYA. I coalesced their opinions on shark and fish welfare into a

cohesive assessment, and after many drafts, the form was completed and then disseminated amongst the parks.

The new form has been in use for the past year and has been positively received. While there is still more work to be done to make it as useful as possible, it has led to an increased awareness of the factors that contribute to excellent fish welfare and how we can continue to strive for it.

Why You WANT Chemically Treated Fish: The use of Chemicals from Point of Capture to Display

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Catch phrases created by clever marketing campaigns or other influential sources are widely distributed at a faster pace than ever with the increasing availability of social media platforms. Some are based in fact, but some may be misleading. To the laymen "Chemical Free Fish" may seem like a good thing…

However, the use of chemicals is intrinsic to Best Practices for marine life care from the point of capture through initial acclimation and quarantine. The point of capture also includes the capture process itself, so why shouldn't the proper chemicals be used then as well?

The Florida Marine Life Fishery commonly uses 2% Quinaldine solution as an anesthetic to reduce stress and capture abrasion during the collection process. While quinaldine is sometimes used just prior to collection, the most common application is for slightly anesthetizing after the capture has already occurred. With the proper use, quinaldine collected marine life leads to a reduced need for antibiotics or other prophylactic treatments post capture.

A holistic approach to treatment plans for marine life should start at the point of capture. Not all chemicals are good and not all are bad and consideration should be given to combinations of multiple chemicals and how they might inhibit or exacerbate their efficacy. Understanding the proper chemicals to use increases survivability and health for marine organisms in human care from capture to the end of their natural life.

The chemicals used from point of capture are just as important as traceability from point of capture so they should be investigated and understood concurrently.

"Medical Care of Large Japanese Spider Crabs (*Macrocheira kaempferi*): A Tale in Three Parts"

Dalton Richardson[1], Kaylee Moody[2]
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Monterey Bay Aquarium's gallery *Into the Deep*/*En lo Profundo* showcases a variety of species and environments from the deep sea. Among these is a Whalefall exhibit, displaying Japanese Spider Crabs (*Macrocheira kaempferi*). Exhibition of Japanese Spider Crabs in public aquaria is relatively common around the world; however, few aquaria display Japanese Spider Crabs in their upper size ranges, weighing approximately 10-15kg with individual cheliped lengths of over 1.5m.

In the process of quarantining and displaying several individuals in this size class, Monterey Bay Aquarium has also worked to improve our medical care and management of our Japanese Spider Crabs. One individual arrived at MBA with deteriorated muscle control, requiring physical therapy. Later on, we used epoxy techniques from the Henry Doorly Zoo to treat blackspot shell disease for the same animal. We also found that he was in need of antibiotics while treating the blackspot; his size made weekly handling dangerous for both the animal and divers, so we created an injection protocol which utilized a custom pole syringe. This animal's motor functions are fully restored, his blackspot is covered, and his infection has been eradicated thanks to these interventions.

In this presentation, we will discuss this Spider Crab's journey through *Into the Deep*, examining each case individually and discussing how his size impacts husbandry practices of this iconic species.

Caring For Crustaceans with Creativity: An Innovative Approach to Shell Rot

[1] Brooke Hernandez
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A common problem faced by aquariums caring for crustaceans is mitigating the challenges of shell rot. Shell rot refers to the degenerative breakdown of the exoskeleton of crustaceans especially prevalent in human care where natural molting is less frequent. This condition compromises the health of the animal over time; however, the Aquarium of the Pacific has found a unique approach to addressing this issue.

The process begins with using aquarium safe, Smooth-on products to create a casting of the animals' exoskeleton. With that casting, we use a series of pourable molding products to create a replica of the animal's shell which is then painted and textured to match. Once we have our replica or "prosthetic", we then turn our attention to addressing the shell rot itself. Our vet staff places the animal under anesthesia and physically removes all areas of shell rot with a Dremel. Once removed, the areas are treated, and the prosthetic is added. This prosthetic protects the exposed, internal body of the animal and makes the animal displayable for our guests.

We have successfully done this procedure on a Japanese Spider Crab (Macrocheira kaempferi) in June of 2024 and a California King Crab (Paralithodes californiensis) in September of 2024. Both these animals were selected due to having aggressive cases of shell rot and neither were estimated to live longer than 2-3 months prior to treatment. Both animals remain alive and well and we hope this new, innovative approach can extend and improve the lives of crustaceans everywhere.

Got Snails? It'd Be a Whole Lot Cooler if You Did. Making the Case for Including Horse Conchs (*Triplofusus giganteus*) and Banded Tulips (*Cinctura hunteria)* in your Institution's Collection.

Rebecca A. Mensch, MS
Washington College, RebeccaMensch@gmail.com

Mollusks are the second largest group of animals in the world and inhabit nearly every ecosystem on earth. Despite this, their representation in zoos and aquariums is generally limited to a handful of, albeit amazing, cephalopods. Most aquarium guests do not know that seashells are animal body parts, or that snails cannot leave their shells, illustrating that there is an obvious knowledge gap to close. The Horse Conch (*Triplofusus giganteus*) and Banded Tulip (*Cinctura hunteria)* are two species of carnivorous gastropod in the Family Fasciolariidae. Both are found in shallow, coastal waters from North Carolina to Yucatan, Mexico, and Brazil, respectively. The Horse Conch is the largest shelled gastropod in America, the second largest in the world, with adults frequently attaining sizes of 12" or more. It hunts other snails and has a bright orange body. The Banded Tulip can grow to 3" in size, has a beautiful shell and soft body, and will successfully reproduce under human care year-round, rather than seasonally. The hatchlings are miniature versions of the adults, and astound aquarium guests of all ages. Both species will eat frozen food, are tolerant of variable water quality, and do well in supervised touch pools. Given this information, I argue that more facilities should include these two species in their collection to broaden their educational and conservation messaging beyond the typical charismatic megafauna.

Getting Into it: The What and How of Submitting Data for the AZA SAFE Shark and Ray Blood Project

Jill E. Arnold[1] and Alexa Delaune[2]
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Blood hematology and chemistry analysis is a critical tool used in elasmobranch health management. To date, blood reference intervals, the statistical range of expected values set through testing that identify lower and upper limits of a population for a specific test, have not been adequately defined. The AZA SAFE Elasmobranch Blood Project team is currently working on blood reference intervals for four species of small elasmobranchs frequently housed in aquarium touch pool exhibits. Whitespotted bamboo sharks (Chiloscyllium plagiosum) are well represented with over 100 submissions, but data and/or samples are needed for brownbanded bamboo sharks (Chiloscyllium punctatum), Atlantic stingrays (Dasyatis sabina) and yellow stingrays (Urobatis jamaicensis). Developing reference intervals for multiple elasmobranch species is the goal of the Blood Project. Facilities are encouraged to submit data from their collections and information on how to submit data is on the AZA SAFE website.

The project welcomes retrospective data in multiple formats, such as Excel spreadsheets, downloaded data from ZIMS, TRACKS or similar software. In addition, AZA is committed to supporting this effort by providing funds for prospective blood samples to be analyzed by ZooQuatic Laboratory, Baltimore, MD. Success of the project and the advancement of elasmobranch science in this area depends on receiving data from facilities around the world.

Session 10: Innovations - Reproduction

Sponsor Presentation
U. S. Mysids

Sand Tiger Shark Carcharias taurus Mating Season in the Northwest Atlantic Inferred from Wound Healing Dynamics

Kelsey Remmes[1], Kate Poelzl[2], Joshua Riter[3], Brenda Young[4], Carol Price[5], and Tim Handsel[6], and Laura E. Edsberg[7], and Jennifer Wyffels[8]
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All sharks and rays reproduce using internal fertilization. This necessitates males and females to be coupled tightly during copulation, and as a result, bite wounds associated with mating occur. The appearance of these bite wounds can be used to gauge the timeframe of mating activity without direct observation of copulation. A wound staging system was developed for the sand tiger shark *Carcharias taurus* through longitudinal observations of an aquarium-housed female that sustained a full-thickness mating wound, an injury that extends through the epidermis, dermis and hypodermis, exposing underlying muscle. Four wound stages were established: 1) full-thickness, 2) healing, 3) closure, and 4) scar revision. The staging system was used to characterize the incidence, severity, and etiology of wounds for in situ sharks aggregating at North Carolina shipwreck sites from digital images contributed to the Spot A Shark USA database. There was a significant association between wound stage and its location or zone on the body as well as season of the year for males and females. Mating wounds on females corroborate a late spring and early summer mating season. The presence of stage 1 and 2 mating wounds on sand tiger sharks in North Carolina suggests the area is used for mating while females with stage 3 and 4 mating wounds provides evidence that the area also serves as gestation habitat for this species. This research highlights minimally invasive methodology that leverages citizen science divers to further characterize the reproductive life history of sand tiger sharks.

Back From the Brink:
Saving Sawfish, Lifesaving Intervention on 4 Smalltooth Sawfish (*Pristis pectinata*)

Ethan Albury[1], Keisha Russell[2], and Dr. Amanda Pinder[3]
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Atlantis is proud to record the first births of the critically endangered Smalltooth Sawfish (*Pristis pectinata*) under managed care. Since 2012 all the animals have been growing steadily and

eating very well, with the females reaching roughly 13 feet and the males 11 feet. In January 2024 the 4 sub-adult sawfish spontaneously went off feeding. The females were the first to stop eating and the appetite of the males became drastically reduced. After consultation with other industry professionals, it was concluded that the animals could go several weeks without eating, with little effect to their health. However, after a period of 2.5 months and offering over 10 varieties of food items, the animals were still not interested in feeding. An intervention was needed! A daunting task lay ahead of the Husbandry & Vet teams with the animals experiencing very little human contact in over 8 years. Coincidentally, this health decline paralleled the mass mortality events of the species in Florida. What followed were numerous ultrasounds, blood draws, injections, hand feedings, tube feedings, research and frequent contact with the network of marine professionals. These interventions allowed us to successfully bring all 4 of these critically endangered animals back from the brink.

Tracking Gravidity in Cownose Rays

Elizabeth Bushey[1], Becka Plautz[2]
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Living Exhibits, Inc., houses a collection of over 200 elasmobranchs, including 56 mature female cownose rays *(Rhinoptera bonasus),* each with a unique personality and an individual tolerance level to routine handling for health checks. For some gravid females with low tolerances for handling, frequent unnecessary checkups on developing pups in-utero can be detrimental to full-term pup gestation and result in non-viable or premature pups with long-term health issues. This presentation delves into a combination of techniques for tracking overall reproductive health and gravidity in female cownose rays to avoid invasive overhandling during critical stages of pup gestation. Over the course of 3 years, Living Exhibits staff have optimized our "hands-off" gravidity tracking process, resulting in proactive veterinary care, informed interventions, and increased success in viable pups as a result.

Sponsor Presentation
Sander (protein skimmers and ozone generators)

Session 11: Innovations – Welfare, Transport, and Exhibit

Sponsor Presentation
Gulf Specimen Marine Laboratories

MORPHing: Adapting and Repurposing Existing Facility Space for Additional Exhibits

Nicholas Quaday[1]
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Adding additional habitats to one's facility is often an easy way to boost attendance. However, space is often a limiting resource and adding footprint through expansion projects is costly. Repurposing an existing footprint can be a cost-effective means to improve the overall

guest experience. Modifying preexisting areas presents many challenges, including more than likely a lack of floor drains! In 2022, The Florida Aquarium began transforming its Mosaic Center, a 3700 square foot multi-purpose space, into MORPH'D, a Changing Exhibits Hall highlighting the adaptations of a wide range of animals. This presentation will address some of the challenges encountered during The Florida Aquarium's development and construction of its new MORPH'D gallery and highlight the solutions that were utilized.

Paddlin' Across America: Studying Long Distance Transport Methods on *Polyodon spathula*

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American paddlefish (*Polyodon spathula)* are known ram ventilators which must remain in constant movement to properly respirate. Additionally, the rostrum of a paddlefish is utilized to maneuver within their environment and can be damaged by physical contact. With a lack of published information regarding best methods for long-distance transport of juvenile to adult sized paddlefish, a mock transport study was performed to test a proposed transport protocol for a cross-country inter-facility relocation. Multiple trials were conducted over a period of three months in Spring 2024, to evaluate variations of transport procedure including time spent in holding, water quality and oxygen supplementation parameters. It was found that the paddlefish could sustain themselves for at least 24 hours under primary transport conditions based upon body condition scores, animal behavior, blood analysis, while remaining within acceptable water quality parameters. Following animal health discussions and risk analysis by animal care staff, trials were halted due to stress responses displayed by the general paddlefish population. These discussions were an important part of decisions made during this study. Conclusions drawn from this study were incorporated into the successful relocation of 0.0.3 American Paddlefish from Scottsdale, Arizona to Springfield, Missouri in Summer of 2024. By further researching other transportation factors and examining the effects on additional physiological characteristics, this type of transport can be utilized to promote safe long-distance movement of the American Paddlefish.

Do You Hear What I Hear? Improving Animal Welfare by Monitoring Noise Levels at an Aquarium

Leah Maurer, Wendi Fellner, & Joseph Soltis
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The effects of anthropogenic noise can have significant impacts on animal behavior and physiology. The impacts of noise can be amplified when animals lack the choice or ability to avoid noise and vibrations especially within aquarium settings. Monitoring sound levels inside an aquarium is important to ensure animal welfare, however, this can be overlooked given the complexity of acoustics in water. What is heard in the air is not always the same as what transmits into the water. Sound can travel unpredictably through building structures, and different species are impacted differently by specific frequencies and amplitude levels. At Disney's The Seas with

Nemo and Friends, we have created a noise monitoring program which examines anthropogenic sounds created within and outside of our animal environments while simultaneously monitoring behavioral animal welfare indicators. When novel sounds of concern are introduced into the environment, underwater and/or in-air microphones are employed to assess the frequency and intensity of the sound. These sounds are then evaluated in the context of the animals' hearing characteristics as well as the animals' behavioral responses. When necessary, noise can be mitigated by modifying noise sources, finding alternatives, manipulating the environment to provide acoustic barriers or prohibiting the use of items creating excessive noise. Conversations with our partners within and outside of our facility allowed us to implement mitigation strategies to maintain the best sensory environment for our animals.

Sharks on a Plane: The Story Behind Live Aquatic Animal Transport on Commercial Aircraft

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A single incident involving live aquatic animal transport could result in the rejection of all future movement of containers on aircraft. Safe, effective transport equipment and methodologies are essential not only to the welfare of the animals involved, but also to the aquarium industry's ability to move animals by air.

The containers and packaging used must be airline approved and satisfy the International Air Transport Association's (IATA) Live Animal Regulations (LAR). To comply with these regulations, the containers used, must undergo rigorous testing and also satisfy Civil Aviation Safety Authorities. These regulatory authorities are responsible for passenger and aircraft safety. The mechanics and detail ensuring all cargo does not create or add risk to any flight, is seldom considered by an aquarium getting ready to receive a big shipment from thousands of kilometres and days away.

Understanding the regulations and methodologies, and how they've been developed, helps us appreciate the diligence we must exercise to assure safe and successful shipments and are vital to the future of air transport of aquatic wildlife.

Long-term Tagging Program to inform Fish Life Expectancy in a Mixed Environment

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Life expectancy of many group-housed fish species in large, mixed exhibits is largely unknown. This knowledge gap has impacts on both welfare monitoring and collection management. Monitoring life expectancy can indicate population-wide welfare issues and allows for many collection planning benefits. This study analyzed coded wire tag (CWT) data to track how long individual fish were living at a single facility. Fish were tagged from 2009 and data from recovered CWTs were logged and tracked following recovery from over 70 species. Analyses were completed both between and within species and, when possible, between enclosures. Results show

that there can be a wide range of life expectancies within and between species. To put these results into further context, data is being collected to investigate differences in fish acquisition, ageing fish brood stocks, and significant events in aquarium life systems. The goal of this project and these study results is to show that CWTs are a viable method for tracking individual fish in a large collection and that informative life expectancy in collection conclusions can be made from the data.

Big Aussie Fishes on Holiday: Handling Techniques and Equipment for Oceanarium Animal Capture and Interstate Transport

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Inherent with any aquatic animal transport are a range of considerations and risks; moving mature, very large oceanarium animals adds to the complexities. In January of 2023, the 25-year-old, 2.2 million litre oceanarium at SEA LIFE Melbourne Aquarium in Victoria, Australia, was scheduled for a major renovation drain-down. In preparation for this event, the resident population, which included a 2.0 metre Speartooth shark *(Glyphis glyphis)*, 3.8 metre Largetooth Sawfish *(Pristis pristis),* and 250+ kilo Smooth stingrays *(Dasyatis brevicaudata),* needed to be temporarily relocated to sister SEA LIFE Aquaria, 1,000-1,800 km away.

The surface of the oceanarium is in the sub-basement level of the facility, with narrow corridors and a 2.7 by 3 metre opening leading to the street/ground level. Because of these constraints, custom capture and transport equipment was engineered and manufactured to ensure the safe and successful handling of all animals. Three years of planning lead to the successful removal and transport of the ocean habitat residents.

MIAZS Spotlight (Minorities in Zoo and Aquarium Science)

https://www.miazs.org/

Thank you to sponsors for our 4-year anniversary celebration this week. $6,200 raised for the organization.

Session 12: Innovations – Training and Enrichment

Underwater Training of a Longcomb Sawfish *Pristis zijsron*

Megan Sanborn
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This presentation explores the innovative underwater training of a longcomb sawfish, *Pristis zijsron*, house name Ginsu. While housed during its quarantine period at Georgia Aquarium's offsite Animal Care Facility, Ginsu developed a medical issue that led to a partial tail amputation. After her amputation, complications developed with her stitches that required intervention. To avoid a potentially stressful manual restraint, a plan was created to desensitize

Ginsu to contact by staff while on SCUBA. Once this was successful, we developed a training plan to minimize stress during exam handlings. The plan would serve as a foundation for less invasive care in the Ocean Voyager habitat where she would reside long term. Utilizing multiple desensitization techniques, we reached a point where Ginsu allowed the team to administer injections and draw blood samples underwater while unrestrained. After transport onsite, the Ocean Voyager team continued this training, and she is voluntarily allowing divers to approach and touch her. In the long term this training could allow aquarist staff to easily access Ginsu for any reason with the goal of improving her overall lifelong welfare.

Nurse Shark Tactile Reinforcement:
Brushing up on Distractions from Unwanted Interactions

Grace N. Carpenter and Avery Obregon
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The nurse sharks at The Aquarium at Moody Gardens were interrupting other feeds occurring in the Caribbean exhibit, a 750,000-gallon multi-species habitat, which was causing safety concerns for keepers, divers, and tankmates. Tactile reinforcement in the form of floor push brooms was introduced during training sessions, and additional training sessions were conducted in conjunction with the other feeds. This created a positive distraction for the nurse sharks and significantly reduced the frequency of interruptions during those other feeds.

Tactile reinforcement was introduced to routine training sessions with diet reinforcement in September 2024 and was used as the sole reinforcement during additional training sessions beginning in October 2024. Data of frequency of nurse shark interruptions during other feeds and dives began in December 2024. Prior to the introduction of tactile reinforcement, nurse sharks would interrupt other feeds occurring in the exhibit upwards of a dozen times in one session. Current data show that interruptions occur as few as zero to two times when tactile reinforcement is offered in conjunction with the same feed.

Moving forward, the team intends to continue implementing the tactile reinforcement sessions, introduce novel tactile instruments, and introduce tactile enrichment in addition to the training sessions to keep interest and distraction of the nurse sharks up.

Beyond the Charismatic: Inspiring Enrichment Practices in Aquatic Husbandry

Kortney Jaworski, Carter Thompson, Britt Sorensen
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Enrichment is now understood to be an integral component of proper animal husbandry, contributing significantly to overall animal wellbeing. Yet for many aquatic and invertebrate species, it can still be treated as optional or “in-addition to” regular husbandry practices. At the Virginia Living Museum, we have been working to expand our enrichment program to include all animals in our collection, including aquatics and invertebrates. While enrichment for charismatic taxa such as birds, mammals, and even large reptiles is well-documented, its application to animals like fish, amphibians, and aquatic invertebrates (e.g., echinoderms and crustaceans) remains relatively unexplored. A portion of this presentation will be geared toward showing some of the diversity of enrichment that we have recently provided to our aquatic animals. Preliminary

observations of these enrichment efforts indicate improved welfare in the form of increased movement and exploratory behavior, possibly indicating increased mental stimulation. We also hope to share results of a behavior-monitoring project where we intend to quantify movement patterns of a subset of our aquatic invertebrates (urchins, spider crabs, hermit crabs, and horseshoe crabs). Using video footage and simple data analysis techniques, we hope to provide some quantitative evidence that providing enrichment to these animals leads to more active animals and increased exploratory behaviors when stimulated by providing foraging and environmental enrichment. It is our hope that our findings will inspire others to incorporate similar practices into their husbandry programs and contribute their ideas and observations to this growing area of animal welfare.

PRESENTATION AND POSTER ABSTRACTS FROM JELLY CAMP 2025
October 6-9, Norwalk CT and Mystic CT, USA

Hosted by the Maritime Aquarium at Norwalk, and the Mystic Aquarium

Rachel Stein, The Maritime Aquarium, rstein@maritimeaquarium.org
David Cochran, Mystic Aquarium, dcochran@mysticaquarium.org

In October 2025, the Jelly Camp workshop was hosted for the second time by the Maritime Aquarium and the Mystic aquarium. The previous workshop was held at the National Aquarium in October of 2023, with the goal of connecting jelly experts from aquariums, zoos, and research institutions to advance collective knowledge of jellyfish through collaborations between public aquaria and academia. A total of 52 attendees participated from across the United States, representing 38 institutions, including 29 zoos/aquariums and 9 research facilities.

Figure 1: Jelly Camp 2025 Logo, designed by the jellies teams at the Maritime and Mystic Aquariums, illustrated by Ella Sharp, and formatted by Ben Jura

The 2025 workshop was split between the Maritime Aquarium in Norwalk CT at the Mystic Aquarium in Mystic CT. Activities began on the evening of Monday October 6th with an icebreaker at the Maritime Aquarium. The entire aquarium was open to participants, including behind the scenes tours. On Tuesday October 7th, lectures and workshops were held at the Maritime Aquarium, focusing on husbandry practices, photography techniques, and artificial insemination and gonad extraction. On Wednesday October 8th attendees traveled north to the Mystic Aquarium. Along the way, participants had the opportunity to attend a guided tour of the Dunn/Musser labs and Seawater Facility at Yale led by Dr. Casey Dunn, Dr. Jacob Musser, and Dr. Mary Beth Decker. This was followed by a guided tour of the Yale Peabody Museum lead by David Heiser. In the evening a poster reception was held at the Mystic Aquarium, where back of house jelly areas were open for viewing. The workshop concluded on Thursday October 9th, with a full day of lectures on research topics, a discussion panel on jelly welfare, a "DIY Show and Tell" lightning round, and hands-on workshops on shipping jellies and building flow-through tanks.

Jelly Camp 2025 provided aquarists and researchers of all backgrounds and skill levels the opportunity to network, discuss collaborations, and learn from each other and from the presentations and workshops. Most of the lectures and workshops were recorded by Animal Professional and will be available for later viewing on their website, animalprofessional.com. Throughout the workshop, participants were also invited to join the Jelly Camp Slack channel, which was created during Jelly Camp 2023. The channel remains an active professional community where jelly-related information is shared, surplus animal shipments are coordinated, and collaborations are developed.

Throughout the week, the workshop hosts encouraged participants to consider hosting the next Jelly Camp at their facility. Several institutions expressed interest, and attendees voiced strong enthusiasm for continuing Jelly Camp in the future. Ideally the next host facility would have partnerships with local universities or research institutions and would schedule the workshop during a time of the year that allows participation from academic professionals. Regardless of where or when the next Jelly Camp is held, the 2025 workshop clearly demonstrated the ongoing need for jelly-focused professional development for aquarists, and the strong desire among researchers to collaborate with public aquariums. The event reinforced the value of creating opportunities for these professionals to connect, share, and learn together.

Acknowledgements

Jelly Camp 2025 would like to acknowledge the many organizers and presenters that made the event possible. Special thanks to our co-host David Cochran, the host committee including Jennie Janssen, Rachel Thayer, and Lauren Mellenthin, and the Yale tour group, including Dr. Mary Beth Decker, Dr. Casey Dunn, Dr. Jacob Musser, and avid Heiser. Many thanks to our presenters, workshop organizers, and panel speakers, including Abrianna Lance, Michele Gibbons, Michael Howard, Lindsey Levine, Emelia Yosy, Travis Brandwood, Nicole Corbett, Paul Bologna, Chelsea Bremmer, Daniel McKenna, Katie St. Clair, Robert Donnovan, Jordan Reed, Julianna Trapp, Claire Bolster, and Mallory Pierce. Thanks to Raquel Gardner of AnimalProfessional.com, and to the teams at both the Maritime Aquariuim and Mystic Aquarium for hosting the evening events and supporting the workshop.

Jelly Camp 2025 would not have been possible without the support of the host facilities, the Maritime Aquarium and the Mystic Aquarium, and the financial support of our numerous sponsors: Immortal sponsors – Envision Acrylics, SSA, and TJP Engineering; Medusa sponsors – Aquatic Equipment and Design, Gulf Specimens, Tenji, Waterdog, Asahi America; Ephyra sponsors – Abyzz, Brine Shrimp Direct, Exotic Aquaculture, Fritz, Marine Enterprise Salt, Reed Mariculture, Hayward, and U.S. Mysids; Polyp sponsors – Consistent Sea Inc., Dynasty Marine, Flying Sharks, Tracks Data Solutions, and Zooquatic Laboratories.

Parasitic Amphipods in Aurelia sp. - Safe eradication in open systems

Abrianna Lance
Alaska Sealife Center, Seward, AK

Parasitic amphipods (Hypheriidae) are common parasitic crustaceans often found in wild-collected moon jellyfish (Aurelia sp.). With the development of veterinary knowledge in jellyfish, most are able to eradicate these parasites using medication baths (i.e., Interceptor, Dimilin) while quarantining in closed, recirculating systems. At the Alaska SeaLife Center, new seawater flows

constantly through each tank in the building before being dumped back into the bay, creating constraints on medications. Medical baths only last a couple hours at most, and medications need to be absorbed with charcoal before being dumped, making current medications for parasitic amphipods not feasible. Removal of amphipods in open systems is a process that relies on safe manual removal of parasites, proper quarantine measures, and use of filtration to prevent reinfestation. Combining all of these will lead to a healthy jelly cohort for your open system.

Go With the Flow; Tips and Tricks for Basic Care and Culture of Jellies

Michele Gibbons
The Maritime Aquarium at Norwalk, Norwalk CT

Since the 1960's, jellyfish (Scyphozoa, Hydrozoa, and Cubazoa) have been captivating the public audience with their beauty and subtle sophistication. Thereafter, aquarists innovated new husbandry and culturing techniques for a wide range of jellyfish species and even species within the phylum Ctenophora. Cnidarians have also been targeted as novel model organisms, due to their ancient body plans, simplistic design, and rapid generation time through sexual and asexual reproduction. Their husbandry is quite different from many other marine animals, which can pose many challenges when keeping them in aquaria. This presentation will go over the how-to of culturing and caring for jellies; starting from species selection, system design, equipment, and short term/long term goals to set for success. This talk is tailored towards individuals who are interested in entry level jellyfish care and basic culturing techniques.

Stocking a mesopelagic exhibit: a review of the sustained efforts at the Monterey Bay Aquarium

Michael Howard
Monterey Bay Aquarium, Monterey CA

Monterey Bay Aquarium's newest exhibition, Into the Deep, open since April 2022, represents an ambitious venture to highlight delicate creatures, observed by few people, from the largest habitat on earth: the mesopelagic zone. When R&D began in 2017, it became clear that new challenges would emerge. With enclosures designed and water chemistry challenges addressed, the identification and development of reliable collection methods have become vital. Blackwater diving and ROV collection dives have greatly influenced the species list, while refinement of collection techniques has increased options and animal longevity. Looking into the future, the team plans to improve culture techniques of deep-sea jellies and strives to identify new candidates for exhibition.

Jellies as a Self-Sustaining Display

Lindsey Levine and Emelia Yost
The Maritime Aquarium, Norwalk CT

In a public aquarium setting, it is essential to maintain continuous operation of exhibits to support guest engagement and institutional sustainability. Jellyfish are among the most captivating

and popular marine invertebrates on display; however, their unique biological characteristics—including short life spans, delicate physiology, and specific husbandry requirements—make them challenging to maintain in captivity. These challenges often result in temporary exhibit closures while awaiting new specimens. To address this issue, in-house culturing of jellyfish can provide a sustainable and reliable supply of individuals for display. At The Maritime Aquarium, we have successfully cultured a variety of jellyfish species to support our exhibits year-round. This presentation will detail the culturing methods and husbandry practices that have proven successful some of our facility's species.

Tips and Tricks for photographing jellyfish and their life stages

Travis Brandwood
The Jellyfish Compendium Project

Jellyfish are some of the most popular exhibits in public aquariums, largely due to their bold colors and mesmerizing aesthetics. Quality photography can be critical for scientific work, outreach and education but jellies can be uniquely challenging subjects. Additionally, their various life stages are often poorly documented, if at all. In this workshop we will cover some of the basics of photography with jellyfish as the subject including photographing adult jellyfish, their life stages and photographing through microscopes and other tools

Gonad Extraction Workshop

Rachel Thayer
Tennessee Aquarium, Chattanooga, TN

The gonad sampling and in vitro fertilization techniques workshop reviews different methods of obtaining polyps of jellyfish species. The workshop reviews the in vitro fertilization process starting from sampling jellyfish gonads and identifying sexes through the fertilization process and ending with settling planulae. We also review things to consider when approaching IVF and common issues you may encounter.

Uncovering Potential Cryptic *Cyanea* Species in Long Island Sound

Lauren Mellenthin
Massachusetts Institute of Technology, Cambridge MA

The jellyfish genus *Cyanea* is known for its morphological variability, which can complicate species identification. In this presentation, I will explore evidence for potential cryptic *Cyanea* species inhabiting Long Island Sound. Drawing on photographic records, morphological observations, and locality and seasonal patterns, I will highlight key traits and trends that point toward hidden diversity within this group. I will also share preliminary genetic data that support, or challenge, these morphological distinctions. This work provides an important foundation for understanding regional biodiversity and the ecological dynamics of jellyfish populations in coastal systems.

Stung by the Moon: Investigating the Emergence of a Potentially Unique *Aurelia* sp. Along Coastal Nantucket Sound

Nicole Corbett
Popponesset Water Stewardship Alliance, Abington, MA

Since 2007, Popponesset Beach located in Mashpee, MA has had an annual influx of an Aurelia sp. phenotypically similar to the common moon jelly Aurelia aurita but possessing the ability to deliver impactful stings when in contact with humans. Generally found in Nantucket Sound, the Aurelia sp. in question has been found to range in size from approximately 5 cm to as large as 38 cm during the later part of their season. Specimens of all sizes have been found to deliver a sting, which can be described as a sharp, burning "shock" followed by lingering redness and irritation comparable to that of a *Chrysaora chesapeakei* sting. In addition to being stung through direct tentacle contact, researchers and beachgoers have also reported being stung by the Aurelia sp. in question by being in the vicinity of the jellyfish. During the late 2000's and early 2010's, Aurelia sp. was prevalent along the Popponesset coastline during the first two months of August each summer with population sizes seemingly varying based on beachgoer and lifeguard accounts. Since the late 2010's, Aurelia have been found along the Popponesset coastline from mid-July to as late as the end of October. Combined with seemingly increasing population sizes of a local Chrysaora sp., jellyfish encounters have been problematic for swimmers along the Nantucket Sound coastline. In 2023, the Popponesset Water Stewardship Alliance (PWSA), a Mashpee-based environmental nonprofit organization, collected tissue samples from 6 Aurelia sp. along the Popponesset coastline, which were DNA barcoded at Northeastern University's Ocean Genome Legacy Center. All sequences had an approximately 89% identity to Aurelia sequences, but no species match could be determined. Since 2024, the PWSA in collaboration with the University of California and 17 organizations in the National Estuarine Research Reserve Network, are collecting tissue samples from Aurelia along the East Coast from Maine to Texas in an attempt to determine if the "Popponesset Aurelia" is an endemic species or one which may have been introduced to the area and not previously genetically barcoded.

Linking Jellyfish Science and Husbandry: Opportunities for Collaborative Work

Paul Bologna
Montclair State University, Montclair, NJ

Over the last 50 years, understanding jellyfish populations and impacts on the global ocean have increased. At the same time, efforts to create and display the beauty and subtlety of these creatures has grown within public aquariums. In the early 1990's, the Monterey Bay Aquarium opened an exhibit specifically crafted to capture the beauty and captivate the public, which has expanded to a global appreciation of these unassuming organisms. While jellyfish are relatively 'simple' animals, they have led to major scientific breakthroughs. On a molecular-scale, in 1962 Osamu Shimomura identified a glowing green protein (GFP) in *Aequorea victoria*, which would ultimately be purified, sequenced, and cloned. This discovery and subsequent research by thousands of scientists has been at the forefront of advances in molecular biology and medicine. More recently, the hydrozoan *Clytia hemisphaerica* has become an emerging model species to replace Zebra fish for scientists studying cancer, gene regulation, developmental biology,

neurobiology and more. On a macro-scale, jellyfish are major predators in the ocean and can cause fisheries declines and community shifts. Blooms can also destroy aquaculture farms, as well as clog intake pipes to power generating stations causing disruptions in critical infrastructure. Despite their importance, little is known about the polyp life stage for most species. This represents a unique opportunity where science and husbandry can work together to better understand and culture these beautiful creatures, while advancing scientific knowledge.

DIY Show and Tell

Chelsea Bremer[1], Katie St. Clair[2], Robert Donovan, Michele Gibbons[3], Daniel McKenna[4], and Jordan Reed[5]
[1]Wonders of Wildlife Museum and Aquarium, Springfierld, MO
[2]Texas A&M University at Galveston, Galveston TX
[3]The Maritime Aquarium at Norwalk, Norwalk CT
[4]New York Aquarium – Wildlife Conservation Society, Brooklyn, NY
[5]Georgia Aquarium, Atlanta, GA

Jellies care requires highly specialized equipment, and aquarists will often need to invent new tools, tanks or techniques to meet their unique needs. In this lightning-round session, aquarists from different facilities will showcase creative solutions and share the methods that have worked for them.

Shipping Jellies

Julianna Trapp
Moody Gardens, Galveston, TX

Packaging and shipping jellies requires patience and creative thinking (and a whole lot of positive manifestation!). During this workshop, we will be demonstrating the most efficient techniques for packaging jellies to ensure their safe arrival. We will also be discussing common species-specific obstacles to keep in mind during jelly shipment planning

Flowthru Building Workshop

Claire Bolster[1], Lindsey Levine[2], and Mallory Pierce[1].
[1]Mystic Aquarium, Mystic CT
[2]The Maritime Aquarium at Norwalk, Norwalk CT

This workshop will go through the basics of flow through systems used for jelly grow out habitats. These systems can be hand built, and utilize what you have around you as materials. In this workshop, we will cover what flow throughs are, how they can be integrated into jelly systems (or on their own), and then proceed to build your own habitat to get the feeling for the construction of them.

Poster Presentation Abstracts

Investigating plasticity and adaptive potential in *Cassiopea xamachana* polyps

Stephanie F. Hendricks[1], Ziyu Wang[1], Robert Bretzing-Tungate[2], Jack Willans[2], Keisha D. Bahr[2], Marie E. Strader[1]
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Cassiopea xamachana, the upside-down jellyfish, is expanding its range into previously unoccupied habitats, but the mechanisms enabling this are relatively unknown. The early-life polyp stage is capable of asexual reproduction through budding or strobilation, which can be modulated by environmental conditions and ultimately impacts population growth. This ability to change phenotypes based on the environment, or plasticity, can be an effective mechanism by which organisms can tolerate thermal stressors associated with future climate scenarios. Plasticity to cold and hot extremes may enable the proliferation of jellyfish globally, but it is rarely investigated in a physiological context. To investigate the role of phenotypic plasticity and adaptive potential in response to global change, we have established husbandry techniques that have enabled the maintenance of long-term polyp lines from multiple genetically distinct populations of *C. xamachana*. Polyps from two Florida populations (Key Largo and Tampa Bay) were acclimated for >6 months to two ecologically relevant temperatures (23˚C and 28˚C). Then, we determined the chronic minimum and maximum lethal temperatures (CLmin and CLmax) and measured oxygen consumption – a proxy for metabolic rate, which can reflect an organism's capacity to cope with environmental stressors such as temperature and oxygen availability. We find that polyps acclimated to both temperatures tolerated cold exposure down to 8˚C, while heat tolerance was enhanced in polyps acclimated to 23˚C, evidence of plasticity. We also found population-level differences in oxygen consumption, evidence for genetic adaptation. Together, this study provides insight into the stress responses and energetic demands of *C. xamachana* polyps, highlighting the importance of plasticity and genetic adaptation in shaping resilience amid environmental change.

Optimizing Round Fiberglass Tanks for Jelly Grow-outs

Jordan Reed
Georgia Aquarium, Atlanta, GA

Fiberglass rounds are versatile tanks used for many different aquatic animals in quarantine, aquaculture, and long-term holding at public aquariums. Optimizing a fiberglass round to house moon jellies for both grow-out space and display holding eliminates the need for large pseudokreisels in behind-the-scenes areas. Biological and mechanical filtration are key components in maintaining aquarium water quality. However, flow is the most crucial element of a jelly tank. Altering the setup of spray bars allows for fine-tuning the jellies' movement around the tank, aiming to eliminate dead spots while checking the speed of incoming water. The more precise control of flow provides the means for smaller diameter moons to thrive in the tank as well. Improving the components of filtration allows the system to efficiently process the nitrogen cycle and increased biological loads. These changes have resulted in water chemistry tests that

sustain the ideal parameters even with supplemental feeds and increased population sizes. Fiberglass round tanks are a viable option for housing moon species with a suitable assembly of life support elements and simple modifications. Ideally, these combinations would broaden the variety of species that could thrive in rounds which would allow for a greater range of husbandry capabilities at aquariums. As our facility's culturing operations expand, we plan to continue to modify our jelly systems, and design future ones, based on what we have learned from altering the rounds for moons.

4TH INTERNATIONAL SEADRAGON HUSBANDRY SYMPOSIUM

21-23 October 2025

PRESENTATION ABSTRACTS

Session I – Reproduction and Behavior

First, second, third time's a charm…
Birch Aquarium's seadragon propagation program
Leslee Matsushige – Birch Aquarium at Scripps Oceanography

Birch Aquarium at Scripps established a seadragon propagation program in 2012. Our experience with breeding was spotty at first with a few egg transfers but none that were viable. Due to the numerous unsuccessful egg transfers we installed a much larger and deeper exhibit. We were hopeful this enclosure would allow for more successful egg transfers.

First: In 2020 there was an egg transfer that was viable but only 2 eggs were viable. We raised these 2 successfully and this was a good experience to allow us to learn how to raise these baby weedy seadragons on a smaller scale.

Second: In 2023 we had a large egg transfer and we used the same methods to raise the babies as in 2020. We had 30% survival rate at the age of 1 year.

Third: In 2024 we had another large egg transfer but changed some of the methods used to raise these babies. We had a 50% survival rate at the age of 1 year.

The methods that were altered were, instead of using small pseudokreisels to raise the weedy seadragon babies, we shifted to a 180-gal cube tank. This allowed the baby seadragons to swim on their own instead of constantly swimming against a current. The thought was that too much energy was used to constantly swim in the pseudokreisel vs. swimming when they chose to in the cube tank. Therefore they would not need as much food to thrive.

The higher survival rate in the 2024 weedy seadragon baby group was most likely due to the shape and water flow dynamics in the cube tank and higher availability of young live mysis shrimp as feed.

The first and second experience of raising baby weedy seadragons, better prepared us for a higher survival rate with the third batch of babies.

First reproductions of the common sea dragon (*Phyllopteryx taeniolatus*) in Europe

Ángel Curros Moreno - Poema del Mar Aquarium, Bruno González - Porma del Mar Aquarium, Rubén Andrade - Poema del Mar Aquarium

Over the past five years, Poema del Mar aquarium in Gran Canaria, Spain, has successfully bred more than 100 sea dragons that have reached juvenile or adult age. The reproductive success rate of hatchlings that reached adulthood increased from 12.5% to 83% based on the experience gained from more than 10 successful egg transfers in which the team has participated in the Aquarium. Precise facility design, adequate nutrition, and healthy parents are essential for successful egg transfers and high fertility rates. Abundant mysis culture and its management for hatchling feeding have been key to these achievements.

Too much of a good thing? Preliminary results of a weedy seadragon (*Phyllopteryx taeniolatus*) fostering program.

Aaron Jeskie – Columbus Zoo and Aquarium

When the Columbus Zoo and Aquarium opened a new weedy seadragon (*Phylloperyx taeniolatus*) habitat in the spring of 2023 no one expected to have success with this notoriously difficult breeding species anytime soon. Individuals in the population were either thought to be too old or too young to reproduce. This all changed with a first successful egg transfer to a male dragon in late spring of 2024. The journey leading up to this point was long and winding with many ups and downs, especially for a team with very little sea dragon experience. The process of designing and building holding and habitat space, finding and transporting animals and simply learning the quirks or sea dragon husbandry had led us to a now gravid male with only 6 weeks to figure out what to do next. Hatch plans were drawn up, kriesels were set up and ideas were tossed around on how to best isolate and transfer the new fry to their new homes. Once the babies started hatching, even the best laid plans needed to be changed on the fly to accommodate the constantly changing needs of the fry. Luckily, with the advice of other seasoned dragon breeders, we were able to find the right mix of things that worked for us and at almost one year old the baby dragons are thriving. Even with this first small success for our institution there are many things that can be improved before next year's breeding season.

The 2025 weedy seadragon *(Phyllopteryx taeniolatus*) breeding season at the Columbus Zoo and Aquarium has been an unprecedented surprise with a total of four successful egg transfers from April 18th- May 7th. These four male dragons hold and estimated 250-300 eggs. While the Columbus Zoo and Aquarium has the infrastructure in place to raise small batches of young weedy seadragon fry, this potentially massive number of young dragons would quickly drain the present

resources. With food being the limiting factor for optimal survivability a plan was developed to not only give the sea dragon fry the best chance of surviving but to also advance the science behind the logistics of fry husbandry while at the same time maximizing the wellbeing of these animals. While weedy seadragons historically have not been shipped younger than six months of age, this group of dragon fry of varying ages will be shipped via different methods to multiple partnering institutions who have the expertise in place to raise sea dragon fry. Data such as survivability, water quality, and food items offered will be collected, shared and compiled in hopes of contributing to the growing knowledge of seadragon best husbandry and wellbeing practices.

Investigating weedy seadragon (*Phyllopteryx taeniolatus*) reproductive events and monitoring courtship behaviors to further our understanding of reproductive success in aquaria.

Nancy Kim Pham -South-East Zoo Alliance for Reproduction & Conservation,
Theodora Mautz - Scripps Institution of Oceanography, University of California San Diego,
Leslee Matsushige - Birch Aquarium at Scripps Institution of Oceanography, University of California San Diego, Teryl Nolen Hesse - The Seas with Nemo and Friends®, Walt Disney World Resorts®,
Kristen Ulrich - New England Aquarium, Jessica Parent - Georgia Aquarium,
Hugo Batista - Oceanário de Lisboa, Ashley Kwok - Ocean Park Hong Kong,
Hannah Miller - SEA LIFE, Kansas City, Linda Penfold - South-East Zoo Alliance for Reproduction & Conservation

At the third International Seadragon Symposium, attendees identified a need to better understand how environmental conditions, social grouping, and habitat design influence reproduction in aquaria. To investigate these factors, a courtship ethogram was developed and shared through the ZooMonitor Community platform to allow institutional participation in standardized behavioral observations. Four aquaria in North America, one in Europe, and one in Asia monitored seadragons ($N = 26$) for at least eight months, and recorded data on the location of courtship observations within the habitat, temperature, photoperiod, and historical egg release dates. The influence of the lunar cycle on egg release was studied by compiling 218 egg release dates from ZooMonitor participants plus two additional institutions. Preliminary data showed that egg releases were not uniformly distributed across the lunar cycle (Rao's spacing test: $U = 310.46$, $p < 0.001$), with a peak in egg release near the new moon. These findings highlight the potential role of lunar cycles in seadragon reproduction and demonstrate how collaborative data collection can inform evidence-based husbandry practices to support sustainable populations.

Three times a charm: Lessons from the exceptional fatherhood of 'Silver Fox' and the weedy sea dragon breeding program at SEALIFE Melbourne Aquarium.

Tereza Todd - SEALIFE Melbourne

This is the tale of Silver Fox, a prolific weedy seadragon who surprised us all by fathering not one, not two, but three batches of eggs in a single season. What started as a routine breeding success quickly spiraled into a logistical puzzle, as our facility was initially equipped to raise just one brood. From creative tank solutions to sleepless nights and more than a few "why is this

happening?" moments, we adapted on the fly to maximize survival. In the end, 70 healthy seadragon fry were raised and sent off to seven facilities around the globe. It was no short of a triumph of improvisation, teamwork, and sheer stubborn determination.

Session II – Health and Medical Management

Causes of mortality and co-morbidities in weedy (*Phyllopteryx taeniolatus*) and leafy seadragons (*Phycodurus eques*) at three north American aquariums from 1999 – 2024

Vivian M. Lee, DVM, CertAqv - Brevard Zoo, Mandy A. Womble, DVM, PhD, DACVP - Zoological Pathology Program, University of Illinois Urbana-Champaign College of Veterinary Medicine,
Deana Edmunds - Animal Health Department, New England Aquarium, Melissa Joblon, DVM, DACZM - Animal Health Department, New England Aquarium, Matthew O'Connor, DVM, MPVM - Georgia Aquarium, Anthony J. Cerreta, DVM, MS, DACZM - John G. Shedd Aquarium, Current: San Diego Zoo Wildlife Alliance

Understanding the causes of morbidity and mortality in weedy (*Phyllopteryx taeniolatus*) and leafy seadragons (*Phycodurus eques*) within professional care is imperative for optimal husbandry, health, and welfare. Published comprehensive pathology investigations in seadragons under managed care are currently lacking. This 25-year retrospective study aimed to summarize the causes of morbidity and mortality of weedy and leafy seadragons from three North American aquariums between 1999 and 2024. Necropsy and/or histopathology reports were evaluated to collect general demographic data, categorize cause of death, and assess common comorbidities. Postmortem data was available for 158 weedy seadragons (83.6%) and 31 leafy seadragons (16.4%). Infectious disease was the most common cause of mortality in seadragons (43.9%), with phaeohyphomycosis (45.8%) and mycobacteriosis (33.7%) overrepresented. This was followed by unknown (41.3%) and non-infectious etiologies such as environmental (6.9%), nutritional (3.2%), neoplastic (1.6%), and degenerative (1.1%) processes. Of the seadragons that had comorbidity data available (56.6%), the integumentary system was most commonly affected (57.9%), followed by the respiratory (57.0%), hepatobiliary (48.6%), urinary (47.7%), and cardiovascular (39.3%) systems. The most common comorbidities included dermatitis (36.4%), hepatic lipidosis (29.9%), branchitis (29.9%), myonecrosis (20.6%), and renal tubular necrosis (17.8%). This retrospective study elucidates that management practices to prevent and control infectious diseases play a pivotal role in the long-term care and survival of weedy seadragons in managed care.

Mortality trends in weedy seadragons (*Phyllopteryx taeniolatus*) and leafy seadragons (*Phycodurus eques*) in a public aquarium.

Anne Goodall, MS, DVM - Steinhart Aquarium

Twenty-one Weedy Seadragons (*Phyllopteryx taeniolatus*) and twelve Leafy Seadragons (*Phycodurus eques*) from Steinhart Aquarium presented for necropsy from 2015-2024.

Previous literature has demonstrated that mycobacteriosis, scuticociliatosis and myxozoanosis are common diagnoses in seadragons, with presentations of phaehyphomycosis being a less-

commonly reported finding. In contrast, at Steinhart Aquarium, the most frequently reported confirmed cause of death was phaehyphomycosis (predominantly Fonsecaea species), with disseminated bacterial disease being the second most common finding. Despite being a prevalent cause of death in these species, mycobacteriosis was not seen in any of the Weedy Seadragons submitted and only two of the Leafy Seadragons had confirmed cases of atypical Mycobacterium .. Lastly, only two animals demonstrated possible signs of and only two patients showed evidence of myxozoans.

Of the thirty-three cases, eleven (33%) of the animals' causes of death were unable to be determined or considered multifactorial in nature. This highlights the complicated nature of disease identification in these species. To deepen our understanding of their pathologies, future considerations for seadragon mortality studies include continued investigation of trends within and between institutions, as well as attempts to identify and characterize possible etiologies for cases in which there are nonspecific signs.

The Curse of Exophiala: A Frightful Fungal Mystery

Allison Waltz-Hill – New England Aquarium, Jeremy Brodt – New England Aquarium, &
Hansen Johnson - New England Aquarium

Beginning in 2019, after a renovation that required a full dismantling and reassembly of their seadragon exhibit, New England Aquarium started to experience an epidemic of Exophiala infections in their exhibit population of weedy seadragons *(Phyllopteryx taeniolatus*). Staff explored multiple possible causes and solutions between 2020 and 2025, culminating in a collaboration with marine-acoustics specialist, Dr. Hansen Johnson to assess noise levels in the exhibit. Adjustments were made based on this assessment but, despite this, Exophiala has continued to cause 100% mortality of seadragons introduced to the exhibit. Aquarists are continuing to investigate causes and risk factors and are planning to replace New England Aquarium's seadragon habitat in 2027-2028. Future potential for a multi-institutional sound study on seadragons in public aquaria is being explored to better understand how sound impacts seadragon health and behavior.

Treating Exophiala in Sea Dragons... A Test of Futility

Melissa Joblon, DVM, DACZM - New England Aquarium

Exophiala species belong to a group of dematiaceous fungi that cause localized or systemic diseases termed Phaeohyphomycosis. Exophiala is commonly reported in fish and appears to have a predilection for lumpfish (*Cyclopterus lumpus*)3,5 and weedy (*Phyllopteryx taeniolatus*) and leafy (Phycodurus eques) sea dragons.1,4 Literature describing treatment of Exophiala in fish is scarce, with most reports showing limited to no success despite attempts with multiple therapeutics.2,4,5 From 2008 to 2025, 48 sea dragons were diagnosed with Exophiala at New England Aquarium and treatment was attempted in 35 of these animals. The most common treatments included various topical medications (n=24), surgical debridement (n=15), various immersion/bath treatment (n=11), parenteral voriconazole (n=9), terbinafine orally or via immersion (n=5) and itraconazole orally (n=2). A combination of two or more treatment modalities

was used in 21 cases. Tissue voriconazole and tissue and water terbinafine concentrations after treatment are described in a limited number of cases. Duration of treatment ranged from 1 to 82 days; however, extrapolation of efficacy of any specific treatment is hindered by the presence of significant comorbidities (scuticociliatosis, bacterial infection, other), variability in time from diagnosis to starting treatment, and lack of consistent record keeping. Limiting environmental stressors and risk of trauma, appropriate sanitation, and immune support is key to prevent Exophiala in sea dragons. Despite being known to be a "uniformly fatal" disease in sea dragons, treatment of Exophila is often pursued due to their scientific, conservation and ecological importance and to advance further learning.

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Session III – Nutrition, Welfare Monitoring, & Wellbeing

Feeding husbandry practices for seadragons at Oceanario de Lisboa: An overview

Ana Patrícia Pereira Rocha - Oceanário de Lisboa, Beatriz Nóbrega - Oceanário de Lisboa, Hugo Batista - Oceanário de Lisboa

Since its opening in 1998, Oceanário de Lisboa has maintained leafy and weedy seadragons in exhibition. The husbandry protocols, particularly regarding nutrition, have continuously evolved, with a primary reliance on frozen mysis shrimp as the staple diet.

Currently, animals are fed three times daily using frozen food from various commercial brands, supplemented with vitamins. Each feeding session includes a 15-30-minute observation period to monitor individual responses. This detailed approach has contributed to outstanding longevity outcomes, including a weedy seadragon reaching 15 years of age—one of the longest recorded in the ZIMS database.

A central component of our husbandry success is the implementation of individualized daily life and feeding logs, which include continuous data analysis. This allows for close monitoring of behavioral and feeding trends, enabling early detection of anomalies and preventive action.
Data analysis has revealed strong correlations between appetite and specific mysis shrimp batches or brands. Even subtle changes in food quality—such as increased fragmentation—can lead to complete feeding refusal, in the absence of any clinical symptoms. Identifying these patterns and developing strategies to mitigate their impact has proven crucial in maintaining animal health and ensuring the long-term success of our seadragon care program.

Mysis 2.0

Erika Moss – Shedd Aquarium

For over two decades, Shedd Aquarium has maintained an in-house mysis shrimp culture, serving as a cornerstone of our live food program—particularly in support of our sea dragon collection. Throughout this time, we've shared our methodologies and insights with the broader aquarium community, highlighting the significant husbandry benefits of a reliable live food source.

As with any long-standing system, periodic reassessment and refinement are essential. This has led to the development of what we're calling Mysis 2.0—a redesigned culturing system that builds upon the strengths of our original approach while addressing persistent challenges. Though still in the early stages of implementation, this updated system is demonstrating promising results: comparable productivity with reduced daily and weekly maintenance demands.

Bored, Busy, or Breeding? Creating an Ethogram for Weedy Sea Dragons

Kristen Ulrich – New England Aquarium, Alyssa Leonardi – New England Aquarium

The New England Aquarium started building an ethogram for our weedy sea dragons back in 2021, focusing on tracking breeding behaviors seasonally and general behavior monitoring. This ethogram went through several iterations starting with a written ethogram log then transitioning to using the ZooMonitor platform. Starting in 2023, NEAq also contributed to SEZARC's sea dragon ethogram project. As we shift gears to the future of ethograms, we're working towards creating an ethogram that will allow us to further understand and explore behaviors, as well as enclosure and habitat usage.

Developing a wellness program for seadragon acquisition at the Seas with Nemo and Friends

Teryl Nolan Hesse – The Seas with Nemo and Friends

At Disney, we have designed a comprehensive, strategic animal wellbeing program using a multidisciplinary approach that includes life plans for each species or taxa. Once weedy seadragons were approved for acquisition in our Institutional Collection Plan, we began incorporating them into our animal wellbeing program. This included evaluating risk analysis, reviewing life stage needs, identifying intended role in the collection, and developing a life plan

for the species. We believe this approach will maximize the potential for seadragons to thrive in our care. In this presentation, we will share the framework of our Animal Wellness Program as it applies to this species.

Session IV – Research & Conservation

Keynote Presentation
Wild seadragons: their ecology, conservation and threats

David Booth - University of Technology Sydney

Seadragons are iconic and magical fishes found only on Australia's Great Southern Reef. In this talk I'll reveal what we have found about the lives of the weedy seadragon over the past 2 decades. Their behaviour, reproduction and movement pattens in Southeast Australia have been documented by our research team linked with dedicated citizen scientists. While relatively safe from direct human exploits such as collecting, they face new threats under climate change. In April 2022 we witnessed an event where over 200 weedy seadragons were washed up along Sydney's coastline, around ½ of the total population in the area. This was a result of climate change-linked storm events (East Coast lows) which brought massive waves and surge, and removed much of the food source (mysid crustaceans). Recovery has been very slow to date. This year a massive toxic algal bloom event in South Australia has decimated habitats across the core range of weedy but especially leafy seadragons, with 1000s of animals (and 100s of other species) washed ashore. I will discuss this event and responses to date, inkling whether ex-situ breeding can play a role.

Keynote Presentation
SeadragonSearch: shifting the dial on seadragon conservation

Nerida Wilson - University of Western Australia

Evidence-based seadragon conservation has been limited to date by a lack of range-wide information. SeadragonSearch seeks to address this by engaging citizens in a community-science project, across temperate Australia. The project applies machine learning and AI tools to uploaded images, and generates new data to better understand seadragons. The information gathered so far has been used in both scientific publications and in applied outcomes. SeadragonSearch was instrumental in carrying out a reassessment of the extinction risk of the weedy seadragon, allowing it to be recognized as 'Vulnerable' on the IUCN Red List. The project will run for at least 10 years, and provides a stable, data-driven approach to conservation decisions.

Don’t Let Perfection Get in the way of Progress:
Updating the Syngnathid Husbandry Manual

Teryl Nolan Hesse -, The Seas with Nemo and Friends®, Walt Disney World Resorts®, Leslee Matsushige - Birch Aquarium at Scripps Institution of Oceanography, University of California San Diego, Jeremy Brodt - New England Aquarium, Paula Carlson - Dallas World Aquarium, Steven Yong - Steinhart Aquarium at California Academy of Sciences, Laurel Johnson - Newport Aquarium, Nancy Kim Pham - South-East Zoo Alliance for Reproduction & Conservation

Updating husbandry manuals can be a slow process involving multiple people and chapters. With the last Syngnathid Husbandry Manual update dating back to 2005, the need for timely dissemination of information has become increasingly evident. In response to the two-decade gap, we have embraced a dynamic approach, departing from the conventional wait for a completed manual release. This initiative aims to share completed updates promptly, addressing advancements of syngnathid care. Some highlights of the updated manual include Acquisition and Transportation, Research in Zoos and Aquaria, Health Management, updates on the weedy and leafy seadragon chapters and the introduction of additional syngnathid species chapters. Recognizing the collaborative nature of manual updates, we are committed to mentoring individuals interested in contributing to other chapters, thereby enhancing the collective expertise within aquaria. Understanding the labor of love involved in authoring chapters, we approach timeliness with compassion. As additional chapters are completed, we encourage authors to showcase their insights at upcoming zoo and aquaria conferences. The significance of syngnathids in aquaria cannot be overstated, and it is imperative to highlight the global and impactful contributions of aquaria to the care and conservation of these charismatic fishes.

Abstracts from the European Union of Aquarium Curators Conference

Life Support Systems

In-situ trials with a new denitrification system in a cold-water marine mammal pool at Hagenbeck's Tierpark, Hamburg

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The open-air walrus pool at Hamburg Zoo with a volume of 1600m³ has seen an accumulation of nitrate over years resulting in excessive filamentous algae growth and other problems. In order to reduce the nitrate levels without large water changes it has been agreed to install and test a new heterotrophic denitrification system which had been tested before at a much smaller scale and at constantly high temperatures only. Over a period of 2,5 years a chemically proven denitrification method with acetic acid as carbon source has been tested in-situ in the system with an initially high nitrate concentration of about 350mg/L in a newly designed reactor vessel with permanent internal circulation and a periodical high-flow pump activity in order to avoid moving-bed biomedia clogging and subsequent and inevitable mechanical labour. Carbon source dosing has been implemented as on-demand based on medium temperature, bacteria population size and resulting activity. A special emphasis has been given to operational stability, easy handling and lowest possible maintenance requirements. Technical challenges and solutions as well as biochemical performance results will be presented. The nitrate concentration had been reduced to around 80mg/L at the end of the test period with a low though of some 600L/h only but a removal rate of >99%.

Filtration System at the Aquarium-Museum, a heritage from 1962

Arianna Schiona, Aquarium-Museum Universitaire de Liège
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The Aquarium at the University of Liège was created as part of the post-war modernization of the Institute of Zoology, led by Marcel Dubuisson—then Chair of Zoology and Rector of the University. Inaugurated in 1962, the Aquarium responded to a growing scientific interest in ichthyology, hydrobiology, marine biology, and oceanography. It was designed to support research and education while also being accessible to the public, especially schools.

The Aquarium was built beneath the new amphitheater of the Institute and equipped with a complex system to circulate, purify, oxygenate, and regulate the temperature of water for 27

display tanks, as well as several hidden experimental and reserve tanks. Central to this system were gravity filters—technology commonly used in aquariums and pools during the 1960s and 1970s. Although still functional today, these gravity filters have largely been replaced elsewhere by more efficient modern systems since the 1990s, due to limitations in filtration performance and energy efficiency.

Our current project aims to upgrade the filtration systems across the Aquarium-Museum's four sections by introducing mechanical filtration, biological filtration, a protein skimmer, and UV sterilization.

So far, we have removed the original substrate from one gravity filter and installed a mechanical sock filtration system. This single intervention has already led to a 66% reduction in ammonia levels—from 0.27 mg/L to 0.09 mg/L.

This modernization is essential for improving water quality and, consequently, the health and well-being of the animals in our care, while upholding the educational and scientific mission of the institution.

MicroBiom in aquatic exhibits

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The microbiome plays a crucial role in maintaining the health and ecological balance of aquatic systems, particularly in controlled environments where fish are kept under human care. Recent advances in microbial research and molecular techniques have deepened our understanding of the diverse and dynamic microbial communities present in recirculating aquaculture systems (RAS), aquaria and other closed aquatic environments. This presentation highlights the importance of regular microbiome monitoring as a vital management tool for ensuring water quality, preventing disease and promoting the overall welfare of fish.

We will introduce a newly developed test kit designed for the practical and reliable assessment of microbiomes in fish-keeping systems. By analysing bacterial community diversity, the kit enables the early detection of imbalances and facilitates informed intervention. Case studies will demonstrate the application of the test kit in various settings and highlight the benefits of routine microbiome monitoring for both private aquarists and institutional facilities.

Beyond its operational value, microbiome monitoring has significant potential for research and conservation. Standardising protocols and sharing microbial data across institutions could foster collaborative learning and innovation. Integrating microbiome analysis into regular husbandry routines allows the aquatic community to adopt a more preventive, evidence-based approach to managing fish health.

This presentation advocates the wider adoption of microbiome-based diagnostics and outlines practical steps towards implementation in private and professional fish-keeping environments.

Conservation & Husbandry

Trafficking of European Eels *Anguilla Anguilla* and an example for housing confiscated animals

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Since ancient times, juvenile European eels (*Anguilla anguilla*) arriving in European coastal estuaries from their long journey from the Sargasso Sea have been a valuable nutrition source. In recent decades, these so-called glass eels have increasingly been collected en masse for (now illegal) trade.

Eel populations are now severely depleted and populations have declined by approximately 95% since the 1980s, primarily due to habitat loss, overfishing, and illegal trafficking.
We will present a review of the trade with this fish and the measurements in force on a European level. We will present an example from 2019, where 130'000 eels were confiscated at Geneva airport and temporarily taken into care by Aquatis. What challenges and problems need to be addressed before the seized animals can find their place.

Saving Sharks in the Mediterranean

Paul Cox, Shark Trust
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The Mediterranean Sea is a hotspot of extinction risk for sharks and rays. A complex body of water home to nearly 80 species of shark and ray, of which at least 53% are at risk of extinction. Surrounded by 22 different countries across 3 continents, and home to over 77,000 small boats, the Mediterranean Sea is subject to a broad range of diverse fisheries pressures.

The Shark Trust's Mediterranean programme, one of the major strands of Trust work, brings together a range of actions aiming to prevent species extinctions and improve the conservation status of sharks and rays in the Mediterranean.

From engagement with the General Fisheries Council of the Mediterranean (GFCM) and national governments to ensure delivery of commitments, to partnership with local partners to enable on the ground implementation of conservation measures. From development and delivery of sub-regional action plans for angel sharks to a broad communication effort to engage fishers and communities across the region. It's an ambitious effort, requiring patience, diplomacy and a genuine ability to see things from all perspectives.

This talk will introduce the programme, the people involved in the effort and discuss how shark conservation – all conservation – is as much about people as the animals and habitats that we set out to protect.

Smooth hound shark (*Mustelus* spec.) breeding program – findings and new approaches

Nicole Kube, German Oceanographic Museum Aquarium
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Population management of existing shark and ray aquarium populations are sometimes difficult to handle. Genders can be distinguished very well in elasmobranchs, however with more than one breeding pair, the genetic disposition of different litters of pups may cause undetected relationships and lead to a diluted gene pool. Including genetic sampling can help to improve this matter.

In the case of European Smoothhound sharks (*Mustelus* spec.) it started with a genetic investigation of the European aquarium population to distinguish two separate species held in human care, as it seemed that there might be some misidentification of the species. An alternative sampling method was tested to collect as many genetic samples as possible within the European aquarium community. The results and follow-up decisions will be presented.

According to that, offspring in certain institutions were tested for parenthood to ensure a better genetic distribution of animals within the European community. It also includes the decision making of the rehousing of the complete *Mustelus asterias* stock of Berlin Sea Life Centre before closing down in January 2025.

The aim of the presentation is to show the advantages of genetic sampling to ensure a sustainable future population management of the *Mustelus* programme and opportunities for other breeding populations.

Bridging Ex Situ and In Situ Monitoring: Photogrammetry Applications for Marine Species Conservation.

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Accurate biometric data are essential for understanding the biology of marine species and for shaping effective conservation strategies, particularly for elasmobranchs and other vulnerable taxa. Oceanário de Lisboa has adopted stereo-video photogrammetry (stereo-DOV) as a non-invasive, precise, and scalable technique to collect morphometric data in both controlled (ex situ) environments and natural (in situ) settings. While this technique is extensively applied in the wild, it remains underutilised or unreported in aquariums.

In the aquarium, a low-cost, home-built stereo-DOV system facilitated minimally invasive biometric pilot surveys of 47 species (teleosts and elasmobranchs), totalling over 100 individual measurements in a single day. Comparison with physical measurements revealed minimal discrepancies (1.3 – 5.5%), demonstrating the technique's accuracy and value for husbandry, welfare monitoring, and long-term conservation planning. The transition to official equipment reduced errors to 1%. Species biometrics are now accessed with minimal stress, and new insights into the growth of collected or bred marine species are being investigated.

Field campaigns expanded the application of photogrammetry to critical marine habitats. In the Azores, during the 2024 Manta Conservation Experience, 32 *Mobula tarapacana* were measured and photographed, with eight individuals matched to a decade-long Photo-ID database. Several pregnant females were identified, adding valuable data on reproductive status and supporting regional conservation initiatives. During the Gorringe Bank 2024 expedition, stereo-

DOV systems facilitated the identification and measurement of 33 fish species at shallow depths (0–45 m). Among them, a notable aggregation of Torpedo marmorata was recorded—28 pregnant females exhibiting stacking behaviour not previously reported in the Eastern Atlantic. Measurements (mean TL = 587 mm, DW = 382 mm) and age estimations (10–30 + years) highlighted the site's potential importance as a reproductive habitat. These findings underscore the method's capacity to document novel biological patterns and contribute to species assessments.
Stereo-photogrammetry offers substantial benefits over traditional methods: reduced animal stress, decreased field effort, and the creation of reusable image data. Despite initial equipment costs, this approach proves cost-effective in the long term, particularly in settings where animal welfare and data integrity are paramount.

Oceanário de Lisboa's use of stereo-DOV exemplifies how public aquaria can lead innovative research that bridges ex situ and in situ conservation. The technique enhances our ability to gather robust, high-resolution data across settings, informing species management, enriching global databases, and ultimately contributing to the conservation of marine biodiversity.

Exploring the behavioural patterns of the Pacific oyster (*Magallana gigas*) through bio-sensor technology

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Understanding the well-being and behavioural deviations of animals in aquarium settings is essential for responsible care, research, and welfare standards. While attention often centres on fish and other charismatic species, invertebrates, particularly molluscs, remain largely overlooked, despite their ecological significance and sensitivity to environmental change.

The project Beneath the Mirror Waves seeks to uncover the subtle behavioural language of oysters through the use of bio-sensor technology known as molluSCAN-eye®. The study was focused on a group of sixteen Pacific oysters (*Magallana gigas*), which served as “living sensors.” Their micro-movements, especially the rhythmic opening and closing of their shells, were continuously monitored using custom-designed micro-sensors installed directly on the shell surface.

Conducted in a controlled aquarium environment, the study examined how oyster behaviour was influenced by various factors, including light fluctuations, feeding times, water quality, the presence of other aquatic organisms and human activity within the exhibition space. By linking behavioural data to specific events, such as school visits, guided tours, or individual observers, the project revealed how aquarium activities influence oyster behaviour and provided real-time insights into their sensitivity to environmental changes.

The collected data was further interpreted through an interdisciplinary lens and transformed into an interactive audio-visual sculpture. This installation translates biological responses into a dynamic, tactile experience, allowing visitors to perceive the invisible rhythms of oyster behaviour. The sculpture not only visualises the oysters’ interaction with their surroundings, but also prompts reflection on the often-overlooked complexity and responsiveness of invertebrate life.

Project Beneath the Mirror Waves thus highlights the potential of integrating bio-sensor technology into aquarium research and exhibition practices. It invites us to reconsider the role of molluscs as sentient participants in their environments and offers innovative pathways for

public engagement, welfare monitoring, and interdisciplinary collaboration.

From Welfare Assessment to Scientific Insight: Linking Practice and Research.

Ana Ferreira, Oceanário de Lisboa
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Ensuring the welfare of marine species in public aquariums is fundamental to ethical husbandry and meaningful public engagement. At Oceanário de Lisboa, a multidisciplinary team of aquarists, curators, veterinarians, and life support specialists implemented a structured, science-based protocol for welfare assessment across diverse exhibits. These evaluations combine behavioural observations, clinical assessments, and environmental parameters, forming the basis for tailored management strategies. A central element in this process is the Welfare Index (WIndex), an internal framework developed to quantify and visualise welfare needs across exhibits. The WIndex synthesises biological, behavioural, and environmental indicators into a composite score, allowing for standardised comparisons over time and between enclosures. This structured approach ensures timely identification of welfare concerns and supports evidence-based decision-making. It serves as a critical tool for identifying priorities, planning interventions, and communicating welfare status internally across teams. Actions derived from these assessments include habitat enrichment, nutritional optimisation, and system modifications. Crucially, the implementation and outcomes of each intervention are tracked through regular follow-up meetings, continuous staff training, and rigorous record-keeping. This iterative process facilitates continuous improvement and responsiveness to species-specific needs.

Beyond operational outcomes, these welfare evaluations also drive scientific research. Several investigative projects have emerged directly from assessment findings. These include the development of a body condition index score for *Mobula hypostoma*, a longitudinal time budget analysis of sea otters to evaluate behavioural consistency, and a study on Port Jackson sharks' behavioural responses to feeding schedules. Additionally, space use analysis in garden eels is being investigated to search for potential links to reproductive behaviour, and the installation of an additional current pump in a coldwater exhibit was found to influence activity patterns in North Pacific species.

These applied research efforts, underpinned by systematic welfare assessments, have yielded peer-reviewed publications and internal technical reports, enhancing Oceanário de Lisboa’s contribution to marine science and animal welfare.

This presentation will detail the methodology of our welfare evaluations, demonstrate the structure and utility of the WIndex, and provide case studies that exemplify the synergy between welfare monitoring and applied research. By sharing our experience, we aim to reinforce the role of public aquariums as institutions where animal welfare and scientific inquiry coexist, promoting best practices for the care and understanding of marine life.

Long-Term Maintenance of the World's Largest Nature Aquarium at Oceanário de Lisboa: Challenges Over 10 Years

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The Oceanário de Lisboa's Nature Aquarium, which is part of the "Forests Underwater" exhibition at the Oceanário de Lisboa was created by renowned aquascaping master Takashi Amano. Over the past decade, maintaining this iconic exhibit has posed numerous challenges, demanding a seamless integration of technical expertise, biological knowledge, and innovative solutions.

Key challenges in sustaining the exhibit included maintaining consistent water quality in such a vast system. This required regular monitoring of water parameters, and precise adjustments to promote the well-being of the existing plants and animals. The vitality of aquatic plants, essential to the aquarium's design, necessitated meticulous management of lighting, CO_2 levels, and nutrient dosing, alongside routine pruning to uphold the aesthetic vision set by Mr. Amano. Algae control emerged as another significant challenge, requiring a delicate balance of light, nutrients, and biotic factors to prevent outbreaks.

This 10-year journey not only highlighted the intricate complexities of managing a large-scale Nature Aquarium but also emphasized its importance in fostering public awareness of the importance of aquatic ecosystems. The knowledge and experience gained offer a valuable benchmark for future projects, uniting artistry, technology, and conservation in a living masterpiece

Conservation assessment of a threatened pupfish species flock from "Laguna de Chichancanab", Mexico.

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Lake Chichancanab is located in the Yucatan Peninsula. One of its most outstanding features, is a fish species flock composed of seven morphologically distinct species, thought to have diverged as recently as 8,000 years ago.

After the introduction of tilapia, all the species were considered threatened or extinct, but population assessments were made in the same portion of the lake, and questions remain on their status.

Due to the threats, Chichancanab was declared a Ramsar site in 2004, however no management plan was produced, nor actions implemented towards the protection of the threatened species.

Chichancanab has not benefited by state tourism development is still underdeveloped, it has the first place in poverty, and despite some support by Federal and State Agencies, it has not made an economic impact on the people, leading to discontent towards the conservation policies in the area, increasing the risk to the biodiversity of the lake.

This provides an opportunity for positive change, via participatory planning with the local community establishing a sustainable management strategy for Chichancanab, with the aim

of benefiting the species, and the communities. An evaluation of the conservation status of each species and the identification of major threats must be carried out.

Applying elements of brown seaweeds aquaculture techniques to enhance the kelp forest tank at Primorsky Aquarium

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Primorsky Aquarium is located in Vladivostok on the coast of the Sea of Japan. The total water volume is 24,000 m³. The exhibition aquariums (excluding the Dolphinarium) contain 8,500 m³, while the Scientific and Adaptation Complex holds 1,500 m³.

One of the most important areas for us is showcasing the marine ecosystems of the Russian Far East. The centerpiece here is the Kelp Forest Tank (measuring 12.2 m long, 5.2 m wide, with a water depth of 6.9 m and volume of 420 m³). It has three main acrylic panels (7.1×7.9 m, 2.3×3.3 m, 2.6×2.2 m) and an open-top section for viewing. Water temperature is maintained at 11–13°C. This aquarium was specifically designed to maintain live giant kelp, equipped with powerful artificial lighting and Solatube750 DC systems that transmit natural sunlight from the building's roof.

Additionally, our Quarantine Facility contains a specialized tank for working with large algae species (12.45 m long, 5.65 m wide, 3.20 m water depth, 225 m³ volume).

The only Russian species of giant kelp is *Eualaria fistulosa*, which can reach 25 m in length. However, we have been unable to obtain this species from the wild, as it grows in very remote areas.

For the initial Kelp Forest exhibit, we used artificial replicas of *E. fistulosa*, *Macrocystis pyrifera*, and *Nereocystis luetkeana*. While these were high-quality reproductions, they couldn't match the appearance of live plants. Furthermore, the artificial Eualaria would twist and cluster against the end wall due to water currents, which compromised the visual appeal of this tall, narrow aquarium.

Our goal was to improve the exhibit design to better demonstrate how kelp forests function in nature, interacting with water currents and sunlight. We experimented with planting various live macroalgal species on the bottom and artificial rocks, but the exhibit lacked vertical elements in the water column.

After evaluating several options, in addition to the existing giant artificial algae, we implemented an aquaculture-style solution using vertical hanging ropes with buoys, to which live brown algae *Saccharina japonica* and *S. cichorioides* were attached. Their thalli, growing up to 2 meters long, create an impressive display as they sway in the currents. This has significantly improved the exhibit's appearance while introducing visitors to sustainable aquaculture techniques.

We consider this solution very successful and plan to continue developing macroalgae cultivation techniques for our aquarium systems.

The work was partially performed at the Primorsky Aquarium Shared Equipment Facility of the Zhirmunsky National Scientific Center of Marine Biology, Far Eastern Branch, Russian Academy of Sciences (NSCMB FEB RAS)

Long-term ex-situ breeding of endangered freshwater fish in the new facility at Vienna Zoo

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We have built a new breeding facility at Vienna Zoo for the long-term breeding of endangered freshwater fish. For many years we have been managing different species with different requirements and would like to present our experiences and the resulting challenges with some selected species.

In the new facility, technical possibilities have been realized to adapt abiotic parameters better and faster to the ecological requirements of the species kept. In this way, we want to build up fitter populations with higher reproduction rates in the long term. The genetic diversity of the populations kept and the different strategies for selected species will be discussed.

Florida Coral Rescue: Public Aquariums Creating Conservation Impact Together

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In 2018, at the invitation of State of Florida and United States government agencies, 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 (FWC), National Oceanographic and Atmospheric Administration-Fisheries (NOAA Fisheries), the Fish and Wildlife Foundation of Florida (FWFF), and AZA accredited facilities across United States. In 2025, The Florida Coral Rescue Project (FRTRP), under the oversight of the AZA SAFE (Saving Animals From Extinction) Coral Program, will be six 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 had its foundations in the decades of coral conservation efforts independently and collaboratively pursued by AZA members. From that foundation, FRTRP has become a game changer for coral reef restoration efforts in the United States and beyond. The FRTRP, an international network of coral care facilities has prioritized advancing coral science with an eye to 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. Over the last six years, the collaboration to save an entire reef ecosystem has made significant conservation impact and this impact will be explored.

The Florida coral rescue effort is evolving to build the reef's future and so too, is the FRTRP. Much of the work being planned and executed requires the skills sets, resources and professional experience of professional aquarium facilities and animal care teams. Sustaining the effort and sharing what has been learned with others will be essential. In the future, collaboration will remain our foundation and significant conservation stewardship impact, our outcome.

Adapting to Change: The Beluga Sturgeon's (Huso huso) Response to New Environmental and Feeding Challenges

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The Lithuanian Sea Museum boasts a remarkable track record in raising beluga sturgeons (Huso huso). Today, our aquarium is home to 13 magnificent beluga sturgeons, with our largest resident tipping the scales at an impressive 300 kg and stretching a majestic 2.5 meters in length. With over two decades of hands-on experience, we've discovered that these fascinating fish are surprisingly low-maintenance and incredibly resilient to diseases—remarkably, we've had no disease outbreaks throughout their entire care period.

Yet, our journey hasn't been without its challenges. Ensuring these gentle giants live in a stress-free, emotionally enriching environment has been a primary focus. The extensive reconstruction we completed in 2017 revolutionized their habitat. We introduced an awe-inspiring 18-meter acrylic tunnel, enhanced the landscape with rocks and decorative elements, upgraded our filtration system, and implemented a dynamic current system. These enhancements aimed to create an ideal home for our belugas.

However, we soon encountered significant hurdles in feeding them. Competition among the sturgeons made it difficult to guarantee each fish received adequate nourishment. Additionally, food often got trapped behind the aquarium's structures, complicating retrieval and causing injuries when the sturgeons attempted to feed.

Seasonal changes brought another layer of complexity. During spring and autumn, the sturgeons' behavior shifted—they became less interested in food, more restless, and more prone to injuries, likely due to their natural spawning migration instincts.

To tackle these issues head-on, we made a pivotal decision: personalized underwater feeding. This approach, combined with enriching their environment with new elements like brushes, ropes, and pulsing water currents, has been a game-changer.

Collecting/Acquisitions & Transports

***Rhina ancylostomus* transport: Ex situ Conservation.**

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In early 2024, Oceanogràfic of Valencia and Churaumi Aquarium in Okinawa, Japan, signed a Memorandum of Understanding (MOU) establishing collaborative efforts focused on conservation initiatives.

In October 2023, Churaumi Aquarium got eleven *Rhina ancylostomus* captive born pups (6.5.0).

The proposal was transferring 6 pups (3.3.0) to Oceanogràfic of Valencia to help increase the number of individuals and participating institutions in Europe. The objectives were to study the species' development in different environments and to support future captive breeding efforts. *Rhina ancylostomus* is listed under CITES Appendix II (Annex B in the EU) and is classified as Critically Endangered (CR) by the IUCN Red List.

Transporting these animals from Japan to Europe posed significant challenge, not only in terms of regulatory paperwork but also due to the logistical and financial complexities involved. The operation began in April 2024 with the initiation of CITES permit applications and concluded in March 2025, following the final transfer between Oceanogràfic Valencia and Burgers' Zoo.

Ultimately, five individuals (3.2.0) were successfully transported to their new institutions, even though, unfortunately, one female (0.1.0) was lost during this highly complex process. This presentation aims to illustrate the numerous challenges involved in international wildlife transport and conservation collaborations.

Sharks on a Plane: The Story Behind Live Aquatic Animal Transport on commercial Aircraft

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A single incident involving live aquatic animal transport could result in the rejection of all future movement of aquatic shipping containers on aircraft; or worse catastrophic loss of live. Safe, effective transport equipment and methodologies are essential not only to the welfare of the animals involved, but also to the aquarium industry's ability to move animals by air.

The containers and packaging used must be airline approved and satisfy the International Air Transport Association's (IATA) Live Animal Regulations (LAR). To comply with these regulations, the containers used, must undergo rigorous testing and may need also satisfy individual countries'Civil Aviation Safety Authorities. These regulatory authorities are responsible for passenger and aircraft safety. The mechanics and detail ensuring all cargo does not create or add risk to any flight, is seldom considered by an aquarium getting ready to receive a big shipment from thousands of kilometres and days away.

Understanding the regulations and methodologies, and how they've been developed, helps us appreciate the diligence we must exercise to assure safe and successful shipments and are vital to the future of air transport of aquatic wildlife.

Why You WANT Chemically Treated Fish - The use of Chemicals from Point of Capture to Display

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Catch phrases created by clever marketing campaigns or other influential sources are widely distributed at a faster pace than ever with the increasing availability of social media platforms. Some are based in fact, but some may be misleading. To the laymen "Chemical Free Fish" may seem like a good thing…

However, the use of chemicals is intrinsic to Best Practices for marine life care from the point of capture through initial acclimation and quarantine. The point of capture also includes the capture process itself, so why shouldn't the proper chemicals be used then as well?

The Florida Marine Life Fishery commonly uses 2% Quinaldine solution as an anesthetic to reduce stress and capture abrasion during the collection process. While quinaldine is sometimes

used just prior to collection, the most common application is for slightly anesthetizing after the capture has already occurred. With the proper use, quinaldine collected marine life leads to a reduced need for antibiotics or other prophylactic treatments post capture.

A holistic approach to treatment plans for marine life should start at the point of capture. Not all chemicals are good and not all are bad and consideration should be given to combinations of multiple chemicals and how they might inhibit or exacerbate their efficacy. Understanding the proper chemicals to use increases survivability and health for marine organisms in human care from capture to the end of their natural life.

The chemicals used from point of capture are just as important as traceability from point of capture so they should be investigated and understood concurrently.

Moroccan Madness x 4, the beginning of a beautiful friendship

João Correia, Rui Guedes, Nuno Rodrigues & Patricia Campos, Flying Sharks & Canary Aquatic Live Animals
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In 2023 we received a monumental order from Clear Reef, which was building the Al Hoceima Aquarium in Morocco. Immediately we feared the fact that this is a non-European Union destination, which typically means a heavier administrative load and considerably longer times of waiting at customs. We were not mistaken about these aspects, because each of the first 3 transports conducted this far involved customs brokers from Lisbon (Portugal), Algeciras (Spain) and Tangiers (Morocco).

The 4th transport included a vast number of animals from the Canary Islands, which were obtained through a mutually profitable partnership with Canary Aquatic Live Animals. The Canary Islands are considered a "non-E.U." territory from a fiscal perspective, which mandated additional paperwork and customs brokers both in Las Palmas and Cádiz.

During all four transports all animals were delivered safely, despite their high numbers: 853 in June 2024, 906 in September 2024, 329 in December 2024, and 849 in June 2025, totaling over 2.900 animals. This included mostly *regular* species, such as *Scomber scombrus* and many others, but also some unusual species, like *Sardina pilchardus* and *Squalus megalops*. The collection process of sardines on board commercial purse seiners is illustrated, including a specific protocol devised to hold them, which was based on medicated pellet food and extremely stable water quality.

While the first three transports (which included two trucks in the first one) involved refrigerated trucks and our 220 Volts traditional filtration powered by an inverter and consisting of protein skimming and mechanical filters, the 4th transport saw the maiden voyage of our "Mobile Station", an half million euros EEA Grants Project that now constitutes the most modern fish moving apparatus in the world.

With autonomous filtration powered by its generator, each of the four tanks is equipped with a protein skimmer, ultra-violet disinfection, 50 to 200 micra mesh bags (both gravitational and pressurized) and pressurized activated carbon. This unit also includes both white and red lighting, autonomous probes that automatically measure temperature, oxygen and pH, and a fully integrated electric board that allows for remote access and adjustments from a supporting vehicle.

These are but a few of the countless details that are included in the features of this impressive equipment, which includes adaptable water intakes that are adjusted to the nature of the animals moved per tank, amongst multiple other aspects that will be presented.

Polska Madness 2024: A very long transport, with very heavy headaches

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At the end of 2023 the Gdynia Aquarium (Poland), placed a rather large order that included small sharks, skates, multiple sizes of teleosts, and quite a few invertebrate species as well. These were to be delivered at the end of March 2024, for the opening of a new exhibit. Immediately one problem arouse, which was the fact that schooling fish, such as *Scomber scombrus* and *Trachurus trachurus* can only be collected with the assistance of a set-net targeting bluefin tuna in the south of Portugal, which doesn't start operating until April.

This presentation therefore focuses on such multiple challenges that had to be overcome to ensure that all the animals were delivered on time. These challenges included the fact that some fish were larger than expected, which had a dire impact on oxygen consumption and required collaboration from multiple institutions, along the way, to lend life-saving oxygen cylinders. These problems also included shifting the route of a 4.000 kilometers transport halfway, with all the necessary adjustments in flights and other logistics, not to mention the fact that the team's vehicle, with 830.000 km under its hood, broke down in France. Additional challenges included a severe storm that delayed the arrival of a lot of fish which were transported from the Canary Islands.
All solutions adopted to a myriad of problems are presented and discussed.

This presentation also includes some details on a bonus "4 in 1" operation that included one single van rental that did four jobs over ten days. These were (1) moving captive-bred bluefin tuna (*Thunnus thynnus*) from Mazarrón (Spain) to Hirtshals (Denmark); (2) moving captive-bred *Galeorhinus galeus* from Hirtshals to Vienna (Austria); (3) moving wild caught *Gadus morhua*, *Triglophorus lastoviza* and *Merlangius merlangus* from Hirtshals to Ílhavo (Portugal); and (4) finally moving captive bred *Salmo salar* parr from Galway (Ireland) to Vila Real (Portugal).

While these 4 transports resulted in a resounding success, they faced multiple technical challenges, including the fact that the van's engine was not powerful enough to feed the 12 Volts inverter that powered the 220 Volts filtration. All problems and solutions are presented and discussed, which included bypassing a safety fuse that was cutting down the van's power. Safety issues are also introduced, since two consecutive traffic tickets in Oberhausen showed us that the van's weight was 5.153 kg, which is vastly above the legal limit of 3.500 kg. Ooops.

Education

Real-time interacting with the public, both present and remote

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There was a time when public aquaria's interaction with their public consisted of (1) displaying interpretation panels containing technical information on the exhibits, (2) offering live commentary from guides and/or volunteers and providing real-time information and answers to questions. Modern technology, however, allows for a (much) wider range of interactive formats, including… the mobile phone.

This little machine revolutionized the world in the new Millennium and offers far more functions than a simple phone-call, including a 24/7 high-speed connection to the world wide web, something that nearly 100% of all phones are equipped with.

Through intuitive QR codes, zoological institutions can now offer endless amounts of information easily accessible through individual phones, but we propose to take that one step further, by offering interactive – educational – games, which audiences may engage with at the aquarium, or at home, with each other.

Our presentation will offer practical examples of such capabilities, by having conference attendees playing educational games – in real-time – with each other and competing to save the world's oceans! We can only hope that competition doesn't drive tempers to run too high, and we will ensure that the atmosphere in the room will remain fun, light, and – above all – profusely entertained!

Educational Technology's Role in the Future of Aquariums: Opportunity or Existential Threat?

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As aquariums grapple with the accelerating pace of technological change, a critical question emerges: is educational technology a threat to the traditional aquarium model—or a powerful tool for advancing its mission? This presentation explores the role of emerging technologies like virtual reality (VR), augmented reality (AR), and AI-driven personalization in enhancing—not replacing—the real-world, sensory-rich experiences that define aquariums.

How do we ensure that digital enhancements support the core mission of education and conservation?

This session proposes a middle ground: a future in which technology is not the experience, but a scaffold for meaning-making. Through three key categories—immersive, overlay, and personalized technologies—we explore how aquariums can thoughtfully integrate digital tools to elevate the guest experience.

We'll examine real-world case studies from aquariums around the world with slides and video clips (Shedd Aquarium, Shark Reef Aquarium, Oceanogràfic Valencia to name a few) and will explore emerging neuroscience on immersive learning, which suggests that immersive technology activates memory and empathy centers in the brain more effectively than passive media. Overlay technologies, such as AR offer opportunities to add contextual depth and

interactivity to exhibits—without sacrificing the power of real-life encounters. Finally, personalized AI-driven systems offer scalable interpretation tools, adaptive content, and inclusive accessibility for multilingual and neurodiverse guests.

This presentation makes the case that technology is not a threat to aquariums, but a catalyst—if implemented with intentionality and alignment with institutional values. We will provide a framework for evaluating and deploying digital tools in service of mission-driven outcomes, not just novelty or spectacle.

Key Takeaways for Attendees:

Understand the strengths and limitations of emerging educational technologies in aquarium settings.

Learn how to design immersive and personalized digital layers that reinforce, rather than compete with, animal exhibits.

Explore strategies for mission-aligned implementation that maximizes impact without compromising authenticity.

Educational Technology's Role in the Future of Aquariums: Opportunity or Existential Threat?

Exhibits Design & Planning

Tropical Getaway: a new exhibition to explore the heart of mangrove forests and the beauty of coral reefs.

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Opened in 1998 and visited by more than 15 million visitors, the "Tropical lagoon" exhibition, in the "Mankind and shores" route, needed a full renovation.

After almost 3 years of construction (complete renovation of tanks, new scenography, restaurant) and many challenges, our new exhibition invites participants to immerse themselves in the richness of tropical ecosystems, discovering the spectacular diversity of coral reefs and mangroves. Through a sensory and immersive journey, they will become aware of beauty, but also the importance for mankind and the vulnerability of these ecosystems in the face of human pressures and climate change.

Through several tropical aquariums, Nausicaa shows the biodiversity of the different areas: mangroves, lagoon, reef flats and channels.

The tour ends in the "Action Corail" laboratory, a place of hope and innovation, where concrete actions to restore and preserve these fragile environments are presented: the world coral conservatory, Caroline BONPAIN's CRIOBE thesis, the Coral Resilience project, coral reef restoration projects, and a participatory fund-raising scheme called "mission corail", to encourage everyone to become involved in protecting these natural treasures.

A new tropical-inspired restaurant, "la table d'Ephelia", with a magnificent view of the lagoon enables us to diversify our catering offer, with a bistronomy menu.

This new space, eagerly awaited by the public, will open its doors in summer 2025. The complexity of the site, the uncertainties and the ongoing adaptations were a real challenge, but the feedback from visitors is the mark of success for this major renovation of the center.

Which challenges [are] ahead for the Public Aquariums Community[?]

Nathalie Gamain Institution, EILAHTAN
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The EU agenda provides a great framework for the aquarium community in Europe to run their activities. We can easily think about the importance of conservation, education, and research in tackling the protection of biodiversity, safeguarding the health and welfare of animals being exhibited and/ or cared in the wild… or adopting the highest standards when running daily operations.

This presentation aims at presenting the challenges public aquariums in Europe should consider while running their core activities, more particularly by addressing the various topics on the EU agenda; as well as highlighting the important role all stakeholders, including the public aquariums community, have while shaping and refining this agenda- in a time at which certain parties call for an end of aquariums activities.

Where is our niche at Ostrava Zoo?

Markéta Rejlková, Ostrava Zoo
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Ostrava Zoo is a city zoo with extensive forest grounds. About 600,000 visitors come here every year mainly looking for entertainment and attractive large animals. We do not have a dedicated aquarium house; aquariums are components of various geographically specialized exhibits. They mostly fill niches alongside mammals or reptiles, even if they are dominant in space. There are a total of 25 aquariums or indoor ponds inhabited by fish or aquatic invertebrates in the exhibit area. Because these are sometimes mixed exhibits or have a narrow geographical scope, the selection of species is restricted and the primary purpose of these tanks is to demonstrate a specific environment, or to educate.

But we also have 128 tanks behind the scenes and we focus on a different aspect of our work there - breeding, species conservation, advancement in husbandry. There is also a bit of play and learning involved. Maintaining a motivated and developing team – of three keepers - is a challenge, as is contributing meaningfully within the European community of zoos and aquariums and on a global scale, too. Ostrava Zoo's focus on conservation is very strong and is key to our decision-making on species selection. But also our capacity, skills, experience, personal affections, ... all of this needs to be confronted with the vast number of species that need our attention. We are still fine-tuning our collection, but it is becoming clear that our strength – and therefore the niche that we can help fill – is in smaller freshwater species. But will the bet on the almost laboratory work pay off in the long term? Can we retain the great keepers who are essential?

Abstracts from the Aquatic Animal Life Support Operators Symposium Oregon Zoo, Portland, Oregon, March 29 – April 2, 2025

You Can't Ball Bio-Self: How Bio-Balls Ascended to Cultural Iconography and Seeded Seattle Aquarium's Ocean Pavilion in the Nick of Time

HANNAH MEWHIRTER
Seattle Aquarium, 1483 Alaskan Way, Seattle, WA 98101, USA

In August 2024, the Seattle Aquarium transformed the historical waterfront by opening the Ocean Pavilion – a building with 25 independent closed seawater systems and a combined 671,000 gallons of tropical habitats. Opening day loomed as construction delays necessitated a creative approach to expedite cycling without bottled bacteria. A 19,000-gallon system was prioritized as the first commissioned habitat to function as a bio-farm to seed subsequent habitats with nitrifying bacteria. The system was filled with 369,000 bio balls, co-dosed with ammonium chloride and sodium nitrite, heavily buffered with sodium bicarbonate, and temperature was increased to create optimal conditions for building robust populations of nitrifying bacteria. Once nitrification was confirmed, bio balls were transplanted to seed each habitat and reduced naive cycling to 31 days. The marketing and water quality teams combined efforts on a campaign to digitally adopt Ocean Pavilion bio balls to educate and engage the public amidst construction delays.

Making it Work: Making the Move to Life Support

JONNY KELLNER
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Are you a maintenance technician looking to apply your 'Jack of All Trades' skills to a more specialized role? Or perhaps you're an aquarist wanting to expand your aquarium operations expertise? This lecture aims to offer encouragement, advice, and, hopefully, a clear path forward

for aspiring Life Support System (LSS) Technicians. During the presentation, I will share my journey to landing my dream job, as well as valuable advice from industry leaders. You'll gain insight into what they're looking for in potential operators. We'll also explore the rewards and challenges of day-to-day Life Support Operations, drawing from both my own experiences and those of seasoned professionals in the field. Additionally, I will provide a list of resources to help you expand your Life Support knowledge and skill set. I look forward to sharing my experiences and hope to inspire the next generation of professionals in this extraordinary career!

A Guide to Fiberglass Repair for LSS Operators and Professionals

ALEX ANDERSON
Georgia Aquarium, 5555 Gwaltney Dr, Atlanta, GA 30336, USA

The purpose of this presentation is to give LSS professionals basic knowledge about fiberglass construction and fiberglass repair, along with how this skill can be used by LSS professionals. This can be a valuable skill since most facilities have a variety of fiberglass tanks and vessels that can require different remedies over time. We will cover everything a person needs to be an effective asset to their organization when maintaining and repairing fiberglass. This will include multiple examples of tools, materials, and theory. I want to give fellow LSS professionals the confidence to tackle a small project or small repair that would benefit their facility.

Making Connections through the Intersections

ANGELA SMITH
Seattle Aquarium, 1483 Alaskan Way, Seattle, WA 98101, USA

In 1989, Kimberle Crenshaw used the term intersectionality to describe the additive effects of discrimination. Since that time, social and healthcare scientists have investigated the best approaches to highlighting and incorporating individuals' distinct experiences with the systems of inequality in society. There has been more focused attention given to societal inequities in the United States since 2020, and in specific careers, how those inequities impact employee wellbeing and retention. Researchers in the zoo and aquarium field have begun investigating employee retention examining two intersectional factors, typically race and gender. Building upon J. Marino's (2023) work, this proposal intends to review and suggest potential analysis method(s) for incorporating three intersectional identities and offer suggestions for survey design. The survey design will be structured to collect information about how the intersections of race, LGBTQIA+ and neurodivergence can impact overall employee wellbeing in the zoo and aquarium field.

Intake Pump Failures at Monterey Bay Aquarium

BAILEY LUCAS
Monterey Bay Aquarium, 886 Cannery Row, Monterey, CA 93940, USA

The past year has been a wild and eventful time for pumping seawater into Monterey Bay Aquarium, with multiple intake pump failures and long factory lead times testing the limits of our redundancy and resourcefulness. As a flow-through aquarium, losing incoming seawater flow

for any length of time can have detrimental effects on LSS, exhibits and the animals. Historically, each of the 50hp, 25-foot long, vertical turbine intake pumps were removed every 5 years for routine rebuilds. In the past 13 months, we have removed and installed the pumps 6 times due to broken shafts, disintegrated bearings, sheared bolts and more. Despite these challenges, we've kept seawater flowing into the building thanks to resourceful ideas and major teamwork. This talk will summarize how we responded to the equipment failures and adapted to the absence of both primary and backup intake pumps. Spoiler alert! We're not out of the woods yet…

30 Year Career in Life Support Systems ("LSS")

RICK LEACH
Monterey Bay Aquarium, 886 Cannery Row, Monterey, CA 93940, USA

This presentation will serve as a retrospective journey through a 30-year career in life support systems. The topics, moving chronologically through my career, will highlight a few of the fundamental changes witnessed that I am excited to share with newcomers to the field. These topics will include the evolution of automation as well as developments in technology and workforce diversity. New engagement, creativity, and collaboration have brought attention to an otherwise obscure and unknown specialty. Through college curriculums, advancement in ocean and environmental sciences, as well as AALSO's influence, "LSS" has evolved into a bona fide career. Having bear witness to it all I am proud to share this snapshot with those of you dedicated to such a unique and fascinating field of work.

Sharks on the Move

BARRETT RHOADES
Georgia Aquarium, 5555 Gwaltney Dr, Atlanta, GA 30336, USA

In 2020, Georgia Aquarium needed a way to move hammerhead sharks from our offsite facility to the main aquarium in downtown Atlanta for our new Predator exhibit. We designed and built a 4,000-gallon transport tank on a 53' aluminum flatbed trailer. This transport tank has its own dedicated life support system complete with generator, chilling and heating, mechanical filtration, oxygen dosing, cameras for monitoring animals and an I/O system with remote monitoring and access as well as WIFI. This trailer has been invaluable to Georgia Aquarium and has been used countless times to move animals across the country. Through the preliminary design and build we made various changes and improvements to numerous aspects including how the baffles are supported and how we dose oxygen to the system, and we recently have been through an additional renovation to make improvements to the trailer's operation. This presentation will highlight the innovation in design and the changes we have made since its original conception.

Big Aussie Fishes on Holiday:
Handling Techniques and Equipment for Oceanarium Animal Capture and Interstate Transport

JOHNNY MAY[1]; LAURA SIMMONS[2]
[1]*Aquatic Development and Consulting, LLC, 7901 4th St N Ste 300, St. Petersburg, FL 33702*
[2]*Merlin Entertainments, 3 Market Close, Poole, Dorset, BH15 1NQ*

Inherent with any aquatic animal transport are a range of considerations and risks; moving mature, very large oceanarium animals adds to the complexities. In January of 2023, the 25-year-old, 2.2 million litre oceanarium at SEA LIFE Melbourne Aquarium in Victoria, Australia, was scheduled for a major renovation drain-down. In preparation for this event, the resident population, which included a 2.0 metre Speartooth shark *(Glyphis glyphis)*, 3.8 metre Largetooth Sawfish *(Pristis pristis),* and 250+ kilo Smooth stingrays *(Dasyatis brevicaudata),* needed to be temporarily relocated to sister SEA LIFE Aquaria, 1,000-1,800 km away. The surface of the oceanarium is in the sub-basement level of the facility, with narrow corridors and a 2.7 by 3 metre opening leading to the street/ground level. Because of these constraints, custom capture and transport equipment was engineered and manufactured to ensure the safe and successful handling of all animals. Three years of planning lead to the successful removal and transport of the ocean habitat residents.

In: Oxygen Concentrators, out: Cryogenic Oxygen: How Seattle Aquarium is Implementing Oxygen Concentrators to Optimize Their Oxygen Supplementation System

JULIETTE HORN
Seattle Aquarium, 1483 Alaskan Way, Seattle, WA 98101 USA

The Seattle Aquarium draws in seawater from Puget Sound via Elliott Bay to supply its flow through temperate fish and mammal habitats. Dissolved oxygen in Elliott Bay is consistently below the ideal 100% saturation which necessitates additional oxygen supplementation. Dissolved oxygen levels are raised by injecting liquid cryogenic oxygen where seawater enters the facility. Over the years that method has proven to be expensive, inefficient, hazardous, and unsustainable, which demanded a change to this process. A facility-wide oxygen supplementation plan utilizing oxygen concentrators is in its beginning stages of execution. The first trial habitat is a 120,000-gallon, semi-open temperate system, where an oxygen concentrator doses oxygen locally, based on habitat-specific needs. While in the early stages of a facility-wide implementation, this method has resulted in efficient oxygen use, cost savings, sustainability success and hazard mitigation. Future objectives include introducing localized oxygen concentrators facility-wide, automation and increasingly efficient oxygen use.

123 Easy Auto-Dosing: Setting Up and Maintaining an Auto-Dosing System

JARRED MCCORMICK
St. Louis Aquarium at Union Station, 201 S. 18 St, St. Louis, Missouri 63103, USA

Manually chemically dosing the largest exhibit at St. Louis Aquarium, Shark Canyon, is both a time-consuming process and a constant uphill battle. To combat this, our LSS team designed

and implemented a sodium carbonate dosing system to maintain steady pH levels. After the initial construction and cross-system connecting, we began to determine a standard operating procedure (S.O.P.). The goal was to find a procedure that would both properly maintain the doser and minimize the amount of time that needed to be spent on servicing it. The S.O.P. demonstrates the steps taken to reach that equilibrium, as well as shows the various troubleshooting steps required to reach a properly functioning system.

Laboratory Induced Marine Snow and Roller Table Mechanics

PARIS WATERS; MADELINE SUNSHINE; ALYSSA ANTOLAK; ANTONIETTA QUIGG
Texas A&M University at Galveston, 200 Seawolf Pkwy, Galveston, TX 77554, USA

Marine snow is an important - but often overlooked - component of aquatic environments, facilitating carbon sequestration, microbial communities, the food web, and even the creation of microenvironments. Marine snow is characterized as an aggregation of microorganisms and organic matter that are highly prevalent in marine environments. These forms of suspended matter harbor communities of phytoplankton, bacteria, and protozoans. Through the creation of these aggregates, carbon particles can be sequestered into the deep ocean, facilitating the biological carbon pump. This downward flux of particulate matter has made marine snow globally significant when understanding marine biological community structures. Marine snow is created and studied in the laboratory setting by utilizing roller tables. Cylindrical glass or plastic tanks are set on parallel bars in which rotating speed is controlled by an adjustable motor. The rolling table utilized in this experiment is equipped to host up to six tanks. Each tank is filled to the top plug then "burped" to expel any outstanding air bubbles, which can disrupt the formation of marine snow. The mechanics of the system are simple, and it can simulate many different events including oil spills, ocean acidification, and rising sea temperatures.

Rebuilding 20HP Pumps - Even You Can Do It

SARAH FALCON
St. Louis Aquarium at Union Station, 201 S. 18th St, St. Louis, MO 63103, USA

At SLAUS we are encouraged to do as much in-house maintenance as possible, including working on all sizes of pumps. We have six pumps that are in excess of 15HP and weigh over 350lbs that we previously had an outside vendor service, as many other facilities in our industry do for pumps this large. Recently my team and I have come up with our own ways of maintaining these pumps, including replacing seals and bearings. The tools, equipment and methods for working on pumps of this size are not so different than needed for rebuilding any old Leeson or Weg pump, and most facilities will already have the equipment and only need to apply the methods. We have saved ourselves and our facility valuable time and money by being able to rebuild these pumps ourselves.

Coca-Cola Cycling: You're Doing it Wrong!

BARRETT L. CHRISTIE
South Carolina Aquarium, 100 Aquarium Wharf, Charleson, SC 29401, USA

Ways to speed development of a new biofilter and increase the efficiency of nitrifying bacteria growth have been of interest to aquarists and operators as long as there have been public aquaria. In 2016, a novel method of combining two different recommended strategies (organic carbon supplementation and overcoming phosphorus limitation) was presented using an off-the-shelf soft drink (Coca-Cola™) as an additive to seawater. Since that time, a number of other aquariums and zoos have experimented with these methods and reported back, sometimes with mixed results. This talk takes a deeper dive into the dynamics of nitrification by ammonia- and nitrite-oxidizing bacteria (AOB/NOB) in a closed system, especially focusing on the differences between heterotrophic and autotrophic species and why the distinction matters in choosing cycling methods. Exploring the 'why' behind various methods, with and without supplementation, will help explain the potential benefits from additional phosphorus, and the potential pitfalls of using organic carbon when new biofilters are being established.

The Impact of Adding Aeration on Dissolved Oxygen

XENA BENITEZ
Odysea Aquarium, 9500 E Vía de Ventura, Scottsdale, AZ 85256, USA

In the Spring of 2024, we noticed that the dissolved oxygen levels (DO%) within our Palometa Exhibit at Odysea Aquarium were dropping (below ~90%). The LSS team theorized that the oxygen levels were dropping due to the over bio-load of palometa in the exhibit and the amount of food being processed in the exhibit. To aid in maintaining levels (optimal range ~90% - ~100%) an aeration device was installed that would draw oxygen from a 6.7 CFM air compressor. It helped circulate the excess waste product bio to the surface of the exhibit and increase oxygen levels. DO% data 2 months prior to and 2 months post installation was collected. The data shows the DO% being ~90% below range pre installation & ~90%-~100% within range post installation. The data indicates that the installation of the aeration device has significantly aided in keeping the exhibits DO% within our optimal range.

Does Double Dosing Ammonia and Nitrite Speed Establishment of a Biofilter?

LARRY BOLES
Oregon Coast Community College, 400 SE College Way, Newport, OR 97366, USA

Cycling new aquariums to establish a healthy biological filter has historically been a mixture of art and science, especially in the hobbyist world. Professional aquarists usually rely on ammonia dosing using ammonia salts to start a community of nitrifying bacteria. Providing the food source for Ammonia oxidizing bacteria (AOB) should create an environment supporting the recruitment of naturally occurring bacteria or enhancing the growth of commercially prepared bacterial cultures added to the tank. In this traditional approach to tank cycling, AOB's will consume ammonia and generate nitrite that then becomes food for nitrite oxidizing bacteria (NOB's). A fully cycled system will consume any free ammonia and nitrite quickly and prevent

the compounds from reaching toxic levels in the environment. During the establishment period, it may take weeks before an adequate bacterial population is established in the biological filter and many aquarists report getting "stuck" at the point ammonia is being oxidized quickly but nitrite is persisting and accumulating rather than being converted to nitrate. We studied the development of nitrifying bacteria in replicated, newly-established marine systems under varying conditions of ammonia and nitrite concentrations. We will report on the differences in time for establishing biological filters under varying conditions. Our hope is that the results will help inform the practices of aquatic professionals and hobbyists when setting up new systems for aquatic animal care.

The Efficacy of Various Filter Media in Removing Copper from Treated Seawater

KESHIA NAIDOO
South African Association for Marine Biological Research, uShaka Sea World, South Africa Durban, 1 King Shaka Avenue, 4001

Antiparasitic copper treatment is a part of routine marine aquaria quarantine, and, at times is used to treat fish on exhibits. Free copper will react with calcareous materials, to form insoluble copper carbonate. This will leach out into fresh, untreated saltwater once a bath treatment is completed. As copper is toxic to invertebrates, any residual copper can cause mortalities. This project investigated and compared the efficacy of various filter systems in removing residual copper in saltwater. The four-filter media were activated carbon, zeolite, poly-filters and powdered banana peels. Results showed that zeolite and powdered banana were initially successful in absorbing free copper. The pH and temperatures were stable. After two months zeolite became deactivated and activated carbon achieved good absorption. The Poly-filter showed slow absorption during the experiment. In conclusion, activated carbon was the best filter media although taking a long period of time to absorb the free copper.

To Waste or Not to Waste: Waste Reduction in Bioburden Testing

KEENAN WONG
Seattle Aquarium, 1483 Alaskan Way, Seattle, WA 98101, USA

The Seattle Aquarium performs routine fecal coliform and enterococcus testing on marine mammal habitats and touch pools. Popular methods include Millipore Sigma's proprietary membrane filtration for bioburden testing or IDEXX's quanti-trays. Both methods produce significant quantities of biohazard and recycling waste, plus comes with significant financial cost. This new "green" method follows the principles of Millipore Sigma's membrane filtration and reusable instrumentation instead of single-use consumables. This in-house developed method uses autoclavable funnels, glass petri dishes, and disposable mixed-cellulose ester filters. This reduced biohazard waste by 88%, landfill waste by 100%, recycling waste by 98%, financial cost by 88%, and labor hours by 50% annually. The "green" method was validated by comparative analyses alongside Millipore Sigma's membrane filtration and with proficiency tests completed annually as part of the Seattle Aquarium's lab accreditation through the Department of Ecology.

Streamlined Success: Optimizing Water Quality Analysis in Zoo Environments

SAMANTHA YORK
San Diego Zoo Wildlife Alliance, 2920 Zoo Dr, San Diego, CA 92101, USA

In this presentation, I will explore the enhancements made to the SDZWA's water quality laboratory processes, ensuring that all analyses align with AALSO-recommended holding times. The water quality laboratory is responsible for monitoring approximately 1.3 million gallons of exhibit water and we have streamlined our procedures to optimize efficiency, precision, and accuracy. I will illustrate how these improvements have not only increased our operational effectiveness but have also enabled us to identify potential issues before they adversely affect animal health. We will also examine obstacles faced by zoos in water quality testing and identify solutions to rectify them. Attending this lecture will provide insights into addressing these challenges and fostering a culture of continuous improvement. Our approach integrates laboratory methods, technology and practical experience to offer strategies for effective problem solving that contribute to the overall well-being of our zoo's aquatic environments.

Aquarium Care in the Classroom to Promote Sustainability and Conservation

ALOENDRA DZUR, LVT, CVT
Alaska Pacific University, 4101 University Dr, Anchorage, AK 99508-4647, USA

Incorporating aquarium care into the curriculum of secondary education offers a unique, hands-on approach to teaching sustainability and conservation. By introducing students to live ecosystems, they can gain a tangible understanding of both the fragility and resilience of complex, biodiverse ecosystems. Aquariums provide the necessary dynamic environment to introduce difficult topics such as ethical sourcing, the impact of human activities on aquatic life, and the importance of conservation. The experiential learning gained through aquarium care can foster and encourage responsible environmental stewardship, and introducing these concepts at an impressionable age not only nurtures an early passion for marine biology but also empowers students to advocate for sustainable practices in their communities. In-classroom aquarium care connects students to real-world ecological issues and can inspire future generations to preserve our planet's delicate ecosystems.

Updating an Effluent Treatment System for Increased Efficiency and Reduced Resource Usage

CHRIS EMMET
Birch Aquarium at Scripps, 2300 Expedition Way Scripps Institute, La Jolla, CA 92037, USA

Birch Aquarium is a public Aquarium located on the campus of UC San Diego in La Jolla. The facility exhibits species native to California as well as species that are considered non-indigenous to the state. The majority of seawater in the facility is discharged to the nearby Pacific Ocean, but any water that contacts a Non-Indigenous Species must be treated prior to discharge to prevent introducing potentially invasive species or pathogens to California water. In 2024, a major overhaul of the NIS treatment system occurred, replacing a bank of filter socks with an automated

drum filter. Since this upgrade, staff hours dedicated to filter upkeep and use of consumables have decreased, an improvement in efficiency & green practices.

"Cool" Corals - Mesophotic Coral LSS Construction

ALEX FORTES
Mississippi Aquarium, 2100 E Beach Blvd, Gulfport, MS 39501, USA

As a deepwater Gulf of Mexico interactive exhibit was planned for Mississippi Aquarium, it was decided that a living coral habitat representing deepwater mesophotic reefs would be incorporated as a final attraction for guests. Deepwater reefs are significantly different from the shallow, tropical reefs most aquarists are used to; a unique LSS design was required as a result. In addition, several challenges were faced regarding habitat placement in a pre-existing building. Constructing the exhibit in inaccessible back of house areas lead to overcoming unique challenges, such as cramped saltwater mixing areas and performing water changes when no drains exist. Utilizing vertical space, creating additional off-habitat water volume, wastewater vats with sump pumps due to lack of floor drains, and creating an LSS layout that minimized husbandry woes and remained accessible to staff, were some of the considerations for system construction.

Pinnipeds in Paradise: The Advantages and Challenges of Life Support Operations at a Specialized Rehabilitation Center in the Middle of the Pacific Ocean

STEFANIE COOKE
The Marine Mammal Center, 73-731 Makako Bay Dr, Kailua-Kona, HI 96740, USA

The Marine Mammal Center's satellite facility in Hawaii, *Ke Kai Ola*, is the only long-term rehabilitation center for endangered Hawaiian Monk Seals. Located along the Kona coast of the Big Island, the center is stationed in a unique location. Our background, mission, and overview of the center will be featured, along with elements of our existing life support system and animal holding areas. We'll explore what it takes to operate and maintain this one-of-a-kind program with a small team, including the challenges we are presented with due to our remote location.

Cincinnati State's Big Automated Water Loop ("BAWL")

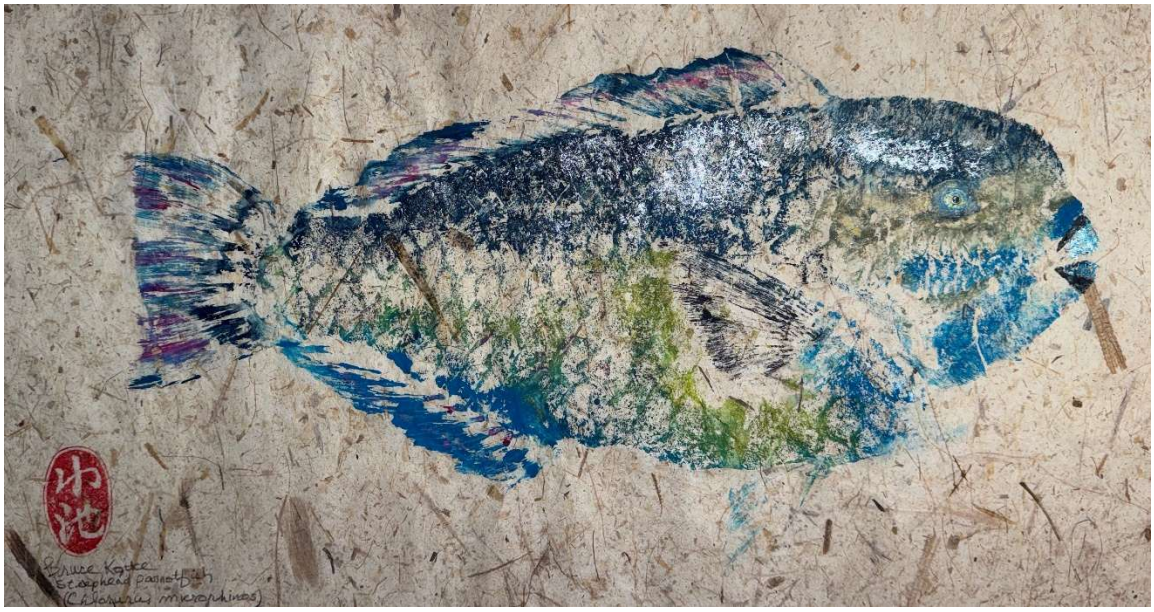
RYAN SCHAFFER
Cincinnati State Technical and Community College, 3520 Central Pkwy, Cincinnati, OH 45223,

Learn about Cincinnati State's Big Automated Water Loop ("BAWL") which has been constructed by students and faculty in the Environmental Engineering Technology (EVT) program. Although the "BAWL" is still a work in progress, the students have constructed the main loop and a couple side loops. Learn how this has been accomplished by participating in AALSO symposiums and through networking with vendors as well as receiving donations, sponsorships, and repurposed equipment from community partners. The "BAWL" is used in several EVT courses for student projects as well as for recruiting purposes.

Lessons in Adaptation: The Evolution of a Teaching Life Support System

AUDREY FOX
University of New England, 11 Hills Beach Rd, Biddeford, ME 04005, USA

The Recirculating Aquaculture system at the University of New England has seen many different animal residents over its fifteen years of operation. The use of the system as a teaching tool has influenced many of the changes, alterations and improvements seen between species. The transition between the system's original purpose, that of rehabilitating seals, to the current cultivation of wild Atlantic Salmon (*Salmo salar*) demanded drastic changes. The constant remodeling and upgrades reflect decisions made due to being resourceful, a commitment to animal well-being, advancements in technology, as well as mistakes and oversights. This constant modification has completely transformed the system, increasing its value as a teaching tool.



November 18-21, 2025
Phillip and Patricia Frost Museum of Science
1101 Biscayne Blvd, Miami, FL 33132

This was the third 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 210 individuals attended the event, resulting in 51 oral presentations, 13 poster presentations and 5 workshops.

-Shannon Jones, Frost Science Senior Director of Conservation
Contact for ReeFL 2026, dates TBD: sjones@frostscience.org

Organizing Question 1: Educate

The Coral City Camera: A Citizen-Science Project on an Urban Reef

Colin Foord[1]
[1]Coral Morphologic

The Coral City Camera is a hybrid art-science project that has been viewed more than 4 million times since it was first deployed at the east end of PortMiami in early 2020. In partnership with NOAA AOML, the CCC serves as a scientific instrument to monitor the health and biodiversity of an urban reef community at the east end of PortMiami. The site consists of limestone riprap boulders deployed in 2011 to protect Port infrastructure from wave erosion, but inadvertently created a biodiverse artificial urban reef worth studying. In only 12 years, these boulders have naturally recruited at least 25 species of stony corals species, including dozens of endangered

Orbicella sp that are now of spawning size. The site hosts high densities of SCTLD-susceptible corals that proved bleaching resistant during the summer of 2023. Research published with NOAA has shown that these urban corals appear to be more resilient than their offshore counterparts. Fast growing strains of elkhorn and staghorn native to inside of PortMiami naturally hosting *Durusdinium* zooxanthellae did not bleach in 2023. The CCC has enabled the creation of a 2+ year long underwater timelapse of coral growth. With the help of viewers on Youtube, we have logged over 65,000 observations and documented 218 species of fish (as well as manatees, sea turtles, dolphins, and diving sea birds). Aside from the research, the CCC has created an active community of 'Coralheads' who watch on a daily basis as a relaxing and non-invasive way to enjoy nature. Many of these people had little experience diving on Florida reefs, but have since become adept at identifying species and helping new viewers. Awarded the 'Best Public Art Installation' in 2020, the CCC has raised people's awareness of Miami's coastal marine ecosystems and built civic pride through our subtropical biodiversity.

Understanding Constraints and Negotiation Strategies of Different User Groups in Monroe County, Florida

Robert Burns[1], Mary Allen[2], Danielle Schwarzmann[3]
[1]West Virginia University, [2]lynker, [3]ONMS

Understanding visitor use at Monroe County coastal recreation settings provides resource managers with critical information needed to deliver high quality and pertinent information about the opportunities that exist on, under, and near the waters in the county. This study examined the socio-economic makeup of users recreating along Highway 1, at bridge fishing sites, roadside parks, and other settings. Twenty-two constraints items were grouped into intrapersonal, interpersonal, and structural constraints. The most reported constraints were *lack of time* (mean = 1.84), it *costs too much* (mean = 2.11) and *FKNMS is too far from me* (mean = 2.13). *lack of time* (mean = 1.84) and *can't afford* (mean = 2.42). The second part of the analysis examined fourteen negotiation strategies to understand how these recreation users overcame the constraints. The strategies that were mostly used by respondents to negotiate their participation was *I set aside time for outdoor recreation activities* (mean=4.08), *I try to plan ahead so that I can recreate* (mean=3.99), *and I recreate close to home* (mean=3.90) and *I save up money to do coastal outdoor recreation* (mean=3.84). Differences were examined between different user groups (age, income, education, race/ethnicity), which will be parsed out in the oral presentation. The resulting findings can be used to develop new and innovative ways of ensuring equity in accessing sanctuary settings. Analyzing these recreation participants enabled researchers to understand what constraints different recreationists perceived and what negotiation strategies they used to overcome known constraints. While constraints remain, resource managers can focus on how users navigated and overcome these constraints, and tailor solutions to specific user groups. These solutions and suggestions will be discussed in the oral presentation.

Protecting Florida's Coral Reef: DEP's Reef Injury Prevention and Response Program

Kimberly Platt[1]
[1]FDEP

Since the implementation of the Florida Coral Reef Protection Act (CRPA) in 2009, the Florida Department of Environmental Protection (DEP) has served as the state's lead trustee for protecting, restoring and educating the public around Florida's Coral Reef resources. The goal of the CRPA is to protect coral reefs from impacts through increased legal authority by making it illegal to anchor on or otherwise damage a coral reef in state waters. This act entrusts DEP with the authority to enforce such violations and collect damages and civil 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 and mitigation when injuries do occur. The high resident and tourist population in Southeast Florida puts increased pressure on coral reefs, including considerable anchor usage along our reef tract. Even small anchors improperly placed on coral reef habitat can crush and dislodge corals, which can take years to recover from. One of the primary goals of the RIPR Program is to reduce coral reef injuries in Southeast Florida by educating the public about the CRPA, safe anchoring practices, mooring buoys and sharing Florida's Coral Reef Locator Map. The RIPR Program works directly with the Southeast Florida Action Network (SEAFAN), a citizen reporting and response system designed for the general public to report a variety of marine incidents. The RIPR program is responsible for responding to all SEAFAN reports concerning vessel groundings or anchor damage. This presentation will give insight into both the preventative and post-impact response measures that DEP's RIPR Program takes to protect and conserve coral reef habitat in Southeast Florida.

Reaching Citizens Where They Are: How Communications and Social Media Play a Vital Role in the Conservation of Florida's Coral Reef

Alexa Pavan[1, 2], Thomas Quintero[1, 2]
[1]Friends of Our Florida Reefs (FOFR), [2]Conscious Content Clips

Through creating hundreds of pieces of content for Friends of Our Florida Reefs (FOFR) over the past two and a half years, we have found that many Floridians do not know coral reefs exist. While vital research is being conducted, there is a significant disconnect in relaying the information in a digestible and engaging way. At Conscious Content Clips, our approach focuses on utilizing digital assets through social media primarily to entice, educate, and elicit behavioral change. This informal approach breaks down barriers to knowledge, providing a casual and interesting way to present scientific information and share en masse. A mix of videos, images, infographics, and straightforward language to execute this delicate balance. In addition to prioritizing accurate and clear communications, we strive to make connections between coral reefs and other ecosystems on Earth, further solidifying that all life is connected.

Fostering a community of engaged citizens has further emphasized the economic value and impact of coral reefs on their everyday lives. While our primary intention is to educate about coral reefs online, we simultaneously focus on inspiring behavior change offline, addressing issues like plastic pollution and rampant overdevelopment that negatively impact coral reefs. Through repetition, consistent branding, and simplified language, we reach citizens where they are. Nonprofit

organizations are particularly poised to connect with the public in an organic way that is mutually beneficial for both parties, but this strategy can be effective for any type of organization.
While coral research findings are compelling, a failure to effectively communicate these topics is a disservice to the arduous effort, time, and resources put into this work. Ultimately, our goal is to bridge the gap between science and the general public, who are not as well-versed in scientific communication, while conveying the value coral reefs provide to all inhabitants of Earth.

Minimizing Potential Effects to Corals While Maintaining Beaches and Channels in Southeast Florida

Kristen Donofrio[1], Nikki Edelenbos[1]
[1]U.S. Army Corps of Engineers

The U.S. Army Corps of Engineers, Jacksonville District (Corps) maintains 27 beach segments, 13 deep draft harbors, and various shallow draft navigation channels, such as the Atlantic Intracoastal Waterway, throughout the peninsula of Florida. Of those projects, almost half (12) of the beach nourishment projects and 4 of the deep draft harbors are located in Southeast Florida. These projects occur within range of threatened and endangered corals that are protected by the Endangered Species Act. In this presentation, the Corps will provide a brief background on the Endangered Species Act followed by a summary of the project design criteria, as well as the environmental compliance and reporting requirements for existing Federally authorized and maintained navigation channels and beach nourishment projects located within range of threatened and endangered corals.

Environmental education for the next generation

Dora DeMaria[1]
[1]Assistant Executive Director, Reef Relief

Reef Relief is a nonprofit organization based in Key West, Florida, dedicated to protecting and preserving coral reef ecosystems through education, conservation, and advocacy. Since its founding in 1986, Reef Relief has worked to raise public awareness about the importance of healthy oceans and inspire action to reduce environmental threats. Through hands-on programs, community outreach, and policy engagement, Reef Relief empowers individuals of all ages to become active in marine conservation.
Reef Relief's education program is a cornerstone of its mission to protect and preserve coral reef ecosystems through informed public stewardship. Since 2010, Reef Relief has reached over 90,000 students worldwide with its dynamic marine science curriculum. The program emphasizes the critical importance of environmental education in fostering a generation of environmentally conscious citizens who understand the impact of human activity on fragile marine ecosystems.
By partnering with schools, leading summer camps, and other programs, Reef Relief creates opportunities for students to become active participants in marine conservation. The program cultivates environmental stewardship by empowering students to act in their own communities—whether by reducing plastic use, organizing cleanups, or sharing what they've learned with others. Reef Relief is helping to build a more sustainable future by planting the seeds of conservation in the next generation. During this presentation, Reef Relief staff will present on how they

communicate the science in a digestible manner, as well as look at impacts that their programs have on long term education goals. Attendees will gain access to free curriculum as well as take the opportunity to discuss different methods of education to the public.

Teaching Coral Science Through Place: Lessons from Peanut Island

Kaleigh Fix[1]
[1]The Reef Institute

Peanut Island, nestled at the mouth of the Lake Worth Inlet in Palm Beach County, offers a rare convergence of accessibility, ecological diversity, and cultural relevance. It is an ideal centerpiece for a community-driven approach to marine science education. For years, The Reef Institute has used this site as a research focus and as the foundation of a long-standing educational program that invites students, teachers, and families to explore and connect with the marine environment through hands-on learning.

This session explores how a place-based, community-oriented education model can deepen scientific literacy while fostering a sense of belonging and stewardship. At Peanut Island, students learn to collect data, analyze marine conditions, and understand local ecology through real-world applications. Importantly, the site acts as an inclusive platform where *anyone*—regardless of background—can participate in marine science. Additionally, this unique location teaches us and the community about the power of adaptation in our reefs.

A key strength of the program is its emphasis on community engagement, which allows all community members to be part of the learning process.

The workshop will highlight:

- How sustained, place-based programming builds trust and long-term impact.
- Strategies for making marine education accessible to diverse audiences.
- The role of local public spaces in bridging science and community.

Empowering students as emerging scientists through repeated, meaningful field experiences.

Peanut Island serves as an example of how local ecosystems can connect community members to the nearby reefs, helping them realize that these natural wonders are accessible. This connection fosters a sense of ownership within the community and reinforces the idea that the ocean belongs to everyone.

Stronger Together: The Power of Partnerships in Coral Reef Conservation

Caroline Donovan[1], Maya Bhalla-Ladd[2], Katy Cummings[3], Shelly Krueger[4], Allison Holevoet[4]
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Coral reef management across federal, state, territorial, and local agencies is key to successful coral reef conservation at local and regional scales. Collaboration across these agencies enhances conservation, improves information sharing, and leads to better outcomes for coral reef conservation initiatives. Collaborative communication and shared messaging is crucial to convey the importance of coral reefs for cultural identity, shoreline protection, tourism and the local economy, public stewardship, and resilience. For example, the U.S. Coral Reef Task Force (the Task Force) is a national-level entity with members from 14 federal agencies, seven U.S. states and territories, four fishery management councils, and the Freely Associated States (Micronesia,

Palau, Marshall Islands). The Task Force focuses on nationally relevant coral reef conservation topics (e.g., restoration, natural infrastructure) that affect all U.S. coral reef areas, leveraging expertise across multiple disciplines. Similarly, Florida's Coral Reef Resilience Program (FCRRP) organizes and collaborates across 16 Florida-based coral reef conservation agencies, including state, federal, university, and non-governmental organizations (NGOs). FCRRP evolved from a massive mobilization of agencies, educational institutions, and NGOs in response to an unprecedented and highly lethal disease outbreak (stony coral tissue loss disease). Collaborating across federal, state, and local organizations led to an action framework for stony coral tissue loss disease response, which is now being applied for responses for other coral reef disturbance events and overall coral reef resilience initiatives. By working together, we have created opportunities to build capacity and support knowledge sharing. This presentation will highlight how shared objectives, common talking points, and media relations supported by science-based information creates stronger, more successful conservation and management programs.

Sustainability Initiatives: Driving Change Through Public Education

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Local businesses are deeply embedded in their communities, making them powerful allies in environmental education and action. Sustainability initiatives create meaningful, lasting change that reaches new audiences beyond traditional environmental circles. By partnering with local businesses, these efforts educate consumers and foster a culture of collective responsibility. Collaborations can take many forms: plastic reduction, sustainable product choices, and educational outreach. When businesses actively participate, sustainability becomes more visible, practical, and economically relevant to the public.

These campaigns help break the "preaching to the choir" cycle by engaging individuals who may not otherwise interact with "environmental" messaging. When a local café ditches plastic straws or a dive shop promotes mineral-based sunscreen, it sends a clear message: sustainability isn't just for activists—it's for everyone.

By combining grassroots energy with the influence of businesses, sustainability initiatives can scale their impact, shift behaviors, and create inclusive, resilient communities. Real change happens when we build together—from the ground up.

Reef Relief's proven approach to building grassroots sustainability initiatives goes beyond theory and we are here to share tips and tricks to build sustainability initiatives from the ground up. Using real-world programs like *Skip the Straw*, *Responsible Sunscreen*, and *Plastic Free*, we demonstrate how to design, launch, and sustain community-driven environmental action. These programs provide tangible entry points to coral ecosystem advocacy that are easy to implement and powerful in impact.

Scouts and school groups visit Sea Base for all-inclusive, educational experiences in the Florida Keys, Bahamas, and U.S. Virgin Islands

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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 14,000 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 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 can house over 15,000 corals and currently has seven coral species. Over 2,000 Scouts visit the coral nursery annually and learn about the role they can play in helping restore Florida's Coral Reef. Of these 2,000+ individuals, more than 1,000 youths work alongside Sea Base staff in the coral nursery and participate in a variety of hands-on activities, including feeding and propagating corals. In addition to assisting with coral restoration and husbandry, 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.

Organizing Question 2: Research

Genetic diversity, population structure, and gene flow among coral communities in urbanized ports and natural reefs across southeast Florida

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Florida's Coral Reef has been devastated by decades of disease outbreaks, land-based pollution, and marine heatwaves. Yet, some of the most resilient corals in the region have been discovered in habitats characterized by extreme environmental stress, such as highly urbanized, artificial substrates in commercial ports throughout southeast Florida. These corals persist under adverse conditions, including particularly poor water quality and acidification, as well as acute thermal stress. As such, they constitute a valuable source of resilient genotypes for restoration initiatives, and may provide critical ecosystem services to Florida's Coral Reef. We have evaluated the resilience of these 'urban coral' populations through field- and lab-based experimentation combined with multi-'omic approaches, finding them to be more capable of handling multiple

environmental stressors relative to natural reef conspecifics. Given their observed resilience, we investigated fecundity and sexual reproduction of urban corals in the Port of Miami, finding evidence they are reproductively viable. Questions remain, however, regarding their potential contributions to the persistence of natural reef populations through maintenance of genetic diversity and gene flow among urban and reef habitats. Using a restriction-site associated DNA sequencing approach (2bRAD) to identify single-nucleotide polymorphisms (SNPs), we genotyped over 900 colonies of the species *Colpophyllia natans*, *Diploria labyrinthiformis*, *Montastraea cavernosa*, *Orbicella faveolata*, *Pseudodiploria clivosa*, and *P. strigosa* sampled from urban and reef sites in Miami-Dade, Broward, and Palm Beach Counties. Here, we present the results of this multi-species population genetics assessment, identifying critical sites that maintain genetic diversity and support gene flow among populations in southeast Florida. By incorporating these genetic datasets into region-specific restoration plans, we can prioritize high-value coral genotypes and habitats for targeted restoration and conservation efforts to support the recovery of Florida's Coral Reef.

Utilizing Alkalinity Enhancement to Increase Growth Rates of Corals in Ex-Situ Nurseries

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Studies have shown that increasing seawater saturation state can increase coral growth rate by 50-100%. Ex-situ nurseries can significantly accelerate the production of outplantable-size corals for restoration efforts by maximizing coral growth rates, making them highly desirable. Ex-situ nurseries offer a stable, controlled environment that supports genetic diversity and coral growth, and establishes a reliable pipeline of corals for coral reef restoration projects. Given the critical depletion of coral populations in the Florida Keys and other regions, it's essential to optimize coral production in these nurseries for effective restoration. At the University of Miami Experimental Hatchery, we have six aquaria within three raceway tanks, each of which has 21 or 22 corals for a total of 129 corals. This experiment includes six coral species with six replicates each: *Siderastrea siderea, Acropora cervicornis, Montastraea cavernosa, Pseudodiplora clivosa, Acropora prolifera, and Acropora palmata*. We assessed coral growth utilizing the alkalinity anomaly method, which allowed for the quantification of net calcification across all corals. Preliminary data reveals that as aragonite saturation state was increased from the ambient seawater level of 4.0 up to 8.0, calcification increased 67%. Above 8.0, the response stabilized and no further increase in growth was observed. These results reflect the collective response of all corals in the aquaria rather than species-specific trends. Future work will determine species-specific responses. These findings demonstrate that in ex-situ nurseries, the growth of corals can be increased by ~1.7-fold with the simple addition of sodium carbonate and bicarbonate to the seawater, cutting the time for a new sexual coral recruit to reach outplantable size by approximately half.

Using Visual Data to Identify Deep-Sea Corals: Taxonomy, Abundance, and Distribution

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Tropical and subtropical zones in the Atlantic Ocean harbor extensive mesophotic coral reef communities at depths from 30 meters to greater than 150 meters; similar to shallow-water reefs, mesophotic reefs contain anthozoans of two classes: Hexacorallia and Octocorallia. Despite these reefs being more widely distributed than shallow-water Atlantic reefs, the identity, abundance, and distribution of community members remain cryptic when compared to shallow-water reefs. In part, this is due to the challenges that come with studying mesophotic communities - increased depth comes with increased difficulty in surveying and sampling. Furthermore, members of Octocorallia specifically are complicated to identify, with genetic sequencing or scanning electron microscopy (SEM) of sclerites (calcium carbonate pieces localized to the tissues of Octocorallia) being the main methods. Genetic barcoding of octocorals is tricky and limited, plus the number of taxonomists trained on sclerite identification is small. This project, completed as part of NOAA's Mesophotic and Deep Benthic Communities Restoration network seeks to: 1. Identify the abundance and distribution of a mesophotic reef-building hexacoral genus, *Oculina* in the Gulf of America and 2. Use SEM to confirm the identity of members of the mesophotic octocoral genus *Bebryce*, also sampled from the Gulf of America. For data regarding distribution and abundance, ROV footage was annotated using the platform TATOR, then verified and processed using Excel, RStudio and ArcGIS. *Bebryce* samples were prepared and then imaged using light microscopy and SEM. This work will both increase available geospatial data of these mesophotic genera alongside adding to the number of researchers who are familiar with sclerite identification.

Habitat-specific stony coral assemblage recovery trajectories following a severe stony coral tissue loss disease event

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Recovery of coral reef assemblages following disturbances hinges upon both the survival of adult coral colonies and the successful recruitment and growth of new individuals. However, these processes are heterogeneous across the reefscape and thus understanding their dynamics is critical to projecting recovery capacity and planning effective restoration efforts. We utilize 12 years of data from the Southeast Florida Coral Reef Evaluation and Monitoring Project to evaluate coral assemblage composition, juvenile abundance, and size structure across 18 sites in four reef habitats following the 2014 stony coral tissue loss disease (SCTLD) outbreak. Between 2013 and 2023, we observed a shift in adult coral assemblage composition away from SCTLD-susceptible species towards eurytopic species across all habitats, driven by both the decline in SCTLD-susceptible species from disease and an increase in generalist, low-relief species. Since 2018, the nearshore and inner reef habitats have maintained relatively high juvenile recruitment rates that have increased over time, while the middle and outer reefs have supported lower, more stable recruitment levels. *Siderastrea siderea* consistently dominated juvenile abundance in all habitats and juveniles of highly SCTLD-susceptible species were rare. In addition to *S. siderea*, *Porites* spp. contributed strongly to juvenile abundances on the nearshore and inner reef habitats, whereas juveniles of *Montastraea cavernosa* comprised a higher proportion of juvenile abundance on the

middle and outer reefs. Despite some recruitment, growth has been limited, resulting in a preponderance of smaller colonies and skewed size distributions, especially on the nearshore and inner reefs. The loss of many SCTLD-susceptible individuals coupled with the abundance of small, eurytopic species that do not significantly contribute to reef structural complexity will likely reshape Florida's reef into the future. Our study reveals minimal recovery of the coral assemblage and highlights how long-term monitoring can detect spatial differences in demographics for use in targeting restoration.

Stony coral tissue loss disease results in persistent microbial-level disturbances on coral reef ecosystems

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Stony coral tissue loss disease (SCTLD) has reduced coral diversity and homogenized benthic communities. Beyond coral loss, SCTLD may disrupt microbiome composition and function, which can have consequences for reef recovery. We examined microbiome changes of apparently healthy corals, water, and sediment at three reefs in the Lower Florida Keys during three SCTLD disease stages: before the arrival of SCTLD (*vulnerable*), during an SCTLD outbreak (*epidemic*), and after the outbreak (*endemic*).
SCTLD significantly altered microbial diversity and functional potential within apparently healthy corals and the surrounding reef environment. In corals, microbial alpha and beta diversity were highest at the vulnerable stage before declining by the endemic stage, which indicates lingering impacts of SCTLD on microbial diversity. Network neighbor and betweenness analyses revealed a loss of connectivity in microbial communities in coral and sediments during the endemic stage. Functional prediction showed increases in taxa with multidrug resistance genes as well as nitrogen and sulfur cycling genes during the epidemic stage. Putative nitrogen fixation genes were enriched in epidemic coral and seawater, and in endemic coral and sediments. SCTLD-associated taxa increased in apparently healthy corals, water, and sediments during the epidemic stage, with some taxa persisting in the reef environment during the endemic stage.

Defining water quality seascapes in the KJCAP, their relationship to hydrographic modeling connectivity, the 2023 coral bleaching, and SCTLD

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This study provides crucial insights into the hydrographic dynamics affecting coral reefs in Southeast Florida. By identifying key nutrient sources and their relationship to bleaching and disease, it lays the groundwork for effective management actions to mitigate coral disease and promote reef resilience. We identified the hydrographic connections between inland water sources

in southeast Florida (Government Cut, Haulover, Port Everglades, and Hillsboro) and coral reefs and investigated the environmental drivers and nutrients associated with bleaching and disease between 2018 and 2024. The most significant outcomes were: 1) analyte concentrations on the reef are increasing, 2) reefs northward of their adjacent inlet are most exposed to the water from that inlet, 3) Government Cut is a major transition between water quality seascapes, 4) increased exposure to terrestrial waters increases SCTLD lesions, 5) turbidity from high winds may help reduce bleaching, 6) mitigative actions in the Biscayne Bay system would have the most beneficial effect to water quality on the reefs, 7) nutrient differences in Biscayne may be affected by oceanside seagrass beds, and 8) the rate of increase in orthophosphates has slowed since the 2021 Miami-Dade County fertilizer restrictions. These findings highlight the importance of managing inland water quality to protect coral reefs. The hydrographic model provides a detailed understanding of how nutrients from inland sources are transported to reefs, offering valuable insights for targeted intervention strategies. Current efforts are extending the model's spatial footprint to capture the hydrodynamics of the entire FCR. Then using subsequent modeled nutrient data, compiled environmental data, and reef monitoring data we plan to conduct machine learning models of the relationships between factors relating to reef health for both corals and fishes. This would provide a deeper understanding of the factors affecting reef health and the ability to target high impact mitigative actions and restoration strategies.

Mapping the extent of the 2024-2025 Caulerpa microphysa macroalgae bloom on southeast Florida reefs

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Coral reefs are facing increasing threats from a variety of anthropogenic and environmental stressors, resulting in heightened coral mortality and a shift towards macroalgae dominance. With the decline of corals over the past 50 years, the Florida Reef Tract has become an algal-dominated system. Over this timeframe many periodic large-scale algal blooms, both native and invasive, have been documented and associated with local water quality, causing further decline. Between July and October 2024, a significant macroalgae bloom of *Caulerpa microphysa* was identified along 26 km of coastline centered off Miami Beach. This bloom was characterized by a dense carpet interspersed with multiple macroalgae species forming a mat 3-5 centimeters thick that smothered and killed low-lying benthic organisms and the bases of gorgonians and stony corals. Mapping the presence of *Caulerpa spp.* over this extent involved over 600 field observations from managers and scientists from Key Biscayne to Fort Lauderdale. The reasons for the bloom remain mysterious, but include the lack of nearby hurricanes, unusually high water temperatures, and high nutrients. Ongoing molecular analysis is underway to confirm species and strain identity. Most of the mat dissipated in November with the onset of windy conditions; however, patches have been documented overwintering. Members of Chlorophyta have a positive correlation between overwintering biomass and intensity of following blooms. With the re-emergence of heavy coverage as early as May 2025, we anticipate more intense blooms and will report on the 2025 observations and extent of the bloom and compare these to the 2024 observations. Given the potential ecological consequences of this bloom, we propose the establishment of a more permanent monitoring effort to track the distribution of *Caulerpa spp.*, with aims to understand

drivers behind these blooms, their impact on reef health, and to inform conservation strategies that facilitate timely responses to future blooms.

Sedimentation reduces coral larval settlement, recruit survivorship, and inhibits the recovery of Florida's coral populations

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Successful recruitment is fundamental to the recovery of coral populations; therefore, it is essential to understand how stressors influence the early life stages of corals to facilitate recovery. Our recent work has shown that the proliferation of sediment-laden algal turfs is severely inhibiting the survival of juvenile corals across Florida's Coral Reef, yet there is a surprising lack of information on the influence of sedimentary stress on the early life stages of Caribbean corals. We conducted experimental studies to assess the impact of sedimentation on larval settlement and recruit survival for multiple coral species across multiple life stages (1-18 months old). 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, burying coral recruits under 4 mm of sediment decreased survival probability to 0-31% within ten days. In addition, we assessed the effects of sediment proximity (without burial) on the growth rates of *Orbicella faveolata* recruits and the photosynthetic yield of their symbionts across an 80-day timespan. Photosynthetic yield decreased after 70 days and coral recruits with sediments 10 mm away from them grew 77% more than recruits that had sediment touching all of their sides. Adjacent sediments severely limited growth, which is essential for coral recruits to mitigate their susceptibility to predation and competition. The sediment loads we tested reflect those found across the Florida Reef Tract, underscoring the tremendous potential for sediments to reduce or completely inhibit coral recruitment. There is an urgent need for actions to decrease sediment loads reaching coral reefs, minimize one of the major bottlenecks to coral recruitment, and facilitate the future recovery of degraded reefs.

Unique pairings of host and symbiont genotypes contribute to stress-induced fitness differences among cnidarian-dinoflagellate symbioses

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The mutualism between cnidarian hosts and their photosymbionts (Symbiodiniaceae) is an essential component of coral reef ecosystem health. Environmental stress can lead to coral bleaching, then colony mortality, and ultimately reef degradation. The ability of coral-algal symbioses to adapt to climate change depends in part on physiological variation in both partners. In this study, we investigated the degree to which host and photosymbiont identity influence the physiological performance of the combined holobiont during thermal stress. We experimentally bleached clonal polyps of 6 genotypes of the model sea anemone, *Exaiptasia diaphana,* and

inoculated them individually with distinct Symbiodiniaceae strains. Using a full factorial design, we created 42 unique holobiont crosses by inoculating individual polyps from each host background with one of 3 strains of *Breviolum minutum*, 3 strains of *Breviolum psygmophilum*, or 1 strain of *Durisdinium trenchii*. We subjected the holobionts to standardized acute heat stress assays in temperature-controlled incubators and monitored symbiont photochemistry using a PAM fluorometer. We also monitored pedal laceration as a proxy for asexual fecundity. Photochemical performance under stress was highly variable among distinct holobionts. Polyps inoculated with *B. minutum* tended to exhibit higher photosynthetic efficiency at elevated temperature, but this pattern was not consistent for all host genotypes. Fecundity also varied based on host and symbiont identity. For example, two host genotypes inoculated with one clonal *B. minutum* strain exhibited both the lowest and highest pedal laceration rates. Given that such performance differences form the foundation for natural selection, our results highlight the importance of considering intraspecific variation and genotype matching among partners when predicting the adaptive capacity of coral populations responding to climate change.

The effects of polyculture and density on South Florida coral outplants

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The use of corals with massive morphology in restoration has become increasingly relevant as thermal stress, severe coral diseases, and habitat loss continue to drive mortality on South Florida reefs. These species were historically underrepresented within restoration due to their slow-growing nature, often overlooked in favor of branching *Acropora spp*. that quickly regenerate through asexual fragmentation. These massive corals are also highly vulnerable to fish predation, especially in the initial weeks following their site introduction. Microfragmentation and reskinning are techniques that are effective at accelerating growth, but require more time and resources for land-based husbandry efforts. As such, more research is needed to address the bottlenecks in non-branching coral restoration efforts in Florida. Studies that have examined the effects of coral diversity generally examine reef species health, such as fish species richness, but have not observed what affects coral species complexity holds for the corals' own growth or mortality. New evidence suggests that Indo-Pacific branching corals may exhibit increased growth when grown in close proximity to other species, potentially as a means to dominate space that could be contested by their neighboring species over time. These corals also seem to display lower mortality when compared to cohorts kept in single-species groupings. If proven true for bouldering corals, this would hold significant restoration implications for future outplanting strategies that challenge the general method of mass-outplanting of the same species in one given area. Therefore, this study examines how outplant diversity may influence coral growth and survivorship through intra and interspecies competition. The effects of outplant density, or coral quantity within both mono- and polyculture assemblies, were also assessed for greatest performance. Overall, this study aims to increase the efficacy of coral restoration efforts by evaluating the return-on-investment for regeneration of these slow-growing species.

Using DNA fingerprinting to map the spatial distribution of Aiptasia sea anemone genotypes

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The pale sea anemone (Aiptasia) is used as a model to study the cell biology of coral-algal symbioses, yet Aiptasia's natural history and genetic diversity are understudied. It would be advantageous to characterize wild Aiptasia populations to fill knowledge gaps regarding their basic biology—such as their fine scale spatial ecology—and establish how well these organisms represent corals across additional dimensions. Here, we describe an ongoing project that will use DNA fingerprinting to investigate the fine scale distribution of both clonal Aiptasia genotypes and their endosymbiotic algae in the Florida Keys. We collected sea anemone polyps along a 100-meter transect at both a mangrove site and a seawall site. At each site, polyps were scraped from 11 total mangrove roots or sea anemone clusters. A modified AFLP protocol will be used to generate separate DNA fingerprints for sea anemone individuals and their dinoflagellate symbionts (Symbiodiniaceae). The resulting gel images will be processed using a custom program (combining Python and R) to quantify banding patterns. The DNA fingerprints of both symbiotic partners will be clustered into putative clonal groups. Based on limited data from a previous study, we predict that (1) each mangrove root or cluster will contain only one clonal host and symbiont genotype, (2) a single host and symbiont genotype may be present across multiple roots or clusters, and (3) there will be more host than symbiont genotypes at a single site. Our findings will help assess the suitability of the model system beyond a cell biology context, provide guidance for future population genetic studies, and contribute to understanding the dispersal strategies of Aiptasia and their associated Symbiodiniaceae.

Patterns of whole genome DNA methylation in Symbiodiniaceae are shaped by phylogenetic and ecological diversity

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Coral photosymbionts in the dinoflagellate family Symbiodiniaceae display extensive molecular, ecological, and physiological diversity. Epigenetic factors such as DNA methylation are variable among symbiont species; this variation may influence coral colony health. However, it is unknown whether methylation patterns among Symbiodiniaceae are driven by evolutionary history and/or ecological factors. Here, we quantified whole genome DNA methylation among phylogenetically diverse Symbiodiniaceae using an ELISA-like assay. To explore the influence of evolutionary history, we reared cultures of 26 species under identical conditions and estimated phylogenetic signal (the extent to which related species exhibit similar methylation due to shared evolutionary history) using multiple indices. To explore the influence of ecological state, we will introduce three cultured species to symbiont-free sea anemone polyps and compare their methylation levels within and without a host. Overall, methylation levels were high among Symbiodiniaceae (1-29.3%) compared to other algae and displayed moderate to strong phylogenetic signal. Additionally, we predict algal methylation will be elevated when cells are engaged in symbiosis with a host compared to the free-living state. We anticipate our results will indicate that Symbiodiniaceae whole genome DNA methylation patterns are both phylogenetically and ecologically determined.

Overlooked "cleaning" roles of macro-invertebrate herbivores on Caribbean coral reefs

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Over the past several decades coral reefs have undergone severe degradation as part of the ongoing climate crisis. Ocean warming, acidification, and increasing storm intensity are impacting reefs globally in conjunction with local stressors such as sedimentation, coral disease and coral bleaching. Consequently, Florida's Coral Reef Tract has experienced substantial declines in coral populations and subsequent recruitment failure. In their place, turf algae and long sediment-laden algal turfs (LSATs) have become dominant benthic place holders, further limiting coral settlement and survival. To complement current restoration efforts, we investigated the potential of two invertebrate grazers including the Caribbean King Crab (*Maguimithrax spinosissimus*) and the long-spined sea urchin (*Diadema antillarum*) to enhance substrate quality and boost coral recruitment. Using aquaria-based experiments, we tested their ability to reduce turf algae and associated sediments on seasoned limestone tiles. Treatments included five different grazer assemblages plus control groups: (1) 1 *D. antillarum*, (2) 2 *D. antillarum*, (3) 1 *M. spinosissimus*, (4) 2 *M. spinosissimus*, (5) 1 *D. antillarum* + 1 *M. spinosissimus*. Tiles from two of the experimental runs were then used in coral settlement assays with larvae of *Diploria labyrinthiformis* and *Acropora palmata* to test whether grazers indirectly influenced settlement. We found that overall sediment dispersal and algae removal plateaued once initial sediment loads reached ~2mm in depth, suggesting that greater sediment loads constrained foraging behavior. In addition, initial sediment load accounted for the majority of sediment dispersal although, mixed species treatments were particularly effective. Treatments with 1 *M. spinosissimus* or 2 *D. antillarum* removed ~3 times as much algae than other grazer assemblages. Subsequently, coral recruitment decreased with increasing sediment load, particularly for *D. labyrinthiformis* while tiles previously grazed more than doubled average coral settlement.

Diversity in disguise: leveraging cryptic coral diversity for conservation in south Florida

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Modern sequencing technologies have revealed widespread, previously undescribed cryptic diversity—the presence of genetically distinct but morphologically similar lineages—within Cnidaria. In the Western Atlantic Ocean, several common coral species, including *Agaricia grahamae*, *Diploria labyrinthiformis*, *Montastraea cavernosa*, *Orbicella faveolata*, *Pseudodiploria clivosa*, *Siderastrea siderea*, and *Stephanocoenia intersepta*, are now known to comprise multiple co-occurring cryptic lineages. These lineages may represent distinct (sub)species with limited reproductive compatibility, which has important implications for estimating population sizes and reproductive potential, particularly in the Anthropocene. These cryptic lineages are often structured by depth or habitat and commonly associate with distinct algal (Symbiodiniaceae) and bacterial partners. Experimental studies further reveal that these lineages frequently differ in their ecological niches and susceptibility to thermal stress. In this presentation, we draw on research from cryptic coral lineages in Panama and Palau to explore the opportunities and challenges posed by cryptic coral diversity in South Florida. We also outline future research

directions to understand and apply this hidden diversity to support local coral conservation and restoration initiatives.

Limited metabolic recovery and prolonged ecological impairment one year after sublethal bleaching event

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Coral reefs are experiencing structural and functional declines due to environmental stressors. Net ecosystem calcification (NEC) and net ecosystem production (NEP) are two metabolic indicators used to assess the functional status of reef communities. Here, we employed a benthic gradient-flux approach to measure hourly NEC and NEP at Cheeca Rocks, a shallow patch reef in the Florida Keys. We monitored the reef from June 26 to August 28, 2024, a period that included protracted thermal stress as well as Tropical Storm Debby. Despite relatively high coral cover (~31%), average NEC and NEP were negative throughout the summer, indicating that the reef was net erosional and heterotrophic. Reef metabolism, however, was variable throughout the summer, with NEC transitioning from net calcification in June to net dissolution in August. NEP trends were comparatively less pronounced, though the highest rates of net respiration were measured in June and late August. Variability in reef metabolism responded to dynamic environmental conditions, particularly temperature fluctuations, which included three distinct thermal spikes, each followed by rapid cooling events. Tropical Storm Debby led to the most pronounced environmental shifts, dropping temperatures from 31.7°C to 29.2°C in less than two days and leading to sharp declines in pH (from 8.0 to 7.6) and aragonite saturation (from 4.1 to 1.7). During the storm, moderate net calcification was observed, suggesting that the thermal relief provided by cooling may have offset the adverse effects of unfavorable carbonate chemistry. In comparison, near-neutral production was measured, indicating storm-driven suppression of autotrophic potential. Our findings highlight the complexity of real-world environments, where chronic stress and stochastic events can rapidly lead to unforeseen changes in ecosystem calcification and production.

All Habitats Are Not Created Equal: The Effect of Reef Type and Depth on Fish Assemblages in Southeast Florida

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Artificial reefs are an increasingly important management tool in tropical ecosystems. However, there is a lack of data on how their construction and environmental context affects the fish assemblage they support, and how these assemblages compare to natural reefs. This study utilized

video footage collected in 2024 by an experimental remotely operated vehicle (ROV) operated by Science From Scientists to assess the composition of fish assemblages on ~30 natural and artificial reefs along a depth gradient on the continental shelf near West Palm Beach on Florida's Atlantic Coast. The artificial reefs included both concrete and metal structures, allowing a comparison among construction materials. Video footage was reviewed to identify the species and number of fish at each site. Univariate and multivariate statistics were then used to understand the correlates of both assemblage structure and species richness, diversity, and the abundance of the most common species. The results demonstrated significant impacts of both reef type (artificial reef construction material or natural reef) and depth on fish assemblage structure and diversity. This study contributes to our current understanding of how artificial reef materials and environmental context affect reef fish assemblages in Southeast Florida. Furthermore, it evaluates the suitability of ROVs for surveys across logistically challenging environmental gradients. Structural complexity is a valuable ecological asset to fishes that offers protection from predators, shelter from currents, and foraging opportunities for fish, but clearly reef type and depth are important for determining which species benefit from artificial reefs. Critically, this study also underscores the differences between fish assemblages on artificial and natural reefs. Understanding these relationships is key to assisting management planning and generating the best solutions for people and nature.

Physiological impacts of ocean acidification and hypoxia on Orbicella faveolata

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Ocean acidification and deoxygenation threaten the health and persistence of Florida's coral reefs. These stressors rarely occur in isolation in the wild, yet the impact of multiple stressors acting in combination remains poorly understood. In this study, fragments from three distinct genotypes of *Orbicella faveolata* (n=96) were exposed to four different pH treatments (7.7, 7.8, 8.0, and 8.1) for 33 days at normoxia (~210 μmol L^{-1}). Following this single stressor phase, fragments were exposed to the same pH treatments in combination with either moderate (~125 μmol L^{-1}) or severe (~62 μmol L^{-1}) hypoxia intermittently for roughly two weeks total. Target treatment levels were achieved by precision injection of three treatment gasses (CO_2, N_2, CO_2-free air) using custom control systems in the Cooperative Institute for Marine and Atmospheric Studies' (CIMAS) Experimental Reef Lab (ERL). Coral growth rates were measured via buoyant weight at the start of the experiment and every two weeks thereafter. Health and paling severity were assessed via color-corrected photographs taken at the same frequency as buoyant weight measurements. Photosynthetic efficiency was measured via pulse amplitude modulated (PAM) fluorometry at three time points: (1) before stressor exposure, (2) at the end of single stressor treatments, and (3) at the conclusion of multi-stressor treatments. Net calcification/dissolution rates were measured via two-hour day and night incubations on a subset of corals at the same frequency as the PAM fluorometry. This study pinpoints the negative physiological impact of multiple co-occurring stressors and distinguishes their impact from that of individual stressors. This study also

underscores the need for more comprehensive experiments to forecast the future of coral reefs and inform evidence driven management decisions.

Estimating habitat suitability for long sediment laden turf algae across South Florida Reefscapes

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Long sediment-laden algal turfs (LSATs) are increasingly persistent features on many Caribbean reefs, often forming when short, productive algal turfs accumulate sediment that reduces herbivory and allows the turf-sediment matrix to stabilize. However, the morphometric conditions that promote LSAT formation remain poorly resolved. This study investigates the relationship between fine-scale reef structure metrics and LSAT characteristics (sediment depth and turf length) across three spatial buffer scales (25, 50, and 100 cm). Using high-resolution digital elevation models (DEMs) and Tweedie GLMMs, the results show that AIC comparisons consistently favor the 100 cm scale, indicating that LSAT development is driven largely by broader topographic features. Morphometrics such as rugosity, slope, curvature, and topographic position index likely mediate microcurrents, sediment retention, and microhabitat stability—key ecological processes enabling LSAT persistence.

Roots of Resilience: Evaluating the Influence of Thermal History and Geographic Origin on the Survivorship and Bleaching Response of Acropora cervicornis Genotypes

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Global warming stemming from anthropogenic climate change is the greatest threat to coral reef ecosystems. Prolonged periods of record-high temperatures have resulted in mass mortality throughout the Florida Reef Tract, causing the continued decline of reef-building coral species and emphasizing the need for effective coral restoration strategies. Current restoration efforts, although expanding, primarily focus on the asexual propagation of thermally sensitive species, such as *Acropora cervicornis,* due to their rapid growth rates and branching morphology. These efforts are often geographically localized, with both in-situ and ex-situ nurseries situated near outplant sites, thereby limiting gene flow across broader reef regions and favoring environmental specialization. It remains unclear if this acclimatization overpowers genotypic performance, raising the question: Can broad-scale reef recovery be enhanced by transplanting corals outside of their local environment? We examined the influence of in-situ nursery origin and reef environment on bleaching susceptibility and survivorship of *A. cervicornis* following outplanting. To evaluate this, 17 unique genotypes of *A. cervicornis* were collected from four regions of the Florida Reef Tract throughout Broward, Miami-Dade, and Monroe County, and outplanted onto three reef sites: 1) nearshore Fort Lauderdale, 2) offshore Key Biscayne, 3) offshore Biscayne National Park. The genotypes used for this study were preferentially selected, as they demonstrated increased resilience and survivorship during the global bleaching event in 2023 and demonstrated higher

thermal tolerance during ex-situ rapid heat-stress assays (CBASS). We hypothesize that fragments transferred from the southern region of the Florida Reef Tract to northern in-situ nurseries will perform better under naturally induced thermal stress than northern genotypes in their native environments. Our findings aim to inform adaptive restoration strategies and consider how thermal history and geographic origin may impact selective propagation and the success of assisted gene flow moving forward.

The Coral Holobiont's Gene Expression Response to SCTLD Transmission

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Stony coral tissue loss disease (SCTLD) affects over 22 species of reef-building Caribbean corals and is characterized by rapid tissue degradation. Notably, *Acropora cervicornis* appears relatively resilient to SCTLD, while *Montastraea cavernosa*, *Orbicella faveolata*, and *Porites astreoides* tend to exhibit higher susceptibility. While previous work has underscored the importance of microbial communities in SCTLD progression, the functional contributions of the microbiome to SCTLD exposure remains less understood. In this study, we conducted a controlled SCTLD transmission experiment using these four coral species, selected for their contrasting susceptibility, ecological importance, and relevance to ongoing restoration efforts. We characterized microbial communities (16S rRNA gene abundance, n=102) and functional profiles (metatranscriptomes, n=77) from the coral host, algal symbiont, and microbiome across all species. Our goal was to better understand the molecular responses associated with SCTLD exposure, and how these responses may relate to resilience or susceptibility. We report patterns of gene expression that distinguish lineage-specific signals which potentially reflect evolutionary constraints or advantages unique to coral species, from those that appear to be dynamically regulated in response to SCTLD. The former may offer insight into why certain species are more vulnerable, while the latter highlight functional processes that could be directly influenced by disease exposure. Together, these observations contribute to advancing our knowledge on the molecular mechanisms of SCTLD and the role of the coral holobiont in mediating disease outcomes. By disentangling lineage-level traits from treatment-driven responses, this work offers a framework for exploring the complex interplay between host, symbiont, and microbial functions in coral disease dynamics.

Murky Waters, Clear Signals: The Behavioral and Epigenetic Responses of Bicolor Damselfish to Increased Turbidity

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Coral reefs face increasing threats from anthropogenic impacts, including bleaching, disease, overfishing, and declining water quality. A critical component of water quality degradation is increased turbidity from coastal development, dredging, boating, and intensifying storms. While sediment effects on corals are well-studied, impacts on reef fish remain poorly understood. We examined turbidity effects on behavior and epigenetics of bicolor damselfish (*Stegastes partitus*) through aquarium experiments. Epigenetics refers to the study of heritable changes in gene expression that do not alter DNA sequence, and these changes can enable rapid environmental

adaptation within a single organism. For a social, mobile species, epigenetics illuminates the molecular mechanisms underlying behavioral changes, though reef fish epigenetics remains significantly understudied. In this experiment, bicolor damselfish were exposed to control (0-1 NTU), medium (5-15 NTU), or high (20-30 NTU) turbidity for pulse durations of one, six, or twelve hours. Results indicated that turbidity impacted food reaction time, with high and medium turbidity groups also consuming significantly less food than controls. In turbid conditions, bicolor damselfish also reduced swimming distance from shelter, consistent with observations in the wild. Following trials, damselfish were dissected and tissues preserved for epigenetic analysis using Methylation-Sensitive Amplification Polymorphism (MSAP) to investigate modifications in three genes associated with stress response, neuroplasticity, and oxygen transport. These results are among the first applications of combined behavioral and epigenetic approaches to reef fish stress responses in Florida. Epigenetics provides a novel framework for understanding rapid environmental adaptation in marine ecosystems. This work emphasizes the critical importance of turbidity and water quality management on Florida's coasts and coral reefs, as behavioral and epigenetic responses may significantly affect the fitness of reef fish.

Chemical ecology and natural products chemistry of benthic cyanobacteria on Florida's Coral Reef

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Benthic marine cyanobacteria are becoming increasingly abundant in tropical and subtropical habitats worldwide, and many species produce diverse, sometimes toxic, natural products. Blooms of cyanobacteria occur regularly throughout Florida and Caribbean coastal waters. Over the past 20 years, we have made progress in characterizing the species composition and natural products chemistry of benthic cyanobacteria on Florida's Coral Reef. Crude extracts and pure compounds from some cyanobacteria deter feeding by natural assemblages of fishes and sea urchins. Cyanobacterial metabolites may serve multiple ecological functions, including inhibition of microorganisms and competition for space. The role of allelopathy (chemical inhibition) in mediating interactions between cyanobacteria and different life history stages of corals has been tested. Extracts and isolated compounds from multiple cyanobacteria negatively influence the settlement of coral larvae. On reefs experiencing increased abundance of chemically rich benthic cyanobacteria, the restocking of adult coral populations may be slowed due to recruitment inhibition caused by cyanobacterial metabolites. One species of interest on Florida's reefs is *Roseofilum reptotaenium*, a filamentous marine cyanobacterium that is a major component of Black Band Disease (BBD), a lethal disease that occurs on corals worldwide. BBD is abundant on Florida's Coral Reef in summer months. To decipher chemical signaling among microorganisms in BBD, we investigated the natural products chemistry of BBD and nonaxenic cultures of *R. reptotaenium* and identified lyngbic acid, which inhibits quorum sensing (QS) in *Vibrio harveyi* QS reporters, and the 20-membered macrocyclic depsipeptides, which we named looekeyolides. Other new natural products have been characterized, such as caldoramide, molassamide and others.

Investigation of waterborne chemical cues for coral larval settlement

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A fundamental step in the sexual propagation of corals is the ability to induce successful larval settlement. While the presence of certain species of crustose coralline algae (CCA) and bacterial cues can promote settlement, the optimal biochemical conditions of surrounding seawater are less explored. Using coral larvae from *ex situ* breeding programs and seawater from various aquaria, settlement bioassays were conducted to investigate the influence of seawater from coral reef ecosystems on larval metamorphosis and settlement. The Smithsonian Marine Ecosystems Exhibit (SMEE) at the St. Lucie County Aquarium served as a primary seawater source. Positive settlement cues were observed in both unfiltered and filtered (0.2 μm) seawater from multiple locations within their coral reef system, such as near the *Acropora palmata*, *Acropora cervicornis,* and a smaller, yet diverse coral refuge with a substantial growth of CCA. For multiple spawning species, including *Colpophyllia natans*, *Diploria labyrinthiformis*, *Orbicella faveolata*, *Pseudodiploria clivosa*, and *Pseudodiploria strigosa*, filtered seawater from SMEE facilitated significant settlement. Since inductive properties were retained after filtration, effectiveness can be attributed to dissolved compounds rather than bacteria or particles. This suggests that waterborne metabolites from a diverse coral reef ecosystem can serve as highly effective settlement inducers. Larvae of the brooding species tested, *Porites astreoides* and *Mycetophyllia ferox*, did not exhibit settlement in filtered aquarium seawater. This supports the species-specific differences in response observed, with reproductive strategy being a potential contributing factor. Inductive compounds were retained on C18 resins, eluted with methanol, tested at natural concentrations, and proved effective in settlement bioassays. Fractionation indicated that polar compounds induced the most settlement, providing a pathway for identifying specific biochemical inducers. This discovery may lead to new approaches for inducing larval settlement during sexual propagation and inform managers of optimal reef conditions for coral recruitment success.

Spatiotemporal shifts in Gorgonia ventalina populations on Florida's Coral Reef reveal resilience against climate change stressors

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Despite significant scleractinian coral mortality, octocoral density has increased on Florida's Coral Reef (FCR) over recent decades. The common sea fan *Gorgonia ventalina* has flourished, becoming a key component of Florida's octocoral community. However, spatiotemporal trends and mechanisms driving its population dynamics on FCR are unknown. Here, we analyzed spatiotemporal changes in *G. ventalina* density and size distribution to assess population trends and resilience to disturbances, as well as investigate site-specific factors that may be influencing these trends. From 2013-2024, monitoring was conducted annually between June and August along permanent belt transects at 46 sites throughout the three regions of FCR: the Kristin Jacobs Coral Aquatic Preserve (CAP), the Florida Keys (FLK), and the Dry Tortugas (DRTO). Colony height and health condition were recorded for all *G. ventalina* colonies along each transect. Populations exhibited resilience through a recovery in density following Hurricane Irma in 2017; however, populations declined again following a bleaching event in 2023. Size frequency distributions were not affected by these disturbances and remained consistently skewed towards small size classes throughout the study. Spatially, average density was significantly greater in the FLK (2.19

colonies/m^2; $p < 0.05$) with a skew towards smaller colonies, suggesting high recruitment. Conversely, the CAP and DRTO had lower densities (0.31 and 0.40 colonies/m^2; $p > 0.05$) with larger size classes in the DRTO, suggesting longevity and colony growth in this region. Site-specific factors including recruit density of the previous year, maximum degree heating weeks of the previous year, and macroalgal cover will also be explored to determine if they are drivers of these spatiotemporal patterns. Despite increased stressors on FCR, *G. ventalina* populations have exhibited resilience, revealing the expected trajectory of FCR's benthic assemblages. These findings contribute to our understanding of FCR's prevalent taxa and potential regime shifts in vulnerable reef ecosystems.

Understanding the Biodiversity of Hardened Shores: A Systematic Map of Epifaunal Communities on Subtropical Coastal Defense Structures

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Florida's coastal areas are shaped by engineered defense structures (seawalls, bulkheads, breakwaters) that introduce novel marine habitat in the region's historically soft-sediment environment. While sea-level rise and shoreline development are driving the use of coastal defenses, their ecology is poorly understood. This is particularly true for the epifauna that reside on these structures, which may provide key ecological functions including water filtration, trophic support, and fish habitat.

This presentation shares results from the first systematic map to aggregate published research on the ecology of epifaunal macroinvertebrate communities inhabiting artificial coastal defense structures in the subtropics (15°-40° North and South of the equator). A predefined search string was entered in the Web of Science Core Collection and yielded 217 initial results, which were screened against inclusion criteria at the title, abstract, and full-text levels using the PECO framework. Information was extracted from the relevant literature to build a database that includes study location, urbanization level, structure types, epifaunal focus, and ecological outcomes.

The map reveals knowledge gaps in how coastal defenses influence epifaunal biodiversity, functional ecology, and indicators of ecological resilience, especially in soft-sediment, reef-adjacent environments like those in Florida. Most studies were observational and taxonomically focused, with limited research on functional traits, ecosystem services, and the presence of non-indigenous species. Eco-engineered structure types were underrepresented in the screened literature, and soft-sediment systems were the least studied habitat type. This systematic map highlights the research needed to inform ecological targets for Florida's engineered shorelines and to guide the integration of urban coastal ecology with coral reef conservation and restoration efforts in the region.

Investigating Coral Response to Relocation in South Florida and the Caribbean

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As coral reef ecosystems continue to decline due to climate change and coastal development, understanding how coral colonies respond to disturbances and mitigation interventions is critical to reef conservation in South Florida and the Caribbean. These efforts, while typically driven by permitting requirements, also provide unique opportunities to study coral resilience, health, and recovery under controlled physical disturbance. This presentation explores lessons learned from three recent coral relocation projects conducted by Cummins Cederberg Inc. located in The Florida Keys National Marine Sanctuary, Biscayne Bay, and the Bahamas. Across these sites, thousands of coral colonies have been relocated in support of large-scale coastal infrastructure projects. These efforts involved the removal and reattachment of corals from docks, seawalls, and construction footprints to carefully selected recipient reef habitats. At each site, biologists implemented standardized monitoring protocols to evaluate coral health, attachment success, and early recovery. Long-term monitoring schedules were established to track outcomes and inform compliance with applicable regulatory frameworks. These results highlight the relocation methods employed to successfully minimize coral stress and mortality and evaluate coral relocation as a viable mitigation strategy. The findings from these projects have the potential to improve adaptive management strategies and support science-based decision-making that balances coastal development with conservation objectives throughout South Florida and the Caribbean.

Understanding benthic habitat distribution around the Seven Mile Bridge to support infrastructure planning

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Although originally constructed for transportation, bridges across waterways often become vital components of the ecosystems they inhabit. The iconic Seven Mile Bridge (SMB), part of the Overseas Highway (U.S. Route 1) connecting mainland Florida to Key West, is bordered by a diverse network of coastal habitats. The Florida Department of Transportation (FDOT) has initiated preliminary planning and design efforts for a potential bridge replacement, while considering the ecological value of the surrounding benthic community. To support FDOT's planning efforts, Cummins Cederberg conducted a qualitative benthic resource assessment within and around two proposed bridge alignments. Prior to field efforts, a satellite-derived seafloor classification (SFC) process was used to map and categorize benthic habitats. From the SFC map, 130 bounce dive locations were selected for ground-truthing. At each ground-truth site, one dominant habitat was assigned of seven pre-determined project-specific habitat types: seagrass dense (>25% cover), seagrass sparse (<25% cover), macroalgae, hardbottom, hardbottom-seagrass mosaic, unconsolidated sand-scour, and disturbed unconsolidated. This survey technique allowed for rapid assessment of a large area, with field-verified observations used to improve the accuracy of the SFC habitat map. Overall, hardbottom was the most prevalent habitat type, comprising 40% of all surveyed locations and 69% of those directly beneath the existing SMB. Dense seagrass was the second most common habitat (30%), growing in areas with suitable substrate and depth. Between hardbottom-dominant and seagrass-dominant areas was a unique intermixed community

of hardbottom-seagrass mosaic, comprising 21% of all surveyed locations. The two proposed bridge alignments were overlaid on the field-verified habitats map and the total habitat area (in acres) for each habitat type was calculated. This approach provided a comprehensive understanding of the spatial distribution and ecological composition of benthic resources in the project area.

No Bite! Optimizing Physical Protection for Newly Restored Corals

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Coral restoration programs in Florida have expanded to include species with massive colony morphologies; however, predation by corallivorous fish has emerged as a significant bottleneck to their success. Typically, corals that survive past 4-6 weeks do not experience further significant predation. Physical deterrents, such as mesh cages, nails, skewers, or non-shading umbrellas, can be effective at limiting predation during this crucial period. However, these structures can become a detriment if left in place permanently. Little is known about the best practices of using obstacles to prevent predation and the optimal duration that predation deterrents should be deployed. To address this, nursery-grown colonies of three coral species that are susceptible to fish predation were outplanted with physical deterrents. Deterrents were removed at two-week intervals and predation impacts were observed. Results are forthcoming; however, because previous studies suggest that predation peaks within 1 month after outplanting, it is anticipated that longer duration treatments will perform better. This study will contribute to a growing body of knowledge around the use of predation deterrents in coral restoration and could inform the development of biodegradable structures that do not need retrieval.

Optimizing solar irradiance for the survival and growth of corals in an outdoor land-based facility

Julia Cafiero[1], Andrew Baker[1], Kelly Peebles[1], Cameron McMath[1], Carly Dennison[1], Alexandra Wen[1], Richard Karp[1]
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Land-based coral nurseries have quickly established themselves as a critical resource for coral propagation and restoration, and allow for greater control of parameters to maximize growth and general health and wellness of corals. However, the relationship between growth rate (linearly and through increases in surface area) and light availability in land-based nurseries is rarely studied. This study presents the results of growth rate variations by genotype and species of two species of mounding corals in differing light treatments, as well as surface area and height for *Acropora cervicornis*. This study took place at the University of Miami Experimental Hatchery in Virginia Key, Florida. Two genotypes each of three reef-building species of Scleractinian Caribbean coral, *Acropora cervicornis*, *Pseudodiploria clivosa*, and *Orbicella faveolata*, were placed into two tanks consisting of three differing light treatments. The light treatments were full light (0% shade), 75% shade, and 97% shade with PAR ranging from approximately 700 nm to 30 nm respectively. All coral genotypes, except one *P. clivosa*, demonstrated a greater increase in surface area and a faster growth rate in full light (0% shade) compared to shaded treatments. Due to the results of this study,

shadecloths have been more regularly removed from tanks, which has allowed for greater light availability and faster growth in X number of species. Maximizing light in land-based nurseries improves growth across multiple species and genotypes, supporting more efficient production of outplant-ready corals. The purpose of land-based nurseries is to assist in the pipeline of (1) sexual coral reproduction, (2) maximized coral growth for asexual propagation, (3) outplanting those corals onto reefs, hybrid structures, etc. for increased coral cover, and (4) having those outplants reproduce in the wild.

Identifying and experimentally validating environmental drivers of disease

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Disease outbreaks have caused mass coral mortality on Florida's Coral Reef (FCR) and continue to threaten the persistence of coral populations. Spatiotemporal variations in disease dynamics suggest environmental conditions influence disease susceptibility. Understanding these may allow us to identify the environmental factors which underpin coral health and predict future disease dynamics. We took an integrative approach, combining field observations and statistical modelling to identify the environmental drivers of disease susceptibility and severity on FCR, and performed lab experiments under these conditions to understand their effect on immunity in *Montastraea cavernosa*. Disease susceptibility was most strongly influenced by the interactions between maximum temperature and maximum chlorophyll-a concentration the month prior to the disease survey, and between maximum chlorophyll-a concentration and three month mean PAR. Disease probability was highest when chlorophyll-a concentration (nutrients proxy) exceeded ~6 mg m^{-3} and maximum temperatures were low (<30 °C) or when PAR and chlorophyll-a concentrations were high. Disease severity had a significant negative relationship with maximum temperature, where a colony had a 50% chance of dying unless temperatures exceeded 31.08 °C. Lab experimentation was conducted under conditions experienced on FCR to investigate the influence of temperature and nutrients on immune response. After one month of environmental manipulation, coral fragments were immune challenged to assess immune response. Heat stress largely drove broad suppression of constitutive immunity (peroxidase, phenoloxidase, and antibacterial activity), but increased catalase activity, which suggests stress within the host. These results suggest further disease outbreaks are likely as ocean temperatures increase. Corals exposed to moderate levels of ammonia (0.01 mg/1) induced the strongest immune responses (catalase and phenoloxidase activity), but that ceased under high concentrations (0.05 mg/l). Experimental nutrient enrichment conditions are experienced on FCR, and results suggest reducing ammonia in these locations could improve coral immunity and reduce the likelihood of another disease outbreak.

Quantification of Interactions Between the Sponge Mycale laevis and Scleractinian Coral Species to Support the Design of a Co-Outplanting Program at Restoration Sites on Florida's Coral Reef

Annalise Nisly[1], Bobbie Renfro-Price[1]
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Coral restoration researchers continue assessing novel methods for securing outplanted colonies onto the reef substrate. While technological innovations have helped advance these methods, natural ecological associations can be instrumental in promoting coral attachment and survival. Sponges (Porifera) play several functional roles within coral reef ecosystems, including acting as habitat, serving as the primary water filtration system, and increasing coral survival by an order of magnitude. The latter function can be seen in how sponges help reconsolidate loose rubble, acting as an additional attachment point, and securing coral heads to the substrate. These interactions with living and non-living reef structure reduce substrate movement that has the potential to damage the reef in surge. *Mycale laevis* is a sponge species that forms a symbiotic relationship with reef-building corals, growing along the free edge of a colony, protecting the base of the coral. I.CARE is a community-based coral restoration and education organization; at I.CARE restoration sites on Florida's Coral Reef, these naturally occurring coral-sponge associations were observed between *M. laevis* and coral species including the mustard hill coral, *Porites astreoides,* and the mountainous star coral, *Orbicella faveolata.* Potential benefits of symbiosis include protection of coral colonies from dislodgement, protection of sponge tissue from grazing, as well as provision of a continually expanding surface for sponge growth. These associations have been previously observed in the field; however, formal quantification of these interactions are needed on Florida's Coral Reef. The frequencies of sponge-coral associations were quantified at I.CARE's restoration sites. This data supports novel restoration methodology for the purpose of increasing coral outplant survival and storm resistance through the addition of *M. laevis* as an additional attachment. The relationship between scleractinian corals and *Mycale laevis* in Florida's Coral Reef highlights the critical ecological functions that sponges offer in holistic ecosystem restoration.

Corals are friends, not food: using "recycled" Acropora cervicornis skeletons as a predation deterrent for boulder coral outplants in the Florida Keys

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Coral restoration practitioners utilize a variety of outplant strategies to maximize long-term coral health and survivorship. Boulder coral outplants suffer from intense finfish predation as compared to Acroporid species, which greatly reduces their overall survivorship and contribution to reef structure, given their relatively slow growth rates. The higher lipid concentrations in boulder corals, which increase the energetic value of this food product for fish, and the function of these corals as a novel environmental stimulus are suggested as reasons for increased predation pressure. Because predation is often greatest during the first several weeks post-outplant, previous studies have created deterrents for coral predation. However, these are often made from fabricated materials that are difficult to deploy around outplants, to maintain for long periods in variable reef conditions, and to remove. In this study, I.CARE used skeletons from *Acropora cervicornis* (ACER) colonies that experienced natural mortality to create "cages" as deterrents for finfish

predation on outplanted bouldering coral clusters. Cages were placed immediately around outplanted clusters and were removed at 90-days post-outplant. Clusters were monitored at one-week, one-month and 90-days post-outplant, as well as within 14 days of cages being removed to observe any new predation. Success of caging efforts was compared between coral species and coral origin (*in-situ* corals reared from larval spawn and *ex-situ* rescued corals of opportunity) among six outplant sites of varying depths. Cages provided the greatest deterrence for predation for the first three months post-outplant, and very little predation was noted within 14 days post-cage removal. Though variation in cage success existed among all comparisons, our use of a natural product to reduce predation pressure has increased coral survival, reducing the introduction of synthetic materials to the reef, and given new purpose to a sustain resource that is often produced as a by-product of coral husbandry work.

Utilizing ecosystem-wide surveys to understand temporal changes in benthic communities at reef restoration sites within the Florida Keys

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Coral reef communities have experienced rapid changes over the past several decades which have not only triggered major changes in coral cover but also altered the entire benthic community. As the diversity of coral communities and the dynamic species interactions occurring within these ecosystems play a crucial role in shaping the natural coral populations, abiotic factors can also influence the community structure. I.CARE is a reef restoration organization that takes an ecosystem-wide approach to monitoring by conducting quarterly surveys to estimate changes in community assemblages on active restoration sites. Four of these restoration sites with various habitat profiles were compared for temporal changes in natural coral species composition and benthic community assemblages. Roving diver surveys were conducted along established transects at each site to document species presence, approximate size and disease condition of naturally occurring corals. Substrate composition was estimated by analyzing photos of the benthic habitat using Coral Point Count with Excel extensions (CPCe). Analyses revealed distinct community types between deeper offshore habitats having higher coral cover and shallow patch reefs having less coral cover. Substrate composition also varied with site type, but benthic biota composition fluctuated through time with annual shifts. This approach of integrating ecosystem-wide monitoring and analyses into coral restoration allows practitioners to adapt future restoration strategies to identify sites where coral outplants are predicted to have the highest chance of long-term survival.

Spatiotemporal mapping of algal symbiont communities in Orbicella faveolata and their associations with SCTLD

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Variation in algal symbiont communities (Family Symbiodiniaceae) within individual coral colonies has been attributed to changes in phenotypic traits in some coral species. In the threatened coral species *Orbicella faveolata,* this variation has been documented throughout the Caribbean

and is related to critical parameters such as bleaching sensitivity. However, its influence on the susceptibility to stony coral tissue loss disease (SCTLD) has not yet been studied in situ. This study investigated associations between within-colony mosaics of Symbiodiniaceae taxa and lesion development on *O. faveolata* colonies >2 m diameter in southeast Florida by mapping their distributions and monitoring over time. Five repeatable transects were set up on seven colonies in a radial pattern, where thirty-one biopsies were taken per colony at eight timepoints between 2022 and 2025. Quantitative PCR results showed the five northernmost colonies dominated by either *Breviolum* or *Durusdinium* and two southernmost colonies with variable distributions of *Breviolum* and *Cladocopium*, possibly relating to latitudinal or nutrient exposure differences. Five colonies exhibited active SCTLD lesions and bleaching throughout the 2-year sampling timeframe based on monthly monitoring. The two colonies without recorded lesions had the lowest proportions of *Breviolum.* Symbiont to coral host cell ratios showed significant differences between colonies and across time points, with the greatest decline corresponding to a severe bleaching event, even in corals not visibly affected. Spatial analysis within colonies indicated significant clusters of symbiont genera in colonies with variable communities with one colony showing variations between the wet and dry seasons. Further microhabitat characteristics are being investigated using 3D modeling such as angle and light exposure of each sample location. These high-resolution symbiont distribution data provide further evidence of how environment influences algal symbiont communities in *O. faveolata* and how inter and intra-colony variation influences patterns of SCTLD severity and spread.

Coupled Observations and Models Reveal Coral Reef Trajectories in the Florida Keys Under Multiple Stressors

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The coral reefs of the Florida Keys represent one of the most extensive and ecologically valuable reef systems in the continental United States, supporting biodiversity, fisheries, tourism, and shoreline protection. These reefs, however, are under increasing pressure from a range of environmental stressors. As part of a four-year, multi-institution project, the Florida Regional Ecosystem Stressors Collaborative Assessment (FRESCA), we evaluate long-term drivers of reef change using nearly 30 years of bi-monthly water quality surveys across the Florida Keys National Marine Sanctuary, supplemented by satellite observations. These data underpin a regional ocean-biogeochemical model (MOM6-SIS-COBALT) that projects key environmental variables, such as temperature, oxygen, and pH under different future scenarios. To capture fine-scale hydrodynamics influencing reef environments, we apply a high-resolution modeling approach that tracks how water movement interacts with benthic habitats across the Keys. A central focus of FRESCA is understanding how coral reef ecosystems—and reef-building corals in particular—respond to multiple stressors. Using a novel experimental system, we simultaneously manipulate temperature, dissolved oxygen, and pH to assess the physiological responses of 17 important habitat-altering species, including corals, seagrasses, macroalgae, and bioeroders. At key restoration sites within the Mission: Iconic Reefs initiative, we quantify carbonate budgets using

large-area imagery and a new automated analysis pipeline, linking ecological condition to reef accretion or erosion potential. By integrating projected stressor regimes, species-specific sensitivities, and reef carbonate dynamics, we generate forecasts of coral reef persistence under different restoration and management pathways. This work provides critical insight into the future of coral reefs in the Florida Keys and supports science-based decision-making for reef conservation and restoration.

Impacts of 2023 bleaching events on net carbonate production at two reef sites in the Dry Tortugas and Florida Keys

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The carbonate budget of a coral reef characterizes the balance between calcification (by scleractinian coral, crustose coralline algae) and bioerosion (by parrotfish, urchins, micro- and macroborers), ultimately yielding net carbonate production (NCP), a metric of reef habitat persistence over time. As part of NOAA's National Coral Reef Monitoring Program, census-based carbonate budget surveys were performed at Bird Key Reef (Dry Tortugas National Park) and Cheeca Rocks (Islamorada, Florida Keys National Marine Sanctuary) to evaluate the effects of the 2023 mass coral bleaching event. Bird Key reef is a spur and groove habitat in a remote national park with an average depth of 30ft. Cheeca Rocks is a mid-channel patch reef with moderately high coral cover for the region whereas with an average depth of 10ft. Surveys were conducted across six fixed 10 m transects in June 2021 (Dry Tortugas) and August 2022 (Cheeca Rocks) to identify baseline conditions, and repeated in June 2024 (Dry Tortugas & Cheeca Rocks) to assess the ecological response. In Dry Tortugas, NCP significantly declined from 1.77 ± 0.72 (mean ± sd) kg m^{-2} yr^{-1} in the pre bleaching survey to 0.77 ± 0.72 kg m^{-2} yr^{-1} in the post bleaching survey. Comparatively, Cheeca Rocks NCP declined from 4.65 ± 2.52 kg m^{-2} yr^{-1} in 2022 to 2.969 ± 1.867 kg m^{-2} yr^{-1} in 2024. This change was mainly driven by reduction in coral cover. Bird Key Reef coral percent cover went from 11.5% pre bleaching to 5.1% post bleaching, losing 6.4%. Cheeca Rocks lost 8% coral cover starting at 34.% in the pre beaching surveys down to 26.4% in the post bleaching. These data illustrate how mass bleaching events can lead to rapid declines in reef growth potential which has significant implications for habitat structure and the ecosystem services.

Symbiont shifts in Florida corals during and after the 2023 marine heatwave

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Reef-building corals form an obligate symbiosis with dinoflagellates in the family Symbiodiniaceae, whose identity can influence phenotypes such as thermal tolerance. One species, *Durusdinium trenchii*, is relatively heat tolerant, increases the bleaching thresholds of its host, and is often found in higher abundances in corals after bleaching events. The 2023 marine heatwave resulted in unprecedented bleaching on Florida's coral reef, where reefs experienced more thermal stress than previously observed in the satellite record. This provided an opportunity to assess which

Caribbean coral species alter their symbiont communities in response to extreme heat stress and bleaching in the field. We collected 748 samples across 12 coral species and 15 unique reefs in Miami-Dade and Biscayne National Park during the bleaching event to quantify changes in symbiont community composition. We then resampled 330 corals in March 2024, after heat stress had subsided, to monitor if these shifts persisted. Using quantitative PCR we measured the symbiont composition for the four major Caribbean symbiont genera (*Symbiodinium*, *Breviolum*, *Cladocopium*, and *Durusdinium*). We found that three-quarters (9 of 12) species associate with *Durusdinium* due to bleaching, and that over half (7 of 12) increased their proportion of *Durusdinium* in direct response to accumulated thermal stress and coral bleaching. Furthermore, we found that many of these shifts persisted six months after thermal stress had ceased. Our results show that many coral species along Florida's Coral Reef respond to extreme thermal stress by shifting their symbiont communities toward *Durusdinium* or by naturally maintaining it. This has significant implications for the survival of Florida's corals, the future composition of its reef communities, and their management in an era of continued warming.

Changes in stony coral recruit density following substrate stabilization at ship grounding sites

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Chronic stressors and acute disturbances have severely degraded coral reefs off southeast Florida, reducing coral cover and limiting recovery potential. Among the most destructive of these acute disturbances are ship groundings, which at their most extreme can fracture substrate, creating rubble areas which limit coral recruitment and survival. In 2006, two cargo ships, the M/V Clipper Lasco and the M/V Spar Orion (170m and 189m in length), ran aground offshore Fort Lauderdale. These events caused extensive damage to the reef, requiring restoration to recover lost ecological services. In 2015, limestone boulders were cemented into the bow scar of each site to stabilize the substrate, and amongst other things, promote coral recruitment. Here, we investigate how stabilization influenced the recruit assemblage. From 2016 to 2025, we monitored all coral recruits (colonies <5cm) along 10 permanent transects at the two stabilized ship grounding sites: three on unrestored rubble, three on boulders, and four at unimpacted reef sites nearby. Over the study period, recruit density increased 1427% on boulder transects, predominantly due to an increase in generalists such as *Siderastrea spp.,* which made up 84% of boulder transect recruits. Recruit densities at both rubble and reference reef sites remained relatively unchanged across the study period. As of 2025, *Siderastrea* spp. was also the most abundant species on rubble transects (68%), but overall recruit density was lower than reference and restored boulder transects (4.67, 5.35, and 20.36 recruits/m^2, respectively). This is likely a result of consistent rubble movement. Reference transects showed increased recruit diversity but were still dominated by generalists such as *Porites spp.* (39%) and *Siderastrea spp.* (24%). These results emphasize the importance of substrate stabilization after ship grounding events to support recruitment. However, the limited diversity highlights the lack of reef-building species recruitment, a trend that is mirrored on the reef.

Causes of coral mortality observed during the Port Miami dredge project

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Recent papers and media reports have claimed that the impacts of the Port Miami Dredge Project (PMDP) were far greater than reported by the project contractors. As a result, uncertainty remains about the amount and causes of coral mortality that occurred due to dredging. An outcome of the higher coral mortality claims is a demand by a local NGO and some government agencies to perform costly additional mitigation. But is the story of high coral mortality accurate? We report results from both weekly compliance and longer-term pre- and post-construction biological monitoring, which showed that while project impacts did occur, the claims of high impacts to corals were not as devastating to the environment as portrayed in the media and some scientific publications. Specifically, claims that the PMDP killed more than 500,000 corals based on modelling coral populations are problematic. So, what are the facts, and how can we sort out the differences between the real and perceived impacts caused by the dredging operation? We used results from the various monitoring projects to calculate mean coral mortality (including variance terms) to the population of corals impacted by the PMDP. Combining these data with other abiotic metrics allowed us to differentiate between chronic and acute stressors, natural and anthropogenic. Using this approach, we were specifically able to calculate the prevalence of corals impacted by sedimentation, predation, competition, coral bleaching, and disease. Most importantly, in cases where corals died, we were able to discern the cause of mortality by carefully evaluating the sequence of events recorded prior to their death. The greatest source of coral mortality that occurred at the project sites between 2013-2015 was associated with a regional coral disease (SCTLD) outbreak and not local dredging operations.

Organizing Question 3: Restore

Urban coral fecundity and its role in the restoration of Florida's Coral Reef

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The Florida Coral Reef has experienced significant declines in coral cover, particularly among species highly susceptible to stony coral tissue loss disease (SCTLD) and thermal stress. However, unexpected populations of these sensitive species have been found thriving in atypical environments, such as the Port of Miami and other heavily urbanized habitats. These urban populations may have the potential to serve as sources of coral for the restoration of degraded reefs. To assess their reproductive viability, we initiated spawning assessments in 2023 during anticipated reproductive windows to determine whether these populations can contribute to

regional reef persistence through sexual reproduction. Histological cores were taken before and after spawning seasons from urban *Colpophyllia natans*, *Diploria labyrinthiformis*, *Orbicella faveolata*, *Pseudodiploria strigosa*, and *P. clivosa* to quantify gamete production and development (fecundity). Stage three oocytes and late-stage spermatocysts were observed, indicating that urban corals are producing and releasing viable gametes. While all samples had empty mesenteries following spawning with no indication of oocyte reabsorption, we have not observed these corals spawning in their native habitats during the predicted peak spawning windows. For the first time since the onset of this project, a single colony of urban *D. labyrinthiformis*, however, was observed to spawn in a land-based aquaculture facility in April 2024. Despite a >2-hour delay between reef and urban conspecifics releasing gametes, we were successful in the fertilization, settlement, and recruitment of nearly 2,700 urban x reef hybrid juveniles, emphasizing the potential for incorporation of urban coral genetics into land-based sexual reproduction initiatives. Restoration efforts at UM and NOAA are now leveraging an abundance of urban corals in the region to increase production of broodstock for outplanting and maintaining genetic diversity on Florida's Coral Reef.

Kanopi: Scalable Coral Reef Protection Against Thermal Stress

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Unprecedented water temperatures during the summer of 2023 in the Florida Keys led to a historical coral bleaching event, highlighting the urgent need for effective reef protection. In response, the Kanopi has been designed to alleviate thermal stress by shielding coral reefs from ultraviolet (UV) rays. Bioinspired by a honeycomb structure, Kanopi employs hexagon-shaped shading structures—composed of six triangular shade cloth units—that float above the water's surface to effectively block a large percentage of UV rays while allowing for some transmittance of essential light. The modular design of the Kanopi allows for scalability across reef sites. This solution utilizes existing marine-grade material alongside innovative technologies that enable rapid deployment and retrieval while ensuring durability. By leveraging existing technologies, internal floatation provides structural stability and improved performance. Implementation of this blue tech solution also provides broader impacts by engaging the public and students in the process, while raising awareness around reef conservation. Furthermore, this offers a unique opportunity to explore these landmarks, enhancing overall understanding and appreciation. This approach holds potential as a promising strategy for protecting these vital, yet fragile, ecosystems.

Investigating the origins of quarry populations of the Caribbean King Crab (Maguimithrax spinosissimus) to inform coral reef recovery efforts in the Florida Keys, Florida (USA)

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Coral reefs in the Florida Keys (USA) are declining due to natural and human-induced stressors, including macroalgal overgrowth, threatening biodiversity and ecological balance. Increasing

herbivory, particularly through the stocking of native herbivores, has been proposed as one method to enhance reef restoration. The Caribbean King Crab (*Maguimithrax spinosissimus*) is a promising candidate due to its substantial rates of herbivory, rapid growth, and consumption of a variety of algal taxa. The Caribbean King Crab naturally inhabits reefs and rocky substrates throughout the Western Atlantic, including isolated saltwater quarries in the Florida Keys. These quarries are being evaluated as potential semi-wild mariculture sites for rearing of crabs for restoration stocking. However, before quarry-derived crabs can be stocked onto reefs, it is crucial to assess their genetic diversity compared to wild stocks and determine their origins to avoid unintended ecological impacts. In this study, we used genetic data to investigate the origin, diversity, and genetic structure of quarry crab populations, analyzing mitochondrial markers (CO1, 16S, and 12S) from 233 individuals across Mexico, Costa Rica, Florida, and four Florida Keys quarries. Our results suggest that quarry crab populations likely originated from Florida, have lower genetic diversity than wild populations, possess unique haplotypes and show evidence of differentiation among sites. By revealing the origins, genetic diversity, and population structure of quarry crab populations, this research offers valuable guidance for using these populations in restoration practices while safeguarding the genetic health of coral reef ecosystems.

Treating Acropora Cervicornis for ciliate infection within aquaria

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In this presentation, I will be sharing my documented journey with ciliate infection of Acropora Cervicornis. The presentation will start by giving a brief history of Caribbean ciliate infection, and its effects on the reef. There will be information highlighting what exactly this disease is, statistical numbers of the general population affected, along with any new research on this disease.
Following that, information about the Acropora Cervicornis we have here at Philip and Patricia Frost Museum of Science will be shared. Some topics covered will include how long the Museum has had these, and the timeline of events for when the ciliate infection first was observed. Images and documentation for treatments will add to the story of the cervicornis' journey. I will talk about the info we received from fellow coral colleagues and vets for the best treatment options, and how each treatment was administered and the results. More pictures and documentation will be shared to show the corals progression after treatment, once the ciliates subsided.
Then the presentation will move into the second batch of Acropora Cervicornis that had the same issue, in one of the display tanks here at Frost. Documentation of events as well as details of a more streamlined treatment plan will be shared. This second batch of corals had more success with treatment and recovered much quicker than the initial batch. I will conclude with sharing updated images of the second batch of corals to show a comparison of this batch to the results of the initial, more experimental batch, of Cervicornis. The goal is to spread awareness of this possible effective treatment method for other facilities/personnel to utilize for treatment of any ciliate issues on Acropora Cervicornis.

Identifying physiological and microbial predispositions that contribute towards coral bleaching resilience in the staghorn coral, Acropora cervicornis

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Coral reefs are threatened by marine heatwaves. A common restoration intervention is to propagate thermally tolerant coral colonies for outplanting to restoration sites, but identifying reliable predictors of coral bleaching resilience remains a challenge. Here, we conducted a 3-month artificial thermal stress and recovery experiment in the staghorn coral, *Acropora cervicornis*. We determined whether common physiological metrics and/or 16S microbial community compositions were predictive of long-term survival. At peak heat stress (5 degree heating weeks), stressed colonies featured reduced Symbiodiniaceae cell densities and altered microbial communities when compared to ambient control fragments. After a 1-month recovery period, 26 out of 38 genotypes exhibited partial to full mortality in at least one of their replicate fragments. Resilient genotypes had higher symbiont densities and host protein concentrations than susceptible individuals under control conditions, suggesting that genotypes with greater biomass were more likely to recover. Holobiont microbial communities did not vary between the susceptible and resilient genotypes, indicating that community composition may not be a primary factor in determining bleaching resilience. However, microbial communities were influenced by the change in temperature, as shown by elevated community dispersion during peak stress, which may have indirect effects on bleaching outcomes. Other than photochemical efficiency, the metrics in this medium-term experiment did not correlate with previously collected effective dose of heat stress (ed50) values for these colonies, potentially due to the narrow ed50 range for *A. cervicornis*. Although this study illustrated that stress responses are difficult to predict, physiological metrics that corresponded with holobiont biomass were indicative of bleaching resilience, supporting the notion that coral nutrition is a critical factor for bleaching recovery.

Evaluating early ecological use of artistic and nature-based artificial reef modules deployed off Hollywood, Florida

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While natural Southern Florida coral reefs provide vast ecologic, economic, and cultural value, the reefs and resultant services suffer from numerous environmental stressors stemming from warming sea surface temperatures, ocean acidification, disease, and eutrophication. Additionally at risk is the economic value, infrastructure, and local population that the southern Florida reef system protects annually from storm flooding, erosion, and other coastal impacts. Hybrid artificial reef system deployment has recently increased in popularity, often providing more relief from

anthropogenic environmental pressures on Florida's natural reefs. With proper planning, these structures have the potential to stimulate local economies while also creating recreational fishing and snorkeling/diving opportunities to support ecotourism. Ocean Rescue Alliance International (ORAI) has developed hybrid artificial reef structures, in particular, that use a nature-based biomimicry design to connect communities through artistic engagement. From May 22-24, 2025, ORAI's new snorkel-friendly (76.2-106.7 meters from shore) "Guardians of the Reef" project totaling 50 reef modules was deployed at two North Hollywood Beach sites (N 26° 02.385' W 80° 06.70133'; N 26° 02.201' W 80° 06.75') and two South Hollywood Beach sites (N 26° 00.24' W 80° 06.8358'; N 25° 59.846' W 80° 06.879'). Within the first month, monitoring results indicated rapid colonization. Specifically, 15 fish species and multiple octocoral and barnacles made use of and colonized the artistic and nature-mimicking artificial reef modules. Continued scheduled artificial reef and adjacent natural reef benthic and fish monitoring will provide additional insights regarding the ecological benefits of functionally designed near-shore artificial reefs with artistic elements. Results and concurrent hydrodynamic and economic studies will be used to further improve artificial reef design using rigorous science-driven methodology intended for targeted, positive ecosystem restoration and local community engagement outcomes.

Unlocking the potential of Florida Keys quarries for sustainable semi-wild mariculture.

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[1]Florida International University

The Florida Keys quarries are landlocked limestone quarries created to supply materials to build Henry Flagler's Overseas Railroad. Limestone quarries comprise calcium carbonate-rich rocks that retain water to create a sustainable saltwater environment over time. Abiotic factors such as water retention, the composition of the substrate, and the natural influence of tidal patterns make these quarries relatively stable for marine life. The abundant macroalgal assemblages within the quarries enhance marine life's habitat complexity and food availability. The interaction between both the abiotic and biotic factors within the quarries creates a suitable and sustainable place to foster semi-wild mariculture, especially of herbivore species commonly controlled by predation on coral reefs. The Caribbean King Crab (*Maguimithrax spinosissimus*) has been proposed as one key invertebrate herbivore with potential use for coral reef restoration in the Florida Keys. Given the low natural densities of the Caribbean king crab and the need to boost their ecological impact to promote outplanted coral survival, we propose using quarries as a semi-wild mariculture system. We placed 20 artificial habitats with five different area surface volume ratios in South Cudjoe Quarry. Each artificial habitat type provides a new substrate that is expected to enhance the crab population. While the project is still a work in progress, macroalgal growth in a short period on the enhanced habitats leads our research to believe that the quarries are facilitating the development of these improved habitats. The growth of macroalgal assemblages in artificial habitats could increase the recruitment and succession of *M. Spinosissimus.*

Investigating the genomic diversity and connectivity of quarry populations of the Caribbean King Crab (Maguimithrax spinosissimus) to inform coral reef recovery efforts in the Florida Keys, Florida (USA)

Pedro Peres[1], Natalie Whitaker-Allen[1], Mark Butler[2], Heather Bracken-Grissom[1]
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The semi-wild mariculture of the Caribbean King Crab (*Maguimithrax spinosissimus*) in saltwater quarries has emerged as a promising tool for coral reef restoration in the Florida Keys, USA. When introduced to reefs, this native herbivore reduces macroalgal cover, helping coral viability. However, before scaling up restoration efforts, it is essential to understand the genomic structure, connectivity, and long-term suitability of this species across quarries and natural habitats. Building on prior work on mitochondrial DNA, we combined genome-wide SNP data with ecological niche modeling to assess the current genomic diversity and connectivity, and projected habitat suitability of this species under future climate change scenarios. Genomic analyses revealed similar levels of genomic diversity between wild and quarry populations, with weak but detectable population structure. Notably, individuals from No Name Key appear genetically distinct, potentially representing local adaptation. Connectivity analyses suggest that quarries were colonized by nearby wild populations and that gene flow among sites in limited, which is explained by low adult mobility and short pelagic larval durations. South-to-north gene flow was the predominant pattern detected. Ecological niche models indicate that the Florida Keys are likely to remain suitable for *M. spinosissimus* in future conditions, even under high-emissions climate scenarios. Given the observed directional connectivity, we propose prioritizing stocking efforts in the southern Florida Keys, leveraging natural dispersal routes that can facilitate the spread of migrants. Together, these findings reinforce the potential of this species as a climate-resilient candidate for coral reef restoration initiatives.

Coral probiotics as a novel tool to boost thermal tolerance in Diploria labyrinthiformis

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With ocean temperatures continuing to rise, Florida's corals face increasingly frequent and intense thermal anomalies. These stress events can lead to mass bleaching and mortality of critical ecosystem engineers and reef building species. Recent studies suggest that exposing corals to beneficial microorganisms, or probiotics, could be a useful conservation tool to enhance coral thermal tolerance. This study aimed to evaluate whether bacterial strains isolated from healthy *Diploria labyrinthiformis* colonies could enhance thermal tolerance and reduce bleaching and mortality in juvenile *D. labyrinthiformis* colonies under heat stress. Over 30 bacterial strains were screened for antioxidant activity and for siderophore production. Antioxidant activity helps reduce oxidative stress, while siderophores are iron sequestering compounds that can improve nutrient availability. Both traits may aid in maintaining the symbiotic relationship between the coral host and their zooxanthellae under stress. Four strains were chosen based on these traits to be used in an ex-situ probiotic experiment at the Smithsonian Marine Station in Fort Pierce. Six-month-old *D. labyrinthiformis* colonies (n=7) were exposed to one of five bacterial treatments: 1) no bacteria; 2) *Pseudoalteromonas* sp. DL2H-2; 3) DL2H-4; 4) *Pseudoalteromonas* sp. DL2H-6; or 5) *Vibrio* sp. DL2H-8, and one of two temperature regimes: ambient (27ºC) or elevated (33.5ºC). The corals

were dosed with probiotics before a gradual temperature increase, then maintained at high temperatures for over 40 days. The bacterial strain *Pseudoalteromonas* sp. DL2H-2 significantly delayed coral bleaching when compared to controls ($Pr(>|t|) = 0.00902$). This suggests that the bacterial strain *Pseudoalteromonas* sp. DL2H-2 may be used as a probiotic to enhance coral resilience to heat stress. The use of beneficial microorganisms is a very novel intervention method that warrants further investigation. This study adds to the growing body of evidence supporting the use of coral probiotics as a tool for reef restoration and climate adaptation strategies.

How does sediment affect the survivorship of young corals?

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Sediment, an often-overlooked factor on coral reefs, poses an increasing threat to corals in South Florida. From dredging projects to high levels of bioerosion, Florida's coral reefs are currently characterized by heavy sediment accumulation, likely impairing coral recovery. Sediment accumulation is widely recognized as detrimental to coral health, yet limited studies have examined the specific impacts of sediment loads and grain size on young corals. In this project, we assessed the effect of differential sediment load (2 mm/4 mm) and grain size (fine/coarse) on young corals aged 6 months < 2 years of a common reef-building species in the Caribbean, *Orbicella faveolata*. Coral fragments used as a proxy of these ages were exposed to sediment, and we tracked survivorship and measured coral size and photosynthetic efficiency. Photosynthetic efficiency was evaluated using pulse-amplitude modulated (PAM) fluorometry, with fv/fm values recorded before and after sediment burial. A total of 25 chambers per tank were used in nine experimental tanks. Corals were removed at intervals of 2, 4, 6, and 10 days to assess survivorship. Results highlight the severity of sediment-related stressors, including grain size and depth, on young coral survivorship. Survival rates seen in our results indicate that coarse 2mm group saw a 2-time faster decline in a 10-day period than the survival rate of our fine 2mm treatment. Additionally, coarse 4mm treatment cut photosynthetic efficiency by almost 50% for a 6-month-old fragment for only 4 days. Fragments were continued to be monitored 60 days after the experiment was conducted. Photosynthetic efficiency and surface area data was taken to view the recovery process of each fragment after uncovered from the different treatments. Coarse treatments recovered 15 days slower for the 6-month-old fragments than the 2-year-old fragments. Findings emphasize addressing sedimentation impacts in coral reef management.

Short-term TBP pretreatment (1-3 hours) reliably induces coral settlement across species.

Jennifer Sneed[1], Lilyana Newman[1], Valerie Paul[1]
[1]Smithsonian Marine Station

The success of restoration using sexually propagated corals is dependent on the settlement (attachment and metamorphosis) of swimming planula larvae onto appropriate substrates. Current practices involve the use of conditioned/biofilmed substrates or the application of crustose coralline algae (CCA) to induce settlement. Neither approach is scalable (i.e., labor costs are high and CCA supply is limiting) and both can have inconsistent outcomes (i.e., settlement is not even across substrates). Therefore, the development of a consistent, low-cost settlement cue that could

be applied to substrates or to the water column to enhance settlement would greatly increase the effectiveness of restoration via sexual propagation. Tetrabromopyrrole (TBP) is a marine bacterial compound that induces coral settlement (attachment and metamorphosis). However, TBP is unstable at room temperature and has the potential for off-target activity if added directly to the environment. Therefore, we investigated a short-term, pretreatment approach to induce coral settlement using TBP. Larvae of six coral species (*Acropora palmata*, *Colpophyllia natans*, *Diploria labyrinthiformis*, *Montastraea cavernosa*, *Pseudodiploria clivosa* and *P. strigosa*) were treated with 250 nM TBP for either one or three hours. These were then rinsed to remove the majority of the TBP and added to sterile 6-well plates in filter-sterilized seawater for settlement. Larvae were tested at a variety of ages (days post-fertilization) to identify the optimal TBP treatment for each age for each species. In general, 1 hour of treatment with TBP was sufficient to induce significant settlement for all species. In some cases, three hours induced more settlement, but only at the earliest larval ages. The ability to pretreat larvae with TBP prior to settlement either in situ or ex situ greatly enhances the applicability of this strategy to restoration efforts by limiting off-target effects and increasing ease of use for practitioners.

Seeding of Coral Larvae in Field Settings

Hannah Ditzler[1], Emily Timberman[2], Jennifer Sneed[3], Catherine Lachnit[2], Kelly Peebles[2], Margaret Miller[1]
[1]SECORE International, [2]University of Miami, [3]Smithsonian Institution

Successful recruitment of coral larvae is an essential step in ecological restoration and reproduction of corals. With reefs declining globally, natural recruitment of juvenile corals has also declined. One way to combat this growing issue is through assisted sexual reproduction, creating vast numbers of coral larvae to be settled. While the most common approach of assisted sexual reproduction (especially in Florida) focuses on settlement of coral larvae onto moveable substrates to be relocated to the reef after a period of growth, emerging research into settlement of corals directly on to reef or substrates in-situ shows promise. This approach can provide a means for testing various settlement enhancement interventions, such as chemical cues, at scale. We have conducted various larval seeding trials from 2023-2025 with different species of brain coral larvae incorporating chemical settlement inducers, different settings (field nursery and artificial reef), and different substrate types, with varying levels of success. Highest success was observed when seeding larvae directly onto a 3-month-old artificial reef (~ 10 settlers m^{-1}; with 21 surviving for 2 years). A subsequent seeding trial at the same artificial reef was less successful (1 recruit observed after about 1 year), potentially due to greater age and competition of the colonized benthic community on the structure. Additional, better-replicated experiments will be conducted throughout the summer of 2025.

Decadal and multispecies coral connectivity modeling for conservation and restoration prioritization in Florida

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Coral populations are rapidly declining due to global warming and local anthropogenic stressors, with nearly all living corals at risk if temperatures rise beyond 1.5°C. As reversing climate change is no longer feasible, effective local actions are essential to mitigate its impacts and support coral recovery through targeted restoration and protection efforts. Biophysical models that simulate coral larval dispersal at reef-scale resolution are crucial for guiding these actions. However, the high computational cost of such models has limited most studies to a few species and spawning events, lacking insights into interannual and interspecific variability. Here, we used the multi-scale ocean model slim to simulate larval dispersal for six key reef-building coral species (*Diploria labyrinthiformis, Acropora cervicornis, Pseudodiploria strigosa, Colpophyllia natans, Montastraea cavernosa,* and *Orbicella faveolata*) across Florida's Coral Reef over a 10-year period (2012-2021), incorporating experimentally calibrated larval dynamics. Our results show that connectivity indicators are most strongly correlated among species with similar spawning windows. Notably, the weighted in- and out-degrees exhibited the highest interspecific and interannual correlations. By integrating these metrics into a restoration indicator, we identified large clusters of reefs in the Dry Tortugas and northern Broward-Miami regions with significant restoration potential. The in- and out-degrees displayed limited interannual variability, with most fluctuations observed at outer shelf reefs in the Lower Keys and Dry Tortugas, where the ocean circulation is more variable. By providing long-term connectivity estimates for multiple reef-building species, this study offers valuable insights to inform marine conservation strategies.

Maximizing survivorship by reducing predation pressures on sexually propagated juveniles

Tiffany Brubach[1], Morgan Hightshoe[1], David Gilliam[1]
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Integrating sexually propagated stony corals into restoration is essential to increase species abundance and genetic diversity. The success of restoration activities requires evaluation of the effectiveness of all steps along the coral propagation pipeline - land-based sexual reproduction and settlement, offshore nursery intermediate grow-out, and outplanting onto the reef. Land-based efforts in propagating sexually derived stony coral juveniles in Florida have been successful and are typically followed by an offshore nursery acclimation phase prior to outplanting. However, juveniles often face increased predation pressure during this offshore nursery phase, limiting overall survivorship. This study aims to assess survivorship and predation of sexually propagated juveniles by utilizing predation exclusion devices (PED) and assess if an offshore acclimation period affects their vulnerability to predation. From 2021-2025, numerous nursery structures have been utilized to hold various species of juveniles, including PVC trees, cement modules, and mesh tables. Survivorship after three months varied significantly ($p=0.041$) across structure types, with tables (73%) outperforming trees (65%) and modules (44%). Predation was also observed on all structures [tables (23%,) trees (28%), modules (41%)] at one week and declined sharply after one month. Although survival was relatively high on mesh tables, predation still limited survival,

therefore 95 juveniles of *Colpophyllia natans* and *Pseudodiploria strigosa* were deployed on mesh tables in January 2025 in PED (n=65) and non-PED (n=30) treatments using a mesh cover. After 3 months, 100% survival was observed on the PED table and 67% on the non-PED table. After six months, a subset of juveniles will be transferred from the PED to the non-PED table and monitored for predation prevalence and survival. This study will expand the understanding of sexually propagated juvenile performance when relocated to offshore environments and further expand the techniques of the intermediate nursery phase to maximize survivorship and increase restoration efficacy and scale.

Port Everglades Deepening Project and Coral Mitigation

Nikki Edelenbos[1], Kristen Donofrio[1]
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The U.S. Army Corps of Engineers, Jacksonville District (Corps) will provide an overview of the Port Everglades Deepening Project, which has been in the making for over ten years. The project will deepen and widen various components within Port Everglades Harbor to increase navigational safety and efficiency. A key component of the project is the innovative and multifaceted coral mitigation effort. Currently the largest proposed coral mitigation project in the United States, components include natural reef enhancement, artificial reef creation, transplanting nursery-propagated corals, as well as the relocation of existing corals that may be affected within the footprint of the project. In addition to the mitigation overview, the Corps will also describe how the collaboration and coordination efforts with stakeholders, such as National Marine Fisheries Service (NMFS), Florida Department of Environmental Protection (FDEP), Environmental Protection Agency (EPA), Port Everglades, and both the dredging industry and coral practitioners, have contributed to the development of the project and its mitigation approach.

Pillars of Hope: Lessons from a Year Spent with Critically Endangered Pillar Corals

Natalia Hidalgo[1]
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In May 2024, I was given the opportunity to work as the primary aquarist overseeing the *Dendrogyra cylindrus* (DCYL) population housed at Frost Museum of Science, a role which I still hold to this day. These colonies came to our facility as part of the AZA-Florida Reef Tract Rescue Project (AZA-FRTRP) to serve as a genetic bank for this critically endangered species. Throughout this past year and a half, I have had the pleasure of learning the ins and outs of coral and specifically DCYL husbandry, from navigating unexpected challenges to celebrating successes.

DCYL are a vital reef-building species of coral with a number of traits which contribute to their importance and make them stand out among other species. Most notably, they extend their polyps during the day, giving them an incredibly unique, “fuzzy” appearance; additionally, they grow vertically, not only offering additional refuge for their teleost co-residents, including juveniles, but also reducing wave energy heading towards the coast.

Unfortunately, this species is classified as critically endangered by the IUCN (Red List) yet is still somewhat underrepresented in the conservation and restoration community. As such, I would like to share what I have learned so far to hopefully inform any DCYL aquarists of the future. I would

like to present this information as a timeline of events, from when I inherited the corals to the present, showing how far they have come in that time. This presentation will detail how our care for these animals has evolved, and will include discussions regarding management of water quality, diet, light, and flow, as well as a few specific cases involving unhealthy colonies and how they were nursed back to good health.

From Land to Reef. A Look at The Florida Aquarium's Advancements in Ex Situ Coral Rearing.

Gabrielle Vaillancourt[1]
[1]The Florida Aquarium

Florida's Coral Reef is facing unprecedented environmental threats including marine heat waves, disease, and other stressors. Rescue efforts now commonly include ex situ nurseries that support genetically diverse broodstock and produce sexually derived offspring to contribute to restoration efforts. The Florida Aquarium Coral Conservation and Research Center (CCRC) specializes in the ex situ rearing of coral recruits. Increased yield in recent years has enabled both the expansion of the nursery and further collaboration with research partners and in situ restoration practitioners. Staff at the CCRC are continually refining techniques to optimize coral recruit settlement, survival, growth, and outplanting success. To support successful larval development and coral settlement, focus has shifted to limiting densities and occasional use of tetrabromopyrrole (TBP), a biosynthesized proteobacterial compound linked to settlement. To minimize competition from pests, specialized filters have become standard practice in rearing systems. Co-culturing herbivores greatly reduces algal competition during early critical stages. Identifying which herbivores to use at each life stage has been an integral part of the work being completed at CCRC. Water quality, nutrient supplementation, and target feeding have boosted coral growth and can increase chances of survival on the reef. Developments in more secure transport methods have been made possible through relationships with vendors such as Reef Cells, and have created more durable transport methods and streamline facility operations. These advancements support management at various coral life stages and contribute to overall efficiency and higher chances of survival. The goal of the CCRC is to continue to improve on coral recruitment rearing techniques and share innovations to support other ex situ nurseries and contribute to global advancement of coral restoration efforts.

Snailing Lessons: Culturing Gastropods for Use in Coral Propagation

Alex Petrosino[1], Aaron Pilnick[2], Jessica Smith[2], Matt Wade[1], Keri O'Neil[1], Joshua Patterson[2]
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Florida's coral reefs have undergone a phase shift from hard coral cover to a macroalgae-dominated state due to numerous stressors and factors. In efforts to restore the reefs to natural conditions, ex situ stony coral sexual reproduction has become more popular and required. The ability to spawn and rear these native hermatypic corals is paramount to the restoration effort due to loss of wild genetic diversity. However, newly settled coral recruits are extremely sensitive to stressors including smothering by nuisance algae. The time and cost of keeping these coral recruits free of algae is immense. The Florida Aquarium's Coral Conservation and Research Center is making efforts to supplement manual removal of algae with small juvenile herbivores. This is not a new idea; however, some herbivores such as urchins have shown a propensity to grow too large

too quickly and become an irritant to small coral recruits. Due to the limited availability of small grazers from the wild, the team at the Florida Aquarium, partnered with the University of Florida, has been working on rearing gastropod species to provide this early herbivory. Snail species may be able to provide the herbivorous pressure needed to keep nuisance algae away from coral recruits while also alleviating time and cost of the manual labor that would otherwise take place. Two species of interest are *Lithopoma americanum* and *Turbo castanea*, the American Star Snail and Chestnut Turbo snail, respectively. The team has attempted to spawn and raise juveniles in different environments, making improvements continuously. In this presentation, we will discuss improvements such as species choice, culture vessel preference, first feed, larval density, and observations of developmental differences. These methods can prove pivotal in early coral recruit survival and management by providing herbivorous pressure at the most sensitive stage of coral propagation process.

A Re5 Collaborative Approach: Impacts of Supplemental Nutrition on Diploria labyrinthiformis Settlement, Survival, and Growth Across Four Institutions

Sophia Lee[1], Rachel Morgan[2], Benjamin Ballinger[3], Elise Keister[3], Bailey Marquardt[1], Cody Engelsma[3], Amanda Bourque[4], Maren Gibson Stickley[1], Alexandra Wen[1], Katie Curtis[5], Mike Favero[5], Kaleigh Fix[6], Andrew Baker[1], Leneita Fix[6], Keri O'Neil[2], Erinn Muller[3]
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Coral cover has drastically reduced within Florida's coral reefs over the last half century due to a myriad of stressors, both global and local. In response, Florida coral restoration practitioners have increased sexual coral propagation efforts in order to increase genetic diversity and coral cover on these degraded reefs. High post settlement mortality has created a bottleneck, limiting the impact and efficacy of this effort, making it vital to determine simple, cost-effective methods to limit mortality. This study assessed the impact of supplemental nutrition on the settlement, survival, and growth of *Diploria labyrinthiformis* recruits at the University of Miami's Coral Reef Futures Lab (UM-CRFL), The Florida Aquarium (TFA), The Reef Institute (TRI), and Mote Marine Lab's Gene Bank (MML-GB). Coral larvae were placed in dishes with one of three or four treatments: control (C), OA3A formula, OA2B formula, and a triacylglyceride formula (NP800) *sensu* Boulotte et al. (2023), all of which were created by Ocean Alchemists to utilize a nano-particle delivery system. Settlement rates were recorded approximately 10 days following *D. labyrinthiformis* larval treatments. Settled recruits were then monitored at two months to determine overall survival and growth under different treatment conditions at the four separate institutions. This study highlights the potential of collaborative approaches testing novel interventions such as supplemental nutrition to increase settlement, survival, and overall growth during the coral early life stages, thus supporting Florida coral restoration efforts.

Promoting the acquisition of Durusdinium trenchii within Acropora cervicornis at two facilities at Mote Marine Laboratory

Celia Leto[1], Cody Engelsma[1], Ashlee Hylton[1], Morgan Jewell[1], Nick McMahon[1], Elise Keister[1], Sara Williams[1], Erinn Muller[1], Lexi Zagarola[1]
[1]Mote Marine Laboratory

Reef building corals owe much of their ecological and evolutionary success to their symbioses with symbiotic dinoflagellates. For example, thermally tolerant symbionts, particularly *Durusdinium trenchii,* can boost coral bleaching resistance. However, what drives individuals to host *D. trenchii* versus less thermally tolerant algal symbionts is not well understood, and is of particular interest for improving resilient restoration strategies. . Previously, *Acropora cervicornis* sexual recruits reared at Mote's Summerland Key facility (IC2R3) were found to predominately host and/or shuffle to *D. trenchii* after experiencing thermal stress, while their parents associated with *Symbiodinium* spp. and had higher mortality during the 2023 marine heatwave. To investigate the potential role of environmental and genetic factors contributing to the acquisition of *D. trenchii* by sexual recruits, larvae produced from the same parental crosses of *A. cervicornis* were reared at both IC2R3 and Mote's International Coral Gene Bank in 2025. Recruits at Mote's IC2R3 were reared within a flow-through system using filtered and ozonated natural saltwater from a nearby canal, while recruits at the Gene Bank were reared within a recirculating, artificial saltwater system. At each facility, one treatment was "seeded" with adult individuals known to host *D. trenchii* and another was "seeded" with live rock. Each facility's best care practices for coral husbandry were utilized. Environmental parameters were monitored throughout the study to identify potential drivers of symbiont community differences. Results will inform resilient restoration strategies for increasing acquisition of *D. trenchii* in *A. cervicornis* sexual recruits, with a goal of improving their thermal resilience when outplanted.

Growing Pains: Lessons From Scaling Restoration Efforts

Leneita Fix[1]
[1]The Reef Institute

As the urgency of coral reef restoration intensifies, the scalability of land-based efforts becomes a critical topic. The Reef Institute (TRI) has transformed from a modest 3,000-square-foot facility to a sprawling 23,000-square-foot center. This growth journey reveals the opportunities and complex challenges of scaling land-based coral work.

This presentation will unpack the practical realities of scaling up—from infrastructure planning and system redesign to biosecurity management, staffing models, and system redundancies. Growth isn't just about increasing space; it demands entirely new ways of thinking. Processes that worked at small scales must be reengineered, automated, or delegated. Roles shift, data management grows exponentially, and the learning curve steepens.

Attendees will gain insight into how TRI is tackling these transitions, including:

- Building adaptive systems for coral husbandry at scale.
- Managing operational logistics during a live move.
- Developing scalable workflows for husbandry.
- Addressing the hidden costs—staff burnout, changing culture, and workflow inefficiencies.

The session will also offer a candid look at "growing pains" and strategies helping TRI move forward without losing momentum. For organizations considering a similar leap, this talk will serve as both a roadmap and a mirror, reflecting the questions you must ask before expansion: What is your actual capacity? Where do your systems fail under pressure? And what will success require?

By sharing our lived experience, TRI hopes to empower others in the restoration space to scale with intention, resilience, and impact.

Reframing Restoration: Lessons Learned from Coral Outplanting in Palm Beach County

Melissa Wagner[1], Kaleigh Fix[1]
[1]The Reef Institute

Outplanting corals in Palm Beach County presents a distinct set of challenges, from ripping currents and persistent sedimentation to unpredictable site conditions at 50 feet. These environmental factors demand technical flexibility and an entirely new approach to restoration implementation and scale.

This workshop will explore The Reef Institute's journey from a limited pilot program to the early stages of a community-supported, scalable outplanting model. Along the way, our greatest lessons haven't just come from the reef, but from rethinking *who* restoration includes and *how* we get it done.

Rather than relying solely on staff-driven efforts, TRI has begun expanding through collaboration with a local dive shop and the thoughtful integration of volunteers. These new partners bring critical capacity, local knowledge, and a deep investment in protecting nearby reefs. Palm Beach County has guided site selection, ensuring restoration efforts are aligned with regional ecological priorities and logistical feasibility.

More than technique, this session highlights the evolving power of partnership. By building relationships with local divers, community members, and county officials, TRI is exploring new models for how reef work can be done—on the reef's terms, and with the people who depend on it. This cooperative model is still in development, but it has already increased access to reef sites, created new volunteer opportunities, and started to build a more locally grounded, resilient restoration framework.

Participants will gain valuable insights into what it takes to outplant in high-energy, high-stakes environments, and how strategic collaboration rooted in the community can help overcome barriers that technical solutions alone cannot address.

Reef Credits: An Assessment of Biodiversity Credit Frameworks and Their Applicability to Coral Reef Restoration and Conservation

Todd Romberger[1]
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Biodiversity credits have been employed as a mechanism to fund restoration and conservation of natural ecosystems worldwide, and offer a potential tool in the fight to save coral reefs from anthropogenic threats including bleaching, ocean acidification, pollution, and development pressure. However, specifics on how such "reef credits" would be created, measured, verified,

priced, and maintained remain elusive. In this work, a prototype Coral Reef Biodiversity Credit Framework (CRBCF) is proposed by identifying elements from existing biodiversity credit frameworks most suited to the preservation and restoration of coral reef ecosystems. A systematic literature review was conducted by categorizing elements from existing biodiversity credit research into three categories: unit standardization, market dynamics, and monitoring & measurement. These elements were then compared to a set of coral-reef specific criteria, developed through parallel literature review into coral reef specific conditions, conservation strategies, and measurement techniques. Findings indicate that many elements of existing biodiversity credit frameworks have applicability to coral reefs, which provide useful precedent in designing a CRBCF. Key elements of a CRBCF include 1) the adjustment of area-based credit units through analysis of conditions, priority and habitat connectivity; 2) the implementation of government-mandated local trading markets; and 3) the augmentation of direct observations with scalable remote sensing techniques to monitor outcomes. This work concludes that biodiversity credits offer a promising mechanism for novel and market-based financing of coral reef conservation and restoration, and many aspects of existing biodiversity credit frameworks provide useful precedent that can be adopted and adapted by state or local governments in the implementation of a "reef credit" trading system.

Predicting Coral Predation Along the Florida Reef Tract: A Synthesis of Research and Restoration Efforts

Allyson DeMerlis[1], Adam McAnally[1], Joseph Unsworth[1], Bautista Tobias[1], Danielle Tenberg[1], Mason Fitzgerald[1], Erin Weisman[1], Martine D'Alessandro[1], Diego Lirman[1]
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Coral restoration efforts using a diversity of reef-building coral species have been implemented over fifteen years to replenish the severely degraded reefs along the Florida Reef Tract. Small-scale studies as well as monitoring of outplanting efforts have revealed species- and region-specific trends in coral predation from a variety of corallivorous predators. Major gaps remain, however, in understanding the long-term impacts of predation on coral outplants. Furthermore, the field would greatly benefit from a predictive predation index for site selection efforts to improve the efficacy of time-intensive restoration projects. To address this gap, we have synthesized research and long-term monitoring datasets using threatened coral species, such as *Acropora cervicornis* and *Orbicella faveolata*, to observe the influence of predation on growth, survivorship, and disease incidence over time and across reef regions (Broward, Miami-Dade, and Monroe counties). Results reveal differential corallivore abundance across regions, and corallivore preference to certain coral species, which ultimately influenced long-term survivorship. Improving our ability to predict the success of coral outplants in the context of coral predators, particularly for slow-growing coral species, should be prioritized along with coral resilience to a changing ocean climate.

A Dissemination of Protocols for and Outcomes of Coral Reef Sponge Restoration in the Upper Florida Keys

Bobbie Renfro-Price[1], Kylie Smith[1]
[1]I.CARE

As the restoration of reef-building corals becomes increasingly successful, practitioners must consider the restoration of other functionally important taxa to restore ecological interactions that maintain coral reef ecosystems. Sponges (Porifera) provide water filtration, food resources, habitat space, and structural support to reefs and their inhabitants. Sponges can even stabilize coral rubble generated by storm damage, repairing the reef and creating suitable substrate for coral larval settlement. Similar to corals, sponges have experienced declines throughout the Caribbean. In 2021, I.CARE and poriferologists at Florida State University developed the first-ever sponge restoration protocols for Florida's Coral Reef. After four years of program development, I.CARE now hosts monthly sponge restoration dives, maintains *in situ* and *ex situ* sponge nurseries, conducts quarterly monitoring of natural sponge populations, and continues to employ experimental investigations to make data-driven improvements to our sponge restoration protocols. In 2021, 350 restored sponge fragments exhibited a 45% survival rate at six-months post-transplantation. This survival rate rose to 49% at six months and 42% at one year for 365 restored sponge fragments in 2022. One year survival rates continued to increase to 71% for 304 sponges restored in 2023. Survival was dependent on restoration site and sponge species. During the 2023 hyperthermal stress event that led to coral bleaching across Florida's Coral Reef, restored sponge fragments of the photosymbiont-bearing species *Aplysina cauliformis* visually appeared unaffected by heat stress. However, quantification of photosymbiont abundance in this species revealed non-visible sublethal effects of bleaching, highlighting the need for continued restoration of this species and exploration of species-specific sponge responses to changing ocean conditions. The coral reef ecosystem is supported by the functional roles of a diverse host of tropical marine taxa. Our work at I.CARE has exemplified the feasibility of restoring the functionally important roles played by reef-dwelling sponges on Florida's Coral Reef.

Crab Supply for Coral Recovery: Evaluating Quarry-Based Mariculture to Scale Herbivore Restoration

Brandon Sosa[1], Morgan Jarrett[1], Mark Butler[2]
[1]Florida International University, [2]Newfound Harbor Marine Institute

Scaling up herbivore populations is a critical component of Florida's coral reef restoration strategy. As part of the Mission: Iconic Reefs initiative, the Florida Keys National Marine Sanctuary plans to stock hundreds of thousands of grazers—primarily the long-spined sea urchin (*Diadema antillarum*) and the Caribbean King Crab (*Maguimithrax spinosissimus*)—to suppress macroalgal overgrowth and promote coral recovery. However, current grazer production relies heavily on labor-intensive and costly land-based systems, presenting major logistical and financial bottlenecks for large-scale implementation.

This study explores quarry-based mariculture as a complementary grow-out strategy to support existing land-based hatchery operations. We tested the feasibility of using abandoned saltwater quarries in the Florida Keys to rear *M. spinosissimus* juveniles in semi-natural conditions. Across three experimental trials, we compared juvenile survival and growth between laboratory and

quarry-based grow-out, examined variation among quarry sites, and tested the effects of stocking density. We also tracked algal dynamics and environmental parameters over time to understand seasonal influences on grow-out performance.
Results indicate that quarry-based rearing supports comparable or improved survival and growth relative to lab systems, particularly under conditions of lower stocking density. Growth varied significantly by site, suggesting that environmental conditions play a key role in performance. High stocking densities negatively affected both growth and survival, emphasizing the importance of optimized deployment strategies. Seasonal changes in algal biomass and water quality may further influence grow-out success.
Our findings support the feasibility of quarry-based mariculture as a scalable, regionally adapted strategy for supporting grazer stocking efforts in Florida. This approach can reduce infrastructure demands, enhance production efficiency, and help meet the ecological goals of restoring herbivory on degraded reefs.

Advances and Challenges in Scaling Caribbean Coral Recruit Rearing in Land-Based Nurseries

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In recent decades, marine heatwaves, pollution, and disease have decimated the population of stony coral species in the Florida Coral Reef Tract, highlighting the urgent need for large magnitude restoration efforts through propagation in both in-situ and ex-situ nurseries. However, the 2023 bleaching event demonstrated the potential pitfalls of asexual propagation and emphasized the need for an increased focus on sexual reproduction to inject diversity into restoration efforts. However, survival rates for coral larvae are incredibly low, introducing new challenges when scaling up for restoration. A key advantage of ex-situ facilities is the ability to precisely control factors such as temperature, light, water quality, and microbial communities when compared to natural conditions during this critical early-life stage. Over the past two years, the Coral Reef Futures Lab land-based nursery has exponentially scaled up its sexual reproduction efforts through augmenting our systems and protocols to reflect this change in focus. Efforts include the switch to ozonated, recirculating systems, frequent and routine water chemistry testing, better conditioned settlement substrates, and increased light and feeding regimens. While these improvements have enhanced the overall success of recruit grow-out, they have also revealed key challenges chiefly the man-hours required to keep recruits clean of bio-fouling as well as fluctuations in tank conditions such as temperature and light through mechanical issues. By the end of 2024, more than 5,000 coral recruits from 10 species had been successfully reared, significantly increased from the cohorts produced between 2019 and 2023. This growth highlights the increasing effectiveness of sexual propagation techniques on a greater scale, highlighting major advances while emphasizing the continual need for innovation and refinement to address the remaining hurdles in furthering Caribbean coral restoration efforts.

Identify and widen bottlenecks in the asexual restoration of endangered Orbicella boulder corals

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Landscape-scale coral reef restoration is constrained by our understanding of context-dependent responses of corals to environmental and ecological conditions throughout a region. Asexual propagation of corals for restoration depends on rapid tissue regeneration following the relatively traumatic fragmentation process. However, propagation can reduce colony fitness by fragmenting resources, creating open wounds, and diverting energy to healing, increasing disease risk. Nonetheless, high-volume asexual propagation and coral culture are needed to scale up restoration, and identifying factors affecting the growth and survival of key reef-building species—and any context-dependent effects—is essential.
Orbicella faveolata (OFAV) is a major reef-building coral species whose mass reproduction is critical to restoration efforts on Florida's Coral Reef. Unfortunately, the species is susceptible to SCTLD, and strong evidence shows that parent colony source (genotype), culture conditions (nursery location and system type), and their interaction influence OFAV growth, survival, and fitness for restoration. This research will evaluate the effect of source colony location (ECA and Florida Keys) and genotype, ex-situ nursery system characteristics (five systems across Nova Southeastern University, University of Miami, and Mote Marine Laboratory), and in-situ nursery placement (Florida Keys, Key Biscayne, and Broward County) on OFAV tissue regeneration and survival post-fragmentation. The experiment involved synchronized collection of corals of opportunity, colony exchange, fragmentation, and standardized water quality testing and fragment monitoring across the five facilities.
This study will provide insights into optimal nursery systems and conditions for OFAV propagation and rearing based on source colony location, and support the standardization of materials, methods, and workflows. This will inform the regional capacity and infrastructure needed to scale OFAV production and enhance the resilience of Florida's Coral Reef ecosystems.

"Hidden" Upwelling on the Southeast Florida Shelf

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Coral reef benthic communities are sensitive to changes in environmental parameters such as temperature and nutrient concentrations produced by coastal upwelling. Classical wind-driven coastal upwelling is predominantly observed along the eastern ocean boundaries, such as the California Shelf. At western ocean boundaries, such as the Southeast Florida Shelf (SFS), wind-driven upwelling has been observed only during strong wind events, like tropical storms or hurricanes. There is, however, another powerful type of coastal upwelling along the western ocean boundaries, which is sometimes referred to as a "hidden" upwelling. This type of upwelling often does not penetrate through the strong near-surface stratification of the coastal ocean during summertime, which is consistent with numerous reports from divers on the SFS. Yet, it still affects the temperature in the benthic boundary layer and, thus, the coral reef community. How does

"hidden" upwelling form on the SFS? The analysis of 25 years of observations of coastal ocean dynamics on the SFS with ADCP moorings, and more recently with a glider equipped with an ADCP instrument, helps to understand the mechanism of "hidden" upwelling at this location. Continuation of this research is expected to contribute to coral reef management efforts on the SFS.

Prioritizing Massive Coral Genetic Diversity: RRUSA's Restoration Framework

Ashley Elliott[1], Ken Nedimyer[2], Shane Wever[3]
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The 2023 mass bleaching event had catastrophic impacts on Florida's coral reef, affecting all stony coral species, with Acroporids experiencing near complete losses. This mass die-off of Acroporids highlighted the urgent need for restoration practitioners to expand the number and type of species they are propagating to include the seemingly more robust "massive" corals, which are historically underrepresented in restoration efforts. Reef Renewal USA (RRUSA) has been shifting its focus toward the propagation and recovery of massive coral species over the past five years. This presentation explores RRUSA's shift toward massive coral restoration, highlighting how we are using genetic diversity to strengthen reef resilience. We have focused on increasing our genetic holdings of massive species and creating safeguards by replicating genotypes across our nurseries. We do so through "Corals of Opportunity" and targeted coral collections. Our combined land-based and offshore nursery capacity houses over 600 genotypes across +20 coral species. To further improve our understanding of coral environmental tolerance, RRUSA has established offshore nurseries across the Florida Keys. These nurseries, along with diverse outplant locations, expose coral stock to a range of temperature and water quality conditions, allowing us to monitor survival, performance, and suitability for restoration use. We then track outplanted coral survival similarly. Identifying survivor genotypes allows us to select the corals of the future, determine genotype breeding matches to yield desired traits, and invest our resources into corals that will last on the reef. Additionally, a large number of our stock is undergoing genetic testing, sequencing their entire genome. This study may lead to discoveries around massive gene selection or identifiers that will allow us to more quickly resolve which genotypes will survive environmental stressors. By investing in massive-focused restoration and genetic resilience, we are working to ensure that Florida's reef has the diversity, strength, and adaptability needed for long-term recovery.

A Living Crop for a Dying Reef: Propagating Corals for the Future

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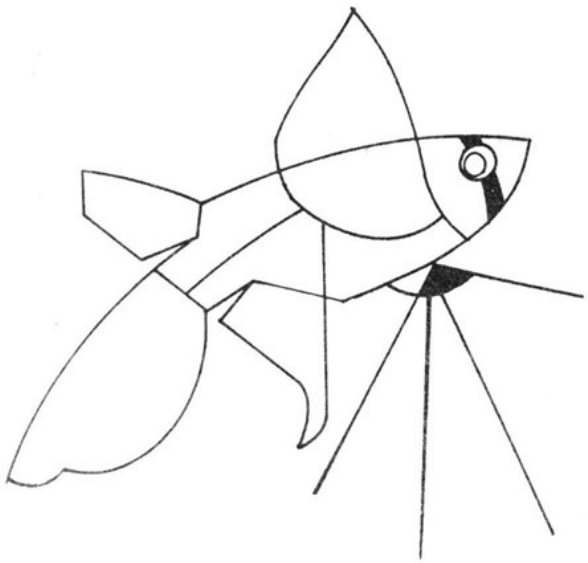
[1]Reef Renewal USA

Stony corals across Florida's Coral Reef have experienced decades of decline, prompting action from resource managers, scientists, and non-profit organizations. Early restoration efforts, which prioritized fast-growing "branching" species, initially showed promise. However, a 2023 marine heatwave devastated coral populations across the Caribbean, causing widespread bleaching and mortality among both wild and restored populations. This bleaching event also exposed critical vulnerabilities in the prevailing restoration model implemented throughout Florida. Anticipating these issues, Reef Renewal USA (RRUSA) has spent the past five years developing new propagation strategies tailored to a broader range of coral species, including those with "massive"

and “weedy” growth forms. Using both opportunistic and targeted collections, RRUSA brings corals into land-based facilities, where colonies are fragmented into specific size classes for gene banking, sexual reproduction, and tissue production for scalable restoration. This includes broodstock strips (~7×2 cm) for long-term tissue growth and gene banking, “spawners” (~10×10 cm) for gamete production and selective breeding, and two sizes of frag plugs (~1.5 & ~2.5 cm) for outplanting. This system allows RRUSA to maintain a self-renewing “living crop” of corals that produces genetically diverse material year after year. With over 600 unique genotypes from more than 20 species, RRUSA is building the foundation for a resilience-focused restoration strategy that can adapt to climate-driven threats. Through spatiotemporal monitoring across nurseries and restoration sites, RRUSA can track genotype-specific performance to identify thermally tolerant, disease-resistant, and fast-growing individuals for future propagation and selective breeding efforts. This approach not only diversifies the coral species being restored but also enhances resilience across restored populations. By expanding beyond branching species and embedding genetic strategy into every step of the process, RRUSA is helping reimagine coral restoration in the Florida Keys and preparing for the next major reef disturbance with a stock of corals capable of surviving it.



A BRIEF GUIDE TO AUTHORS
Updated 2025

This guide is intended for those not accustomed to using a "Guide to Authors", as provided by more formal periodicals. Most authors now make a concerted effort to follow this format, and it makes my job much easier. Please help me out, folks!

The approximate deadline for submissions is December 21st.

As always, typical Drum & Croaker articles are not peer-reviewed and informational content will not be edited. I may correct obvious errors; clarify translations into English; modify incorrect, awkward or cumbersome document and/or sentence formatting; remove decorative graphics: and/or delete superfluous material (such as random photos that don't relate to the text, or whose context cannot be clarified with captions/legends). Other types of contributions (announcements, etc.) may be edited to meet space limitations.

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All Articles Must Adhere to the Following Basic Format:

- Use justified, single-spaced, Times New Roman 12-point font throughout (except for the title section, and figure and table legends as noted below).
- 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.
- 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 line spacing set on 1.5 lines (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

USE OF DUCT TAPE IN THE HUSBANDRY OF *Genus species* AT FISHLAND

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 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.

Please use the following format for figure legends:

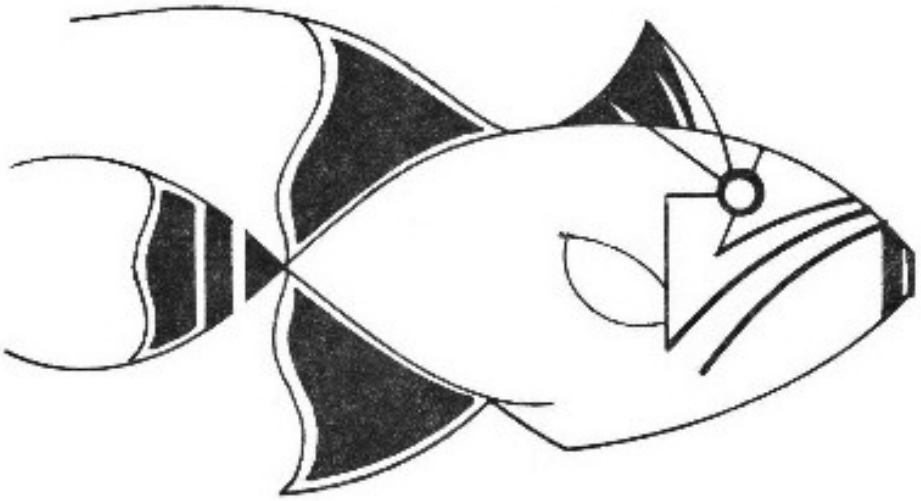


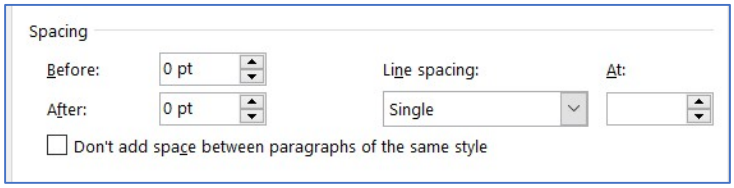
Figure 1. Legends should appear under the photo (such as this drawing by Craig Phillips) or graph in this format in 10-point font, aligned with the sides of the image or figure (center or justify). Very short legends can be centered. Photographs should be pasted into the document in the proper location 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.

Table Legends

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.



- Use the "enter" key for all line spacings ("carriage return" for those who remember typewriters with a slidey thing on top).
- If you submit a table, put the data IN an actual table. Don't use the space bar or tabs to "line up stuff." This formatting can be lost if I have to change margins or otherwise reformat. Center column headings in tables (vertical and horizontal), bold them, and use light grey shading in those cells.
- Use the "tab" key to set your 0.5" indent at the start of each paragraph. It's likely your default. If not, reset it. Again, don't use the space bar.
- Use bullets or numbers to make lists. It is easier to reformat these later if needed.

Short Contributions ("Ichthyological Notes")

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.

Reviews, abstracts, translations (with proper permissions) and bibliographies are welcome. Humor, editorial pieces, apocrypha, and serious technical articles are equally appreciated.

Literature Cited

In the body of the paper, use this method to cite authors: (Phishmonger et al., 2008; Laurel and Hardy, 2009; Frazma, 1992).

When providing full references/citations at the end of a paper, use an accepted standard style. I'm not a stickler about this. Just make sure all the relevant information is present, and try to stick to one style. **APA format is probably most appropriate.** You can enter a known paper title in Google Scholar, and click on the "cite" link below the displayed reference. This will produce an APA-formatted citation that you can copy and paste into your paper. Check to make sure all the information is there. Sometimes the generated citation is incomplete if it refers to a thesis or technical report. You can also use open-source software like Zotero to extract APA formatting from reprints that you have downloaded. The formatting used for the journal Copeia is also appropriate, and was my original preference "back in the day." If for some reason this appeal to you, scroll way down on the page: https:/www.asih.org/ichsandherps/instructions-to-authors